ADAPTABILITY OF WHITE MAIZE AND MITIGATION OF WATER STRESS BY ANTITRANSPIRANT

KANIZ FATIMA

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

June, 2019

ADAPTABILITY OF WHITE MAIZE AND MITIGATION OF WATER STRESS BY ANTITRANSPIRANT

By

KANIZ FATIMA

Registration No. 00908

A Thesis
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

SEMESTER: JANUARY-JUNE, 2019

Approved by

(Prof. Dr. Parimal Kanti Biswas)
Chairman
Advisory Committee

(Prof. Dr. Kamal Uddin Ahamed)	**(Prof. Dr. Md. Fazlul Karim)**	**(Prof. Dr. Md. Abdullahil Baque)**
Member	**Member**	**Member**
Advisory Committee	**Advisory Committee**	**Advisory Committee**

Dr. Parimal Kanti Biswas
Professor
Department of Agronomy
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh
Mobile: +8801552358082
Email: parimalbiswas@hotmail.com

CERTIFICATE

This is to certify that the thesis entitled 'ADAPTABILITY OF WHITE MAIZE AND MITIGATION OF WATER STRESS BY ANTITRANSPIRANT' submitted to the faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY IN AGRONOMY, embodies the results of a piece of bona fide research work carried out by KANIZ FATIMA, Registration No.00908 under the supervision and guidance of her Advisory Committee members. 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.

Dated: November 12, 2020
Place: Dhaka, Bangladesh

Prof. Dr. Parimal Kanti Biswas
Chairman
Advisory Committee

DEDICATED TO MY BELOVED PARENTS, HUSBAND & CHILDREN

ACKNOWLEDGEMENTS

The authoress conveys all praises to "Almightily Allah", the Beneficent and the Merciful for His never ending blessings upon the authoress to enable her to complete the courses and research work followed by a complete thesis preparation successfully.

The authoress expresses her profound respect and gratitude to the chairman of the Advisory Committee Professor Dr. Parimal Kanti Biswas, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, valuable suggestions and constant inspiration throughout the period of this research work and actively helping to prepare the manuscript of the thesis with patience.

The authoress feels pleasure to express her heartiest appreciation to the members of her Advisory Committee Prof. Dr. Md. Fazlul Karim and Prof. Dr. Md. Abdullahil Baque, Department of Agronomy, and Prof. Dr. Kamal Uddin Ahamed, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for their valuable suggestions and constant cooperation during both the course and research works along with reviewing the manuscript of this thesis.

The authoress also feels privileged to express her sincere and profound appreciation to all course teachers of the Department of Agronomy for their kind cooperation and inspirations throughout the whole tenure of this study.

The authoress extends thanks to all the officers and staff of Department of agronomy and farm management wing, of Sher-e-Bangla Agricultural University, Dhaka, who have helped her to complete this research work successfully.

The authoress acknowledges from the core of her heart to her parents Prof. Dr. Md. Jafar Ullah and Mst. Shamim Ara for their continuous inspiration whose blessings, inspiration, and sacrifice helped her to pursue all types of education and reach up to this mark land.

The authoress feels love to her husband Prof. Dr. Jamilur Rahman, son Tasfiq and daughter Tashfin for their whole hearted sacrifice for setting in touch with me throughout the whole period of her study without which it would not have been possible for the authoress to complete this study.

The authoress is delighted to express her gratitude to all of her well-wishers and friends for their inspirational support up to this moment.

The Author
SAU, Dhaka

ADAPTABILITY OF WHITE MAIZE AND MITIGATION OF WATER STRESS BY ANTITRANSPIRANT

ABSTRACT

Six trials with eight varieties of white maize *viz*. PSC-121, KS-510, Changnuo-1, Q-Xiangnuo-1, Changnuo-6, Yangnuo-3000, Yangnuo-7 and Yangnuo-30 were carried out at three different sites *viz*. SAU (Sher-e-Bangla Agricultural University); Dhamrai and Rangpur Sadar of Bangladesh during Rabi seasons of 2015-16 and 2016-17 to investigate adaptability and water stress mitigation. In the first year at SAU, significantly higher grain yields were found in five varieties, PSC-121 (8.26 t ha^{-1}), Q-Xiangnuo-1 (7.17 t ha^{-1}), Changnuo-1 (8.62 t ha^{-1}), Changnuo-6 (8.52 t ha^{-1}) and Yangnuo-30 (8.35 t ha^{-1}) but at Dhamrai, the higher yields were produced by PSC-121 (8.59 t ha^{-1}), KS-510 (8.81 t ha^{-1}), Changnuo-1 (8.24 t ha^{-1}) and Changnuo-6 (9.13 t ha^{-1}) and at Rangpur by Changnuo-1 (6.65 t ha^{-1}) and Q-Xingnuo-1 (6.14 t ha^{-1}). In the second year, PSC-121 at SAU, Changnuo-1 both at Dhamrai and Rangpur gave significantly the highest grain yields of 10.31, 8.45 and 12.15 t ha^{-1} respectively. Changnuo-1 at all the sites, while PSC-121 at SAU was the second best performer. The least seed yields were obtained from Yangnuo-7 (3.76 - 6.74 t ha^{-1}). Drought imposing trial on six varieties namely PSC-121, Changnuo-1, Changnuo-6, Yungnuo-3000, Yungnuo-7 and Yungnuo-30 was conducted under varying irrigation regimes, *viz.* no watering from 80 days after sowing (DAS) to harvesting, no watering from 100 DAS to harvesting and control (with irrigation at every day) where grain yield reduced drastically to almost half (3.44 t ha^{-1}) when watering was stopped from 80 DAS compared to the control (6.57 t ha^{-1}). Changnuo-1 was found to be the most drought tolerant variety, which yielded 5.96 t ha^{-1}. In the antitranspirant trial, two varieties namely V_1- PSC-121 and V_2 = Changnuo-1 were tested under four concentrations of Kaolin (C_O = 0%, C_1 = 2%, C_2 = 4%, C_3 = 6%). The 6% concentration yielded significantly the highest (8.75 t ha^{-1}), which was 16% higher than that of the control (7.38 t ha^{-1}). In the interaction treatment, PSC-121 with all the concentrations yielded significantly higher seed yields. PSC-121 with 6% concentration of Kaolin yielded the highest of 9.12 t ha^{-1}, while 8.21 t ha^{-1} with the control. The results showed 16% yield increase having 6% Kaolin spray and 8% increase in 2% Kaolin spray. The grain nutritional analyses showed the maximum content of protein in Q-Xiangnuo-1 (9%) fiber in Yangnuo-7 (2.96%) and carbohydrate (75.13%) and AAC (apparent amylose content) (24.41%) Changnuo-1. PSC-121, Changnuo-1, Q-Xiangnuo-1, Yangnuo-3000 and Yangnuo-7 had higher fat contents (~ 4%). The highest Glycemic Index (GI) was obtained in Yangnuo-7 (71.24 %). The Changnuo-1 might be recommended for cultivation for its best performance in all the studied sites and tolerant to the drought stress condition as well as for containing the highest fat, carbohydrate and AAC contents. For higher yield and water conservation in plant, 2% Kaolin might be recommended for spraying at tasseling stage.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

ABBREVIATION	FULL NAME
%	Percent
@	at the rate of
AEZ	Agro Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
ANOVA	Analysis of variance
BARI	Bangladesh Agricultural Research Institute
BRAC	Bangladesh Rural Advancement Committee
°C	Degree centigrade
cm	Centimeter
CV	Coefficient of variation
DAS	Days after sowing
DAS	Days after sowing
df	Degree of fredom
et al.	And others
etc.	Excreta
Expt.	Experiment
F_1	Hybrids
FAO	Food and Agricultural Organization
g	Gram
ha	Hectare
HI	Harvest Index
kg	Kilogram
kg ha^{-1}	Kilogram per hectare
KGF	Krishi Gobeshona Foundation
LSD	Least significant difference
mm	millimeter
m	meter
mg	milligram
MOP	Muriate of potash
NS	Non-significant
OM	Organic matter
PSC	Proline Seed Company
r	Correlation coefficient
RCBD	Randomize Completer Block Design
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
Soc.	Society
SRDI	Soil Resource and Development Institute
t ha^{-1}	Ton per hectare
TDM	Total dry matter
TSP	Tripple super phosphate
TSP	Triple Super Phosphate
viz.	Namely

CHAPTER I

INTRODUCTION

Bangladesh agriculture is involved in food production for 175.4 million people from merely 8.083 million hectares of agricultural land (Statista, 2020; BBS, 2020) and hence more food will be required in future because of increasing population. Decreasing resources (e.g. land, labour, soil health and water), and increasing climate vulnerability (e.g., drought, salinity, flood, heat and cold) appeared as the main challenges to keep the pace of food production of the country in the background of increasing population. So far sufficient rice production is the key to ensure food security in Bangladesh. In fact, 'Rice security' is synonymous to 'Food security' in Bangladesh as in many other rice growing countries (Brolley, 2015). Since independence, there has been a three-fold increase in rice production in Bangladesh, which jumped from nearly 11 million MT in 1971-72 to about 23.74 million MT in 2018-19 (BBS, 2011; bbs.portal.gov.bd/2020), however, the yield of rice has been reached to plateau.

Globally, wheat, rice and maize are the most important cereal crops in the world, however, maize has got rapid popularity due to its high yield, diversified uses, easy processing, readily digestibility and less costs involvement than other cereals (Jaliya *et al*., 2008). It is the third most important cereal crop in the world after wheat and rice. It is a high yielder in comparison to rice and wheat occupying first position among the cereals in terms of yield [(maize: 8.014 t ha^{-1}; wheat: 3.078 t ha^{-1}; and rice: 3.031 t ha^{-1}), BBS, 2020].

Worldwide, the maize as a major source of carbohydrate is used as human food in different forms, such as in the textile industry and also in the pharmaceutical industry. Globally 67% of maize is used for livestock feed, 25% human consumption, industrial purposes and the remaining is used as seed and thus its demand for grain food is increasing worldwide (Reddy *et al.*, 2013). Because of its variable use in agro-industries, it is recognized as a leading commercial crop of great agro-economic value. The important industrial use of maize includes in the manufacture of starch and other products such as glucose, high fructose sugar, maize oil, alcohols, baby foods and breakfast cereals (Kaul, 1985). Green plant and grain of maize are used as the feed of livestock and poultry, oil is used as the best quality edible oil, while stover and dry leaves are used as good fuel.

Maize (*Zea mays* L.) is referred as 'Miracle crop' or 'Queen of the Cereals' due to its high productivity potential compared to other Poaceae family members. Maize is one of the most important food grains in the world as well as in developing countries. Two types of maize are cultivated around the world, yellow maize and white maize. The United States, China, Brazil and Mexico account for 70% and India contributes 2% of world production of maize. Like as India, the climate condition of Bangladesh favors maize cultivation. In Bangladesh maize was incepted during 1960 after the Second World War through testing some varieties provided by the CIMMYT mainly for research purpose (Karim, 1992). At present its cultivated area accounts near about 0.304 million hectares with a production of over two million tons a year and its production has an increasing tendency with the introduction of hybrid and adoption improved technology since 1993. Recently it has occupied the 2^{nd} position next to rice and occupied 4.8% of the total cropped land area (Ahmad *et al.*, 2011). Total cultivated area of maize is about 3.307 lac hectare with an annual production is 2687 thousand M. tons (BBS, 2018). Bangladesh although produces enough cereal food grains such as rice and wheat but now-a-days maize avails popularity besides these cereal crops.

Hybrid maize cultivation area has been increased at the rate of about 20-25% per year since nineties. Now-a-days, there are many government and non-government organizations who are working for increasing maize production in Bangladesh. Besides, Bangladesh Agricultural Research Institute has released 16 promising hybrid maize varieties (BARI, 2018). Variety plays an important role in producing high yield and good quality maize. Different varieties respond differently to input supply, cultivation practices and prevailing environment etc. during the growing season. Higher yield up to 9-11 t ha^{-1} can be obtained using hybrid seeds, balanced fertilizers and better management practices (Mondal *et al.*, 2014). However, in spite of the increase in land areas under maize production, yield is still low as compared to the average international productivity. The low productivity of maize is attributed due to many factors like decline of soil fertility, poor agronomic practices, and limited use of input, insufficient technology generation, poor seed quality crop competition with disease, insect, pest and weeds.

In Bangladesh about 75% of maize is fed to animals, thus, indirect consumption by human is greater than direct consumption. Although most of the global maize area is in the developing world, but it contributes to less than 50% of the total global production (Pingali and Pandey, 2000). The average yield of the developed world is 8 t ha^{-1} and that of developing world ranges from 1 - 3 t ha^{-1} (Prasanna, 2016; Pingali and Pandey, 2000). In Bangladesh the area, production and yield steadily increased since the introduction of hybrid maize in 1993 by the private sectors. This is due to favorable growing conditions i.e. no serious constraints during the main maize growing season (October - March) and use of hybrid seeds and improved cultivation practices. Maize productivity in Bangladesh is the highest (8.12 t ha^{-1}) in Asia (BBS, 2018).

Maize is grown almost throughout the country. But major concentrations areas are in the northwest part, Jessore region, Dhaka (Savar), Manikgonj, and Cumilla regions. The major cropping patterns involving maize are as follows, Aus rice - T. Arnan rice - Maize; Maize - Mungbean - T. Aman rice; T. aman rice - Potato + Maize; Potato - Maize + red amaranth - T. Aman rice; Maize - Jute -T. Aman rice and Maize - Fallow - T. Aman rice (BARC, 2011).

One model predicts that the population of Bangladesh in 2030 will be 186.0 million, which will reach to 215.4 million in 2050 (Kabir *et al*., 2015). United Nations Population Division (UNPD) has anticipated that there will be an added population of more than 56 million by 2050 to share the total available food (Mukherjee *et al*., 2011). The current yield level of rice is almost at the pick and on the contrary that of the wheat is declining citing the example of 2015 to 2018 (https://www.indexmundi.com/agriculture) and both of the cereals must have a limitations being C_3 in genetically nature. So, to sustain current food production trend, it is essential to choose a third alternative crop to confirm food security in Bangladesh which obviously be the maize, (the C_4 plant).

A good variety having a high yield potential is a key towards improving maize yield being C_4 plant (Saleem *et al*., 2003). In Bangladesh there was no white maize variety for longtime (except Shuvra) before the inception of this study although BARI has released two white maize hybrids e.g. BARI hybrid maize 12 and BARI hybrid maize 13 during 2017. However, varietal trial is the proper way to screen out the most productive variety(ies).

Drought tolerance is the ability of a plant to maintain its biomass production during arid or drought conditions (Ashraf, 2010; Francois *et al*., 2018; Honghong and Lizhong, 2014). Some plants are naturally adapted to dry conditions, surviving with protection mechanisms such as desiccation tolerance, detoxification, or repair of xylem embolism and production of antioxidant anzymes. Other plants, specifically crops like maize, wheat, and rice, have become increasingly tolerant to drought with new varieties created via genetic engineering (Honghong and Lizhong, 2014). Drought tolerance can be tested by imposing the varieties to varying soil moisture regime through differing irrigation frequencies at different growth stages of the crop.

Application of antitranspirants is one of the means to conserve water both in the soil and in plant's body. Antitranspirants are substances applied to the plants for the purpose of reducing transpiration (water loss) rate without causing a significant effect on other plant processes, such as photosynthesis and growth. They have been used with some success in horticulture, especially in the ornamental industry. In field crops there are evidences that antitranspirant application has roles in increasing crop yields under limited supply of irrigation water (Desoky *et al*., 2013).

1.1 Objectives

Considering the above scheme and discussion in mind, the study was conducted to find out suitable white maize varieties for cultivation in Bangladesh under limited soil moisture conditions and to find out suitable way to cope up with the low soil moisture conditions by conserving the plant moisture through applying the antitranspirant on white maize. The specific objectives of the study were:

1. To find out suitable white maize variety(ies) adaptive to cultivate in Bangladesh.
2. To find out white maize variety(ies) suitable to be grown under limited soil moisture conditions, and
3. To find out the proper dose of antitranspirant (e.g. Kaolin) to mitigate water stress condition.

CHAPTER II

REVIEW OF LITERATURE

In 2001, maize (*Zea mays* L.) became the number one production crop in the world, and current world maize production surpasses that of either wheat or rice. Global maize production is expected to be grown by 161 Mt to 1.2 billion tons over the next decade (FAO 2018a). In 2017 the world production of maize is increased to 1,134 million 1000 tonnes with 496 mil tons of milled rice and 757 million tonnes of wheat.

2.1 Origin and distribution

Maize originates from Central America (Mexico) and was domesticated about 7000 - 10,000 years ago with some other controversial opinion that it was also domesticated in Oaxaca, Guerrero and Guatemala (Dowswell *et al*., 1996; Kato (1976 and 1984), McClintock, 1978 and McClintock *et al.,* 1981). The dispersal of maize from its origin throughout the world is believed to have taken two routes; firstly, in lowlands of South America and finally into the Andes Mountains (Matsuoka *et al*., 2002).

Taba (1997) reported that Coloumbus found maize in Cuba and introduced into Europe (Mangelsdorf,1974) and that maize spread into the Asian continent via three routes in the sixteen century; the Mediterranean trade route, the Atlantic and Indian Ocean route and, after Magellan’s voyage, to the Philippines and eastern Indonesia (Taba,1997).

Maize is one of the most diverse crops both genetically and phenotypically. Current genetic diversity in the crop today is the product of a long selection process practiced by native Americans in central America before the spread of the crop to other parts of the world (Mangelsdorf, 1974).

It spread to the rest of the world in the 16th through 18th centuries, including sub-Saharan Africa, but white maize only became a major staple food in eastern and southern Africa between the 1920s and the 1930s.

Maize is a versatile crop with wide genetic variability and the ability to successfully develop in tropical, subtropical and temperate regions under different agro-climatic conditions. The cultivated area of maize and its production have an upward growing trend globally, especially with the introduction of hybrids due to high yield potential (Izhar & Chakraborty, 2013).

2.2 Climate and adaptation

Currently maize is widely grown in most parts of the world over a wide range of differ environmental conditions ranging between 50º latitude north and south of the equator. It was brought to Ethiopia in the 1600s to 1700 s (Huffanagh, 1961). The crop grows best at moderate altitudes but is also found below sea level in the Caspian Depression and at up to 3,800 meters in the Andean mountains (IPBO, 2017).

Santoso (1981) stated that the climate had a considerable effect on plant growth. Of the many climatic factors, probably temperature, light or radiant energy, and the composition of the atmosphere are the most important due to temperature. Each crop has an optimum temperature range for growth. Temperature directly affects plant functions including photosynthesis, respiration or transpiration. Many environmental factors are closely related so that changes in one, such as air temperature affects others, such as soil temperature.

The climate influences its production, adaption and evolution through centuries along with the factors that also depend on the ambient environmental condition such as soil, biotic factors. In addition to the atmospheric environment, the soil environment such as temperature, moisture content, aeration, fertility level, and other specific properties also affect maize production and adaptability (FAO, 1988; Lana *et al.*, 2018). Santoso (1981) stated that maize varieties apparently vary considerably in their adaptation and responses to soil and/or environment, and in the nutrient composition of their tissue.

The optimum temperature for maize growth and development is 18 to 32°C, with temperatures of 35°C and above considered inhibitory. The optimum soil temperatures for germination and early seedling growth are 12°C or greater, and at tasseling 21 to 30°C is ideal. Genetic variability and environmental interaction play an important role in successful maize production (Olakojo and Kogbe, 2005). Milander and Jeremy (2015) stated that the most important environmental factors are solar radiation, water and temperature. These factors cannot be controlled by the grower and vary with growing season.

Santoso (1981) stated that the temperature of the soil was more important than the air temperature. It has been reported that soil temperature influences germination and emergence of maize (Milbourn and Carr, 1977), which in turn will affect subsequent growth and development of leaves (Cooper and Law, 1977), tassel initiation (Coligado and Brown, 1975), grain growth (Duncan, 1969), and the date of silking and maturity (Millbourn and Carr, 1977). Cooper and Law (1977) also put similar opinion based on their studies in Kenya. Santoso (1981) also proved that not only the soil temperature, but also the plant nutrients in the soil affect maize's adaptation and production.

Jong *et al*. (2003) reported that under long-day conditions, corn plants had a longer period of vegetative growth, delayed silking and tasseling, with taller plant and ear heights and greater leaf number. Moreover, Lee (1979) observed that several yield components of maize were affected by extended day length.

Santoso (1981) stated that the adaptation of a crop to a specific area was determined by the genotype of the crop and its interaction with many environmental factors. It is appropriate, therefore, to mention that changes in one of these environmental factors would affect the adaptability of the crop. The management factors can also affect the adaptation of a crop by altering, to a certain extent, the growing condition for the crop. Planting distance will influence the selection of the best adapted variety of maize, for example, since it is known that some varieties are more shade-tolerant than others. The management of soil reaction by applying lime or sulfur has become a common practice to control many plant diseases. In addition, application of fertilizer can decrease the susceptibility of the crop to plant diseases and insecticides can reduce the insect population. These management practices will allow a crop variety to growth in a certain area where it would otherwise be impossible to grow it due to diseases.

2.3 Nutrition

The maize kernel or grain consists of 73% starch, 9% protein, 4% oil and 14% other components such as fiber, and supplies an energy density of 365 Kcal/100 gr. This energy density is very similar to that of other staple crops such as rice (360 Kcal/100 g) and wheat (340 Kcal/100 g). The endosperm of maize grains is starchy (approximately 90%) and the embryo contains high levels of oil (30%) and protein (18%). Excluding the starch, maize endosperm contains different protein fractions: albumins (3%), globulins (2%), zeins (60%) and glutelin (34%), while embryo proteins are mainly albumins (60%). However, maize is deficient in lysine and tryptophan. Maize also provides many of the B vitamins and essential minerals, but lacks vitamin B12, vitamin C, folate and iron. Maize oil (4%) contains predominantly unsaturated fatty acids (60% linoleic acid, 24% oleic acid and 11% palmitic acid). Due to its high linoleic acid content, maize oil is marketable as a high-value product, because it is both essential and "heart healthy" (IPBO, 2017; Hoon *et al*., 2010; Landoni *et al*., 2015).

The yellow coloured maize contains anthocyanin or Vit-A, while the white maize do not. Waxy maize is a variant of normal dent maize that contains nearly 100% amylopectin (becomes sticky when boiled) and very little amylose (responsible for non-stickiness) compared to about 75% amylopectin and 25% amylose for normal dent maize and can be used as a thickener and an adhesive (Thomison, 2011; Fergason, 2001). Yangcheng *et al*., (2012) reported that the waxy maize was useful for the production of ethanol.

2.4 Use/Importance

Maize is a staple food for more than 2500 million people. With nearly 1046 million MT harvested annually (FAO, 2018b). During 1987, maize provided the world with an estimated 15% of total protein and 20% of total calories, which combined with rice and wheat amounts 42.5 percent of the world's food calorie supply and globally, their contribution to our supply of protein is around 37 percent which is a close second to that of fish and livestock products (Brown *et al*., 1988; FAO, 2016).The bulk of maize grown worldwide is yellow, the most of which is used for livestock feed and only a small portion (25%) for direct human consumption which the white has much greater importance than yellow varieties in respect of maize is free from anti-metabolites (https://www.dairyfarmguide.com).

Lives in nine countries the countries (Australia, Argentina, Brazil, Canada, China, France, India, Russia and the USA) having 50% of the global population produce more than 50% of the global food production (www.ubclfs-wmc.landfood). Since the early 2000's the global corn production surpassed the wheat production which in addition to use as food and fodder has also been attributed to increased yields, using as biofuel and as raw material for industry. A recent study found that in the coming decades at least one-quarter of the world's wheat production will be lost to extreme weather from climate change if no adaptive measures are taken (FAO, 1992). Average annual per capita human consumption of maize is 20 kg in developing countries, but in Latin America and the Caribbean, it approaches 80 kg and, in Sub-Saharan Africa, it is estimated 60 kg (CGIAR, 2002).It is widely used in Latin America to make masa, tortillas and tamales. As the corn flour is gluten-free, it is useful for the gluten susceptible patients. In the United States corn cob is used as boiled or roasted, hominy (hulled kernels) or meal, and cooked in corn puddings, mush, polenta, griddle cakes, cornbread, and scrapple. It is also used for popcorn, confections, and various manufactured cereal preparations. African began white maize as human food in the early twentieth century. Despite this late adoption, white maize rapidly spread throughout Africa and became more popular for the following 3 main social reasons: (1) yellow maize is associated with food-aid programs and therefore perceived as being consumed only by poor people, (2) yellow maize is associated with animal feed and (3) yellow maize is too sweet. These perceptions coupled with better taste, the demand of the white maize has increased worldwide (Doebley, 2004; Ranum, 2014; Ullah *et al*., 2018).

In South Africa annually 3.1 million ha of land is used for maize production half of which consists of white maize needing for human food consumption (Plessis, 2003; Gouse *et al*., 2005). However, the later statistics reports that the African farmers produce, sell and eat white maize more than the yellow maize. Africa produces about 33 percent of the world's white maize. In West Africa, 90 percent of total maize production is white. In South Africa, maize for human consumption is almost exclusively white. Central America is the only other world's area that shares Africa's passion for white maize consuming more maize as human food (95%) than for livestock and industrial purposes. Central American consumers have developed their preference for white maize over the long haul. In the USA, white corn has been being grown recently, specifically to take advantage of opportunities in the Mexican market as the price of white corn is quite volatile (McCann, 2005). White maize has been popular for human consumption in Kenya and Namibia. The UK peoples are also being used to the white maize cobs instead of those of yellow maize (NBC, 2017).

The basic staple food of South Africans is white-grained maize. Yellow-grained maize is also grown in large quantities, but is primarily used as animal feed and as an input in the food industry in RSA. White maize is usually planted on 50–60% of the maize area (Gouse *et al*., 2005).

Although rice production in Bangladesh is near to the self-sufficiency, it is still not sustainable due the non-forecastable natural hazards. Wheat is the secondary staple of Bangladesh which is much consumed as 'Cha-Pati' in the morning breakfast. Bangladesh produces one third of its needs, the rest is imported. Wheat import of Bangladesh increased from 1.071 Million tons in 1971 to 6.472 million tons in 2017 with the inland production of 1.20 million tons (BBS, 2019; USDA, 2019). Adding 20-25% of wheat flour, the white maize flour can be used to prepare foods which are normally prepared from wheat and rice flour. So, introducing white maize in Bangladesh is the only option to reduce the wheat import which would help to assure food sufficiency as well complementing current rice production.

2.5 Biology

Maize (*Zea mays* L.) also called corn, is one of the annual cereals in the family *Poaceae* with a stout, erect, solid stem. Staminate (male) flowers are borne on the tassel terminating the main axis of the stem with paired spikelets, one sessile and another stalked (Figure 2.1). The pistillate (female) inflorescences, which mature to become the edible ears, are spikes with a thickened axis, bearing paired spikelets in longitudinal rows; each row of paired spikelets normally produces two rows of grain (britannica.com) (Figure 2.2). Each ear is enclosed by modified leaves called shucks or husks. Varieties of yellow and white corn are the most popular as food, though there are varieties with red, blue, pink, and black kernels, often banded, spotted, or striped (books-db.space).

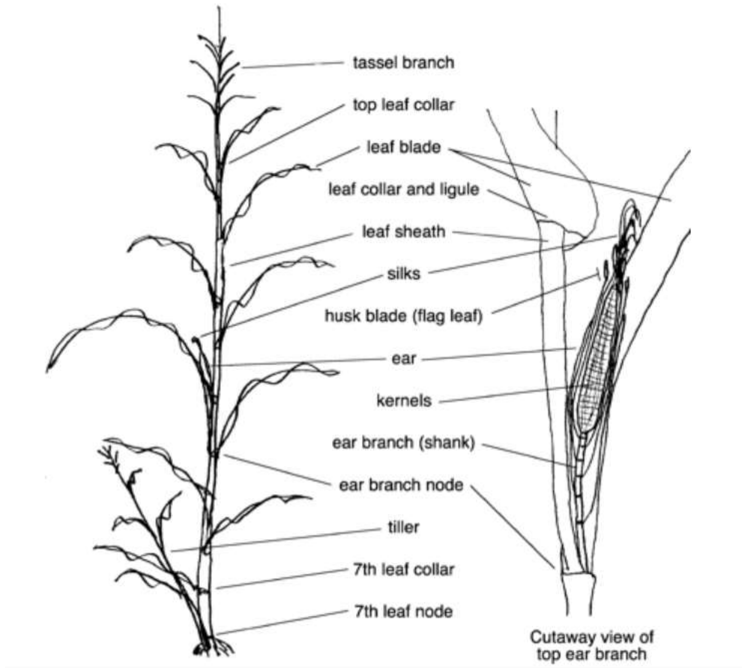


Figure 2.1 Maize plant with its different parts

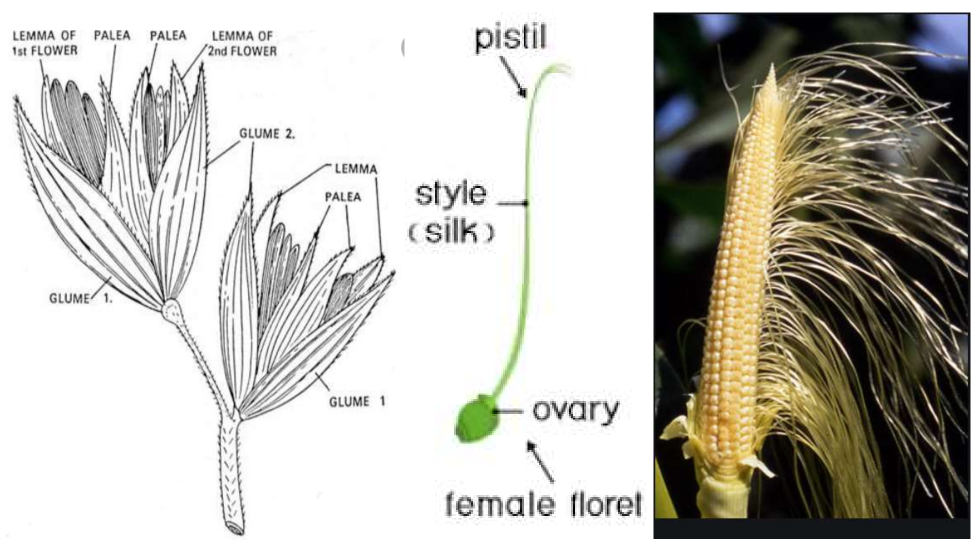


Figure 2.2 Male (left), female (middle) flowers and cob (right) of maize

(Source: https://www.biologydiscussion.com/plants/maize-plant/description-of-a-maize-plant-with-diagram/48957)

After planting, maize seed absorb water from the soil and begin to grow. Emergence occurs when the coleoptile (spike) pushes through the soil surface within five days in ideal heat and moisture conditions (Bonnet, 1947; Ransom, 2013) but may delay up to two to three weeks under cool condition (Pannar, 2013) with the growing point (stem apex) grows between 2.5 to 3 centimetres below the surface (Hanway, 1971). The seminal root system grows from the seed (Figure2.3) and after emergence nodal roots begin to grow (Ritchie *et al*., 1993; OGTR, 2008).

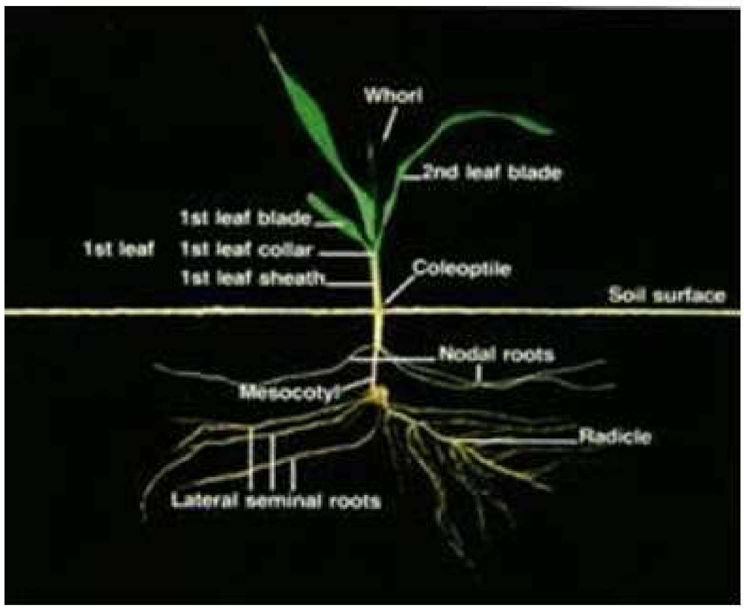


Figure 2.3 A young maize plant (http://www.crsbooks.net)

The young plant develops to the point that the collars start showing on the first leaf. Most of the hybrid corn plants have a single stem differing in height typically 7 to 10 feet tall having 16 to 22 leaves wherein the lowest four nodes remain below ground. The nodal root system grows from the three to four lowest stalk nodes (OGTR, 2008). Some ear shoots or tillers are visible (O'Keefe and Schipp, 2009; Ransom, 2013).

Each vegetative stage in maize is determined by counting the visible collars in the sequence; V1, V2, to VN until the tassel emerges (VT) and maximum height is attained (Figure 2.4) along with counting the lost ones from the bottom (Du Plessis, 2003; Pannar, 2013; Bonnet, 1947).

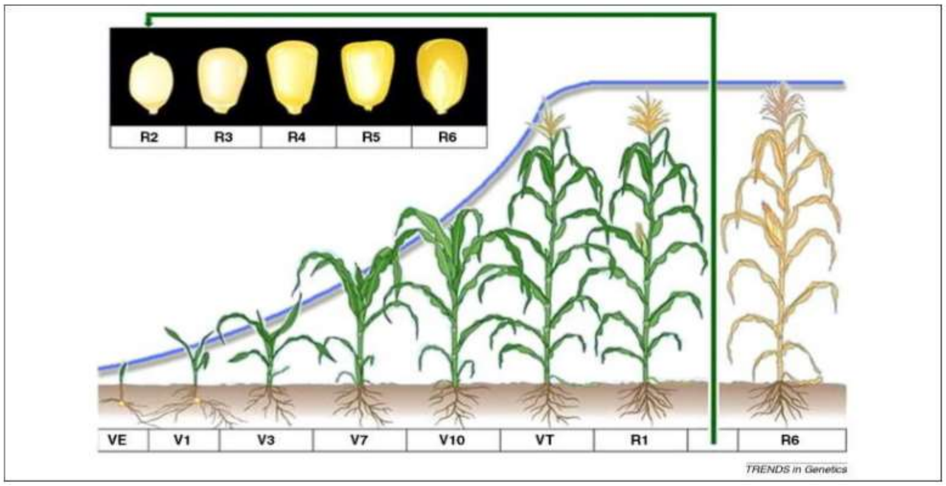


Figure 2.4 Growth and development of a maize plant (odells.typepad.com)

At V3 stage, the stalk (stem) start elongating at a much rate. All leaves and ear shoots are formed inside the stalk from V3 to about V5 (Lee, 2012). A tiny tassel forms at the tip of the growing point (Figure 2.4). The growing point and tassel rise higher above the soil surface at about the V6 stage. The stalk begins to elongate.

The commencement of the reproductive development is noticed at V9 when the ear shoots develop from every above-ground node except the last six to eight nodes below the tassel (Lee, 2012). At first the lower ear shoots grow fast, but only the upper one or two develop to a harvestable ear (Jones and Benton, 1930). The number of kernel rows is also determined by the growing conditions at V9 (Nielsen, 1995; Pannar, 2013). The tassel begins to develop rapidly. Stalks lengthen as the internodes grow (Goldsworthy, 1984). At V10, the time between new leaf stages shortens to about every two to three days. The total number of leaves will vary from 12 to over 20; depending on hybrid maturity and genetic make-up (Uchida, 2000; Ransom, 2013).

The potential number of kernels per row is determined between the V12 and V15 stages. This is the commencement of the most crucial period in determining grain yield (Du Plessis, 2003). Upper ear shoot development overshadows lower ear shoot development (Pannar, 2013; Russel and Sandall, 2005; Eubanks, 2001; Goodman and Brown, 1988; Troyer, 1999; Wallace and Berown, 1988). Silks begin to grow from the upper ears (Lee, 2012).

At the V17 growth stage, the tips of the upper ear shoots may be visible atop the leaf sheaths. The tip of the tassel may also be visible. Just before tasseling, silks from the basal ear ovules elongate first (Bonnet, 1947). Brace roots (aerial nodal roots) grow from the nodes above the soil surface to help support the plant and take in water and nutrients during the reproductive stages (Bonnet, 1947; Glass, 1989; Nazfiger, 2010).

At the VT stage, the last branch of the tassel is completely visible (Ransom and Endres, 2014). VT begins about two to three days before silk emergence; the plant is nearly at its full height (Ransom, 2013). Pollen shed begins, lasting about one week on an individual plant basis and one to two weeks on a field basis (Laekemariam and Gidago, 2012). The interval between VT and R1 can fluctuate considerably depending on the hybrid and the environment. Drought stress lengthens this interval (Russell, 1991; Nazfiger, 2010).

Milander and Jeremy (2015) published that once silks appear from the ear shoot, the plant is considered to be in the silking stage which is the first of the reproductive stages (Figure 2.5). This stage is the most sensitive period for the crop to stress due to the fact that the number of kernels ear^{-1} is determined (Westgate *et al*., 2000). At this stage, both pollination and fertilization occur and silks on the primary ear must be present during pollen shed (Abendroth *et al*., 2011). During silking and just prior to silking unfavorable conditions can cause ear development to be halted and ear abortion (Tollenaar, 1977; Jacobs and Pearson, 1991; Andrade *et. al*., 1999). This could have a negative effect on both ears m-2 and kernel number.

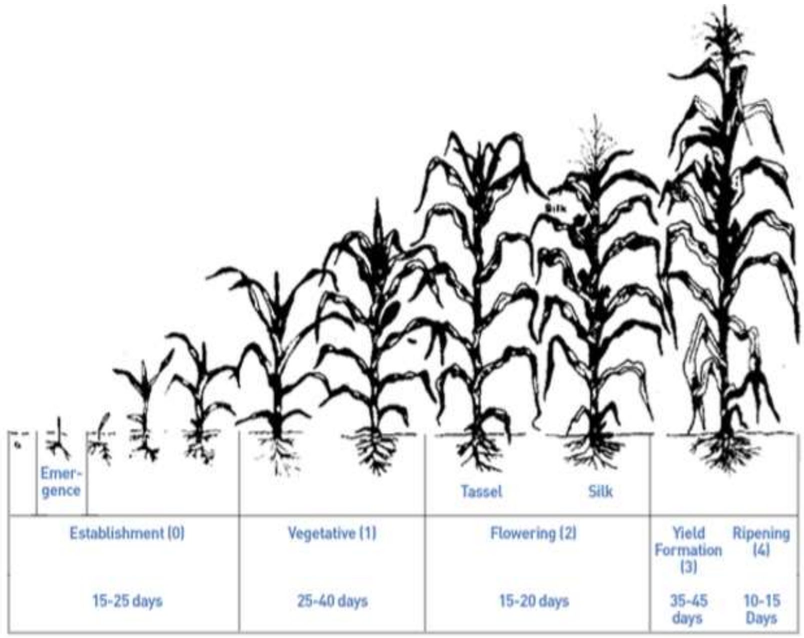


Figure 2.5 The different development stages of a maize plant (http://www.fao.org/nr/water/cropinfo_maize.html).

2.6 Effect of variety

A good variety having a high yield potential is a key towards improving maize yield (Saleem *et al*., 2003). Yield is the primary objective in breeding maize hybrids. Hybrids generally have higher yield potential than open pollinated varieties. Hybrid maize has long ears, more grain rows per ear and greater grain yield than the open pollinated cultivars (Sleper and Poehlman, 2006).

In twenty centuries, approximately 60 percent of the total maize area in the developing world was planted to improved materials (hybrids or improved open-pollinated varieties), and the rest to local materials. If Argentina, Brazil and China are excluded, however, the proportions are reversed: only 40 percent of the total maize area is planted to improved germplasm. It was observed in Nepal that owing to the dominance of the local maize in the cropping system, the maize productivity was 1.5 tons per hectare in 1985. Due to the inclusion of the maize hybrid in some areas, productivity reached 1.6 tons in 1990/91 which further reached 2.6 tons in 2018/19 (Mian and Bahl, 1989; Pandey, 2019). Since most of the required increases in maize production in the foreseeable future is likely to come from yield growth rather than area expansion, this means that further deployment of improved maize hybrids and varieties is crucial.

Warburton *et al.* (2005) reported that the International Maize and Wheat Improvement Center (CIMMYT) includes both white and yellow materials in its breeding programmes, which are aimed at developing countries. The number of white pools (pre-breeding materials of broader genetic composition) roughly equals the number of yellow pools.

In many instances in developing countries, yield gains from crop management changes in maize, both white and yellow, could be greater than those from varietal change alone. This consideration must be qualified by the generally more location-specific nature of crop management research and the extension efforts required to disseminate crop management information to farmers, especially small farmers.

Hallauer *et al.* (1988) reported that twenty-five yellow inbred lines of normal maize were evaluated for eleven parameters to study the genetic divergence using Mahalonabis's D^2 and Rao's canonical variate analysis. The twenty-five inbreds fell into five distinct clusters. The intra-cluster distance in all the five clusters was more or less low, indicating the genotypes within the same clusters were closely related. The highest inter-cluster distance was observed between cluster I and V and the lowest between the cluster II and III. The cluster III and V each contained the highest number of genotypes. Cluster V showed the highest mean values for kernel yield and all the yield contributing traits except days to pollen shedding, days to silking, 1000-kernel weight and cluster I had the lowest mean values for plant and ear height and maturity characters. Days to silking, ear length, number of kernels/row, 1000-kernel weight and kernel yield showed maximum contribution towards total divergence among different characters. Based on medium to high inter-cluster distances, per se performances and desirable traits, fourteen yellow inbred lines viz. BIL 77, BIL 97, CML 287, CML 470, CML 480, CML 486, CZ 2370-22-2, CZ 2370-24-3, CZ 2370-28-2, CZ 2370-31-3, IPB 911-2, IPB 911-22, IPB 911-36 and IPB 911-50 were selected for future hybridization program. Crossing between these genotypes have the chance to obtain higher heterosis with high performing crosses.

Genetic diversity is one of the useful tools to select appropriate genotypes/lines for hybridization. The genetic diversity between the genotypes is important as the genetically diverged parents are able to produce high heterotic effects (Falconer, 1960; Arunachalam, 1981; Ghaderi *et al.* 1984).

Knowledge of germplasm diversity and of relationship among elite breeding materials has a significant impact on the improvement of crop plant. Characterization of genetic diversity of maize germplasm is of great importance in hybrid maize breeding (Xia *et al.,* 2005).

Two important components of maize cropping systems are plant variety and planting date. Proper selection of these components can help in improving maize yields. Maize grain yield potential has dramatically increased during the last 50 years especially in the temperate regions of the world (Russell, 1991; Tollenaar *et al*., 1994).

This yield enhancement can be attributed largely to the release of genetically superior hybrids, reduction of row spacing, higher plant densities, increased use of chemical fertilizers, improved cultural practices and better weed and pest management (Carlon and Russell, 1987; Dwyer *et al*., 1991).

2.6 Growth attributes

Santoso (1981) stated the maize growth as a measure of its adaptation to the environment which may be expressed in terms of plant height, plant nutrient composition, or grain yields. Crop yield is the final product of growth. That is, a product of both the genetic constitution of the crop and the environment. All of the factors included in these two components may not have been identified. Several factors, however, have been studied and shown to affect crop growth.

Giri and Bandyopadhyay (2016) carried out a field experiment at the Bidhan Chandra Karishi Viswavidyalaya of India during 2012-13 and 2013-14 in rabi seasons on medium land new alluvial inceptisol with sandy loam texture to examine the performance of different varieties of maize such as V1- Pinnacle, V2- DKC- 9081 and

V3- all-rounder. Results showed that the maximum growth attributes were recorded by V2 i.e., DKC- 9081 variety followed by the V1 variety i.e., pinnacle.

Moshood *et al*. (2018) conducted an experiment to evaluate the effect of the genotypes (EV99 QPM, TZEE-Y POP STRC4, 2000 Syn.EE-W QPM C0, 99 TZEE-Y STR) on varying growth parameters such as leaf length, leaf width, plant height, number of nodes, distance between nodes, stem girth, length of inflorescence and period it takes to tassel. They observed that the varieties had variations on the above said growth parameters. In the trial it was observed that the distance between nodes increased noticeably and differ significantly (p=0.05) across the varieties. Plots having TZEE-Y POP STRC4 recorded the highest distance between nodes (18.00). The lowest distance between nodes (16.33) was recorded in 99 TZEE-Y STR.

Jiang *et al*. (2013) conducted an experiment at the Gongzhuling Experimental Station of Institute of Crop Sciences, Chinese Academy of Agricultural Sciences, Jilin Province, China, during 2009-2010. Six representative varieties of maize (Baihe in the 1950s, Jidan 101 in the 1960s, Zhongdan 2 in the 1970s, Yedan 13 in the 1980s, Zhengdan 958 in the 1990s, and Xianyu 335 in the 2000s) were each tested under two different densities (52 500 and 82 500 plants ha^{-1}) and two different nitrogen application levels (150 and 300 kg ha^{-1}). The results showed that root mass increased with the process of the growth and development of the plant, and it peaked at kernel filling stage, and decreased at maturity due to the root senesces. Root mass of different maize varieties from the 1950s to 1980s had a trend of increase, while it decreased for the modern varieties. Root length and root surface areas had the similar changing trend. The study suggested that early maize varieties may have root redundancy, and reducing root redundancy may be a direction for variety improvement for high yield.

2.6.1 Plant height

Kabir *et al*. (2019) carrying out an experiment on varietal performance of maize in Bangladesh reported that the plants height at harvest was statistically significant at 1% level of probability due to different variety of maize which ranged from 96.33 to 132.80 cm. The highest plant height (132.80 cm) was observed with the variety

Pacific-559 and the lowest plant height (96.33 cm) was observed in BARI hybrid vutta-13.

Moshood *et al.* (2018) carrying out a trial with some maize genetic lines showed that the plant height increased significantly (p=0.05) across the genetic lines. Plots having TZEE-Y POP STRC4 recorded the highest plant height (216.89). The lowest plant height (157.67) was recorded on from 99 TZEE-Y STR.

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.

Gyenes-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.

Tripathi *et al*. (2016) in an experiment in the consecutive two years observed that the plant height of different maize genotypes ranged from 153-222 cm with a mean of 187 cm in 2010-11 whereas it ranges from 149-189 cm with the mean 173 cm in 2011-12. The highest plant height observed in 30B11 which was then followed by P3856 in the first year while, the varieties ‘Top class’ and ‘KirtimanKundan’ respectively showedthe highest and shortest plants tall and dwarf variety in the second year.

Yakozawa and Hara (1995) 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.

Abera *et al*. (2017) conducted trials on some varieties and reported that the mean plant height of maize varieties was significantly affected by variety. Significantly higher in comparison to others, plant heights were recorded from BH-661, BH-660, and BH-543 in descending order.

Khan *et al*. (2017) conducted an experiment to evaluate the different maize (*Zea mays* L.) genotypes under varying agro climatic conditions at Haripur of Pakistan. The experiment was sown on 17th May, 2015, at the Research Farm of the University of Haripur. Four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) were tested in the experiment. Among the tested varieties, PS-1 produced the tallest plants (212.1 cm) which was followed by PS-2 (201.7 cm).

Khan *et al.* (2017) while performing a varietal trial on maize reported that the plant height was lower in both Iqbal (check) (196.3 cm) and PS-3 (197.3 cm). All maize varieties used in this study had diverse genetic background showing therefore, varying plant heights ranging from 196 to 212 cm. The plant height of PS-1 was higher which was attributed to the vigorous growth in this variety in addition to the genetic makeup of the hybrid (Noor et al. 2010). Similar results were also reported earlier by Beyene *et al*. (2011) showing variation in different maize varieties.

Ebuka (2018) stated that the heritability in different varieties was found to vary having the range of 28.82 - 89.53% in the most of the studied agronomic attributes such as plant stands, days to 50% emergence, days to 50% tasseling, days to 50% silking, plant height, leaf area, ear height, stem girth, days to maturity, plant at harvest, cob length, number of rows/cob, number of grains/cob, grain weight/cob, field weight, grain yield indicating that about 28 – 89% of total phenotypic variations are heritable. They opined that the interactions of genotypes across several environments also need to be investigated in the selection of genotypes besides calculating the average performance of the genotypes under evaluation (Fehr, 1991; Gauch and Zobel, 1997).

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that V_2 produced the tallest plants (118.1 cm) and V_3 produced the shortest ones (106.5 cm).

Mukhtar *et al*. (2011) conducted a research at Maize and Millets Research Institute, Yusafwala, Sahiwal, Pakistan during kharif 2009. Six NP rates (0 - 0, 200-100, 250-125, 300-150, 350-175 and 400-200 kg ha^{-1}) were tried non two maize hybrids (YH-1898 and YH-1921) for growth and yield. They reported that, both two hybrid varieties YH-1921 and YH-1898 showed non-significant result (220.56 cm and 213.00 cm, respectively) for plant height.

2.6.2 Stem circumference

Moshood *et al*. (2018) carrying out an experiment to investigate the performance of different varieties of maize reported that the stem girth increased noticeably but did not differ significantly (p=0.05) across the varieties showing the highest stem girth with EV99 QPM (3.73).

2.6.3 Number of leaves $plant^{-1}$

Kabir *et al*. (2019) carrying out an experiment reported that the number of leaves/plant at harvest was statistically significant at 1% level of probability due to the variety. The number of leaves $plant^{-1}$ for different varieties ranged from 14.44 to 17.44 (Table 3). The highest number of leaves $plant^{-1}$ (17.44) was observed with the variety Pacific-559 and the lowest number of leaves $plant^{-1}$ (14.44) was observed in BARI hybrid vutta-13. However, the number of leaves $plant^{-1}$ at harvest was statistically non-significant due to interaction effects of different water management treatments and variety.

2.6.4 Leaf length and width

Moshood *et al*. (2018) in an experiment watched out that the leaf length increased noticeably and differed significantly (p=0.05) across different varieties. Plots having TZEE-Y POP STRC4 recorded the highest leaf length (100.8 cm), while the lowest leaf length (80.8) was recorded from 99 TZEE-Y STR. Leaf width also increased noticeably and differed significantly (p=0.05) across the treatments.

2.6.5 Leaf area/Leaf Area Index

Abera *et al*. (2017) conducted a field experiment in farmers' field to determine the effect of different varieties and nitrogen fertilizer rate on yield and yield components of maize in two cropping seasons. Five maize varieties (BH-540, BH-543, BH-661, BH-660, and BH-140) were tested in the trial. Mean leaf area and leaf area index of maize were significantly affected by use of varieties in three farms, indicating variations of leaf size of different varieties of maize among farmers' field. Higher leaf area and leaf area index of 7246 cm^2 and 3.86 were found respectively from BH-661 followed by BH-660.

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 $plant^{-1}$. He concluded that a large leaf area per plant produced more assimilate in the plant, resulting in increased yield. LAI can be improved in two ways: breeding for increased leaf area $plant^{-1}$ and increasing plant density. One of the breeding strategies available for increasing leaf area $plant^{-1}$ is to incorporate the leafy trait into inbred lines.

Watson (1997) defined leaf area index (LAI) of a crop as the one-sided area of green leaf tissue $plant^{-1}$ unit area of land occupied by that crop. That is the area of leaf per area of land. 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.

2.7 Yield attributes/components

Grain yield in maize is a product of three components; number of ears unit $area^{-1}$, unit grain weight and the number of kernels ear^{-1} (Gardner *et al*., 1985). Increasing or decreasing any of these components will influence the final grain yield (Devi and Muhammad, 2001).

Milander and Jeremy (2015) stated that the yield components that can be considered second order or secondary are those that indirectly effect yield through their effect on first order components. These components consist of rows ear^{-1}, ear length, kernels rows^{-1}, and ear circumference (Figure 2.6).

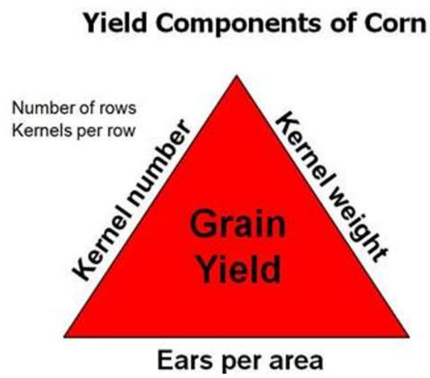


Figure 2.6. Yield component model of maize (Lauer, 2006)

Abendroth *et al*. (2011) and Greveniotis *et al*. (2019) stated that higher yield per unit land area is generally produced with relatively high plant populations combined with an adequate number of kernels ear^{-1} rather than a low plant population with a large number kernels ear^{-1}. This leads one to believe that ears m^{-2} has a larger correlation with yield in maize than the other components; however, this correlation is highly dependent on time of stress. Grain yield is the summation of physiological and morphological development, and these processes need to be understood in order to attain the highest grain yield (Fageria *et al*., 2006).

Moshood *et al*. (2018) conducted an experiment to evaluate four varieties of maize for optimum growth and yield under field condition. The varieties were TZEE-Y POP STRC4, EV99QPM, 2000SynEE-W QPM C0 and 99TZEE-Y STR. The TZEE-Y POP STRC4 had the best potential for increased grain yield due to having a wide genetic base irrespective of soil and environmental difference. The said variety was also resistant to a wide range of biotic and a biotic stress.

Magorokosho (2006) concerning the set of grain yield component traits observed that the most of the correlations among the traits were strong (both negative and positive) except for YLD (yield) and HK (Hickory) WT (variety), YLD and KW(variety), YLD and EL (ear length), YLD and Ed (days to anthesis), YLD and CD (cob diameter), YLD and RD (rachis diameter) suggesting that these traits contribute substantially to final grain yield. There was also strong correlation between KL (kernel length) and ED (ear diameter), KL and CD (cob diameter), ED and RD and CD and RD, and EPP and KL. For this set of traits, the highest values were observed for ED and RD (r = 0.99), CD and RD (r = 0.98), HKWT and KW (r = 0.98), HKWT and KL (r = 0.80), and HKWT and NKR (r = -0.81). He obtained significant variation in the studied varieties for grain yield (GY), days to 50% anthesis (AD), number of ears plant^{-1} (EPP), but not for anthesis-silking-interval (ASI). Although the range in AD was wide across all the varieties tested, the range per breeding period was small enough to allow meaningful comparison of yields without undue concern about maturity. Mean grain yield consistently increased for each decade group (breeding period) beginning at 2.458 Mg ha^{-1} (Mg=mega gram) for the OPVs (open pollinated varieties) grown in the 1900s to 10.993 Mg ha^{-1} for hybrids grown during the 2000s.

Tadesse *et al*. (2014) carried participatory variety selection (PVS) trials in 2012 and 2013 in Ethiopia to evaluate the performance of improved maize (*Zea may* L.) varieties and to assess farmers' criteria for maize variety selection for future maize improvement. Six improved varieties including the local check were used for the study at four farmer villages: Anguaba, Serako and Eyaho. The experiment was laid out in a randomized complete block design and the trials were replicated over farmers' field in the three villages. The results of analysis revealed a significant difference among the varieties for most the agronomic traits recorded except for grain yield.

Milander and Jeremy (2015) describes the yield as being composed of physical components that directly correlate to the amount of grain produced by the crop. Yield components are interrelated, have compensatory effects, and develop sequentially at different stages. First order yield components of maize consist of the number of ears m^{-2} (or ears plant^{-1}), kernels ear^{-1}, and kernel weight. First order yield components are sometimes referred to as primary components and have a direct effect on final yield as well as indirect effects through later developing yield components (Fageria *et al*., 2006).

Bhuiyan *et al*. (2015) carried out a study at the field of Sher-e-Bangla Agricultural University, Dhaka-1207, from December 2010 to May 2011 to determine optimum irrigation levels for the hybrid maize varieties. There were four hybrid maize varieties: V_1 (BARI Hybrid Maize-5), V_2 (Pacific 60), V_3 (NK 40) and V_4 (Ajanta) and three levels of irrigation: I_1 = Two irrigations at 25 and 50 DAS, I_2 = Three irrigations at 25, 50 and 75 DAS and I3 = Four irrigations at 25, 50, 75 and 100 DAS, respectively. It was observed that almost all the plant and yield contributing characters showed significant variation except days to 6 leaf stage and days to bud initiation stage.

Paudel (2009) conducted field experiments during two consecutive years of 2006 and 2007 in full season of maize (May-Sep) at Dukuchhap, Lalitpur to find out impact of growing hybrid and OPV (open pollinated varieties) maize in different rows combinations with respect to their pure stands in same environment of growing and to sort out non-lodging maize varieties ('Deuti') and hybrid 'Gaurab' in different row combinations (50% hybrid + 50% OPV, 75% hybrid + 25% OPV, 75% OPV + 25% hybrid plus their pure stands). The results showed that Gaurab (yellow, flint type) and Deuti (white, semi- flint type, selected from CIMMYT's material ZM 621) did not vary significantly in grain yield and yield components. He also reported that numerically average grain yield performance of pure stand of a hybrid maize in two years' trial was inferior (4581-4740 kg ha^{-1}) to that of OPV (open pollinated varieties). This explains that OPV can compete or even be superior to hybrid at Dukuchhap conditions for obtaining increased grain yield. Gaurab hybrid and Deuti OPV were comparable for grain yield and yield related attributes and they were agronomically and physiologically similar in maturity, plant height and yield attributes. It was therefore advised to farmers that composite variety of maize was superior to hybrid because hybrid in general demanded increased level of inputs such as fertilizer, yearly replacement of seed which is many times expensive than that of OPV, plant protection and improved husbandry practices.

Nawaz *et al.* (2019) set an experiment to study varying nitrogen application methods on yield of maize varieties in Baffa research station of Pakistan during 2018. The experimental results showed that taller plants (200 cm), highest biological yield

(12664 kg ha^{-1}) and highest grain yield were reported from the variety Azam (3765 kg ha^{-1}).

Ali *et al*. (2018) carried out a field experiment at the University of Agriculture Research Farm during summer 2016 to evaluate the influence of sowing dates on varying maize varieties grown under the agro-climatic condition of Peshawar. The varieties (Iqbal, Azam, Jalal, Babar, SB-989, SB-909, SB-292, CS-200, CS-220, and W-888) were sown in varying sowing dates (10 June, 21 June, 1 July, 11 July, 22 July). Among the different varieties the maximum days to tasseling (57), days to silking (62), tasseling and silking interval (7) from the variety W-888. Plant height, (176 cm), biological yield (17279 kg ha^{-1}), 1000 grain weight (410 g), grain yield (5113 kg ha^{-1}) was also obtained from that variety.

Giri and Bandyopadhyay (2016) carried out a field experiment at district seed farm AB block of Bidhan Chandra Karishi Viswavidyalaya, Kalyani, West Bengal during 2012-13 and 2013-14 in rabi seasons on medium land new alluvial inceptisol with sandy loam to examine the performance of different varieties of maize such as V_1- Pinnacle, V2- DKC- 9081 and V_3- all-rounder. In the experiment it was observed that the maximum yield attributes and yield were recorded under V_2 i.e., DKC- 9081 varietal treatment followed by V_1 i.e., Pinnacle varietal treatment.

Sutresna *et al*. (2018) examined responses of ten genotypes of maize varieties in respect of the characteristics of plant height, diameter of stalks, diameter of cob, length of cob, weight of 100 dry seeds, and dry seed weight $plant^{-1}$. The highest plants were given by Lamuru and Sukmaraga varieties, whereas the weight of fresh biomass, the length of the cob, the diameter of the cob and the weight of the heaviest dry seed $plant^{-1}$ are achieved by the Pioner.

2.7.1 Ear height/Ear position

Khan *et al*. (2017) made an experiment to evaluate the "Seed yield performance of different maize (*Zea mays* L.) genotypes under agro climatic conditions of Haripur". The experiment was sown on 17th May, 2015, at Research Farm of the University of Haripur. Four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) were tested in the experiment. The data showed that maize variety PS-1 had maximum ear height (distance/position) of 88.7 cm. It was statistically similar with ear height of PS-2 (83.7 cm) whereas lower ear height was observed with Iqbal (check) and PS-3. The difference in ear height might be attributed to genetic diversity of tested maize varieties (Noor *et al*., 2010; Ajmal *et al*., 2000; Salami *et al*., 2007).

2.7.2 Number of cobs per plant

It has been found that ears m^{-2} is reduced by water stress early in vegetative growth, with longer periods of water stress resulting in a fewer ears (Pandey *et al*., 2000).Previous studies (Agrama, 1996; Mohammadi *et al*., 2003) of maize yield components have used ears $plant^{-1}$ as a primary component rather than ears m^{-2}.Path coefficient analysis has indicated that the number of ears $plant^{-1}$ had a larger effect on grain yield than any of the other yield components (Agrama, 1996) as also found for other crops such as wheat (*Triticum aestivum* L.) (Dhungana*et al*., 2007) and barley (*Hordeum vulgare* L.) (Dofing and Knight, 1994).

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that the number of cobs per plant differed insignificantly both under the irrigation and varietal treatments. Treatment I_1produced the highest number of cobs (1.07) per plant and I_3 produced the lowest number of cobs (0.93) per plant. They also showed that the highest number of cobs (1.09) $plant^{-1}$ was obtained under V_1 and the lowest number (0.89) was obtained under V_2. The treatment combination I_1V_1 produced the highest number of cobs (1.17) per plant and I_3V_2produced the lowest number (0.77) of cobs per plant.

Kabir *et al.* (2019) reported that the number of cobs $plant^{-1}$ were statistically significant at 1% level of probability due to different variety. The number of cobs $plant^{-1}$ for different varieties ranged from 1.02 to 1.07. The highest number of cobs $plant^{-1}$ (1.07) was observed with the varietal factor V_3 (pacific-559) which is statistically similar to V_1 (BARI hybrid vutta-9) and the lowest number of cobs/plant (1.02) was observed in the factor V_2 (BARI hybrid vutta-13).

Moshood *et al*. (2018) reported that the number of cob increased noticeably but not differ significantly (p=0.05) across the treatments. However, plots treated with 2000 Syn. EE-W QPM C0 recorded with highest number of cob (1.78) and the lowest number of cob (1.44) was recorded on 99 TZEE-Y STR.

Eyasu *et al.* (2018) observed that the maximum number of ears plant^{-1} (1.57) was produced by variety Limu, whereas the lowest number (1.0) of ears plant^{-1} was produced by variety Jabi. On the other hand, the number of ears plant^{-1} was statistically the same for maize varieties Lemu and BH-540. Similar result was reported by Abdul Latif (2002), who observed significant variation in maize varieties on number of kernel rows ear^{-1}.

2.7.3 Cob/Ear length

Kabir *et al*. (2019) reported that the cob length (cm) was statistically significant at 1% level of probability due to different variety. The cob length for different varieties ranged from 13.09 to 14.27 cm. The highest cob length (14.27 cm) was observed with the varietal factor V3 (pacific-559) and the lowest cob length (13.09 cm) was observed in the factor V2 (BARI hybrid vutta-13) which is statistically similar to V1 (BARI hybrid vutta-13).

Eyasu *et al*. (2018) observed that the highest ear length (33.84 cm) was recorded for variety Jabi at row spacing of 75 cm, while the lowest (30.03 cm) ear length was recorded for variety at row spacing of 45 cm. Number of kernels ear^{-1} was statistically the same for Jabi and BH-540 maize varieties grown at 65 and 75 cm row spacing.

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that the maize varieties, V_3 provided the longest cobs (17.67 cm) and V_2 provided the shortest cobs

(16.78 cm). Niazuddin *et al.* (2002) and Gab-Alla *et al.* (1995) also reported similar effects of water regimes on the cob length of maize. The combined effects of irrigations and varieties however caused significant differences in cob length.

2.7.4 Cob diameter/Circumference

Kabir *et al.* (2019) found that the cob diameter (cm) was statistically significant at 1% level of probability due to different variety. The cob diameter for different varieties ranged from 11.58 to 12.21 cm. The highest cob diameter (12.21 cm) was observed with the varietal factor V_3 (pacific-559) which was statistically similar to V_1 (BARI hybrid vutta-9) and the lowest cob diameter (11.58 cm) was observed in the factor V_2 (BARI hybrid vutta-13) treatment.

2.7.5 Number of grain rows per cob

Nielsen (1995) noted that the number of rows cob^{-1} is highly dependent on the genetic make-up of a variety, more than it is influenced by the environmental conditions. Khan *et al*. (2017) conducted an experiment to evaluate the “Seed yield performance of different maize (*Zea mays* L.) genotypes under agro climatic conditions of Haripur” of India. The experiment was sown on 17th May, 2015 using four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check). Mean values of the data indicated that higher number of rows ear^{-1} (15.6) were recorded with PS-1, which was statistically similar with grains rows ear^{-1} of PS-2 (14.8) and lower number of grain rows ear-1 (13.9 and 13.6) were observed in PS-3 and Iqbal (check) respectively. These results were in line with (Ahmad, 2000) who reported that hybrid cultivar produced more number of grain rows**.**

2.7.6 Number of grains /row

Kabir *et al.* (2019) reported that the number of grain rows cob^{-1} was statistically significant at 1% level of probability due to different variety. The number of grain rows cob^{-1} for different varieties ranged from 12.49 to 13.24. The highest number of grain rows cob (13.24) was observed with the varietal factor V_3 (Pacific-559) and the lowest number of grain rows cob^{-1} (12.49) was observed in the factor V_2 (BARI hybrid vutta-13). Andrade *et al.* (1999) identified the number of kernels row^{-1} as one of the main components which directly influence the total grain yield in maize.

Eyasu *et al.* (2018) observed that the variety Lemu produced the highest kernel rows ear^{-1} (16.34) at 75 cm row spacing, whereas the variety Jabi showed significant increase in number of kernel rows cob^{-1} as the plant row spacing increased from 45 cm to 75 cm with significant difference between row spacing's. The highest mean number of kernels row^{-1} (51.67) was observed from the Lemu maize Varity, while lowest mean number (36.34) at 45 cm by BH-540 maize Variety, which was statistically similar to other varieties.

2.7.8 Number of grains (kernel) cob^{-1}

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that the effect of irrigation and varietal treatments on the number of grains cob^{-1} were insignificant. The highest number of grains cob^{-1} (547) was obtained under I_4 and the lowest number (509) was obtained under I_3. The V_3 provided the highest number (552) of grains per cob while V_1 provided the lowest (510) number of grains cob^{-1}. The treatment combination of I_4V_3 produced the highest number of grains cob^{-1} (585) while I_3V_1 produced the lowest (485) number of grains cob^{-1}. There were significant differences among the number of grains per cob under the combined effects of irrigation and varietal treatments.

Kabir *et al*. (2019) published that the number of kernels/cob was statistically significant at 1% level of probability due to different variety. The number of kernels/cob for different varieties ranged from 261.00 to 310.40. The highest number of kernels cob^{-1} (310.40) was observed with the varietal factor V_3 (Pacific-559) and the lowest number of kernels cob^{-1} (261.00) was observed in the factor V_2 (BARI hybrid vutta-13).

2.7.9 100 seed weight

Individual kernel mass (1000 sw) is one of the most important parameters for the total grain yield in maize (Severini *et al*., 2011). Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The highest 100-seed weight of 32.10 g was obtained under I_3, while the lowest of 30.59 g was obtained under I_3. For the three maize varieties, the highest 100-seed weight (31.24 g) was obtained under V_3 while the lowest (30.60 g) was obtained under V_1. The 100-seed weight under both irrigation and varietal treatments were identical. These results were in agreement with the findings of Hossain *et al.* (2011) and Orfanou *et al.* (2019). Considering interaction effects between the irrigation and maize variety, there were significant differences in 100-seed weights among different treatment combinations. The highest 100-seed weight of 33.18 g and the lowest of 29.05 g were obtained under the treatment combinations $I_1V_2$and I_0V_1, respectively.

Eyasu *et al.* (2018) reported that the highest weight of 1000 kernels (456.33 g) was obtained from variety 'Lemu'. Sutresna *et al.* (2018) informed that the Pioner hybrids could better adapt to a growing environment with adequate cultivation technology, which means it is more suitable to be cultivated in the growing environment with the average weight of the highest dry seed equivalent to 13.03 ton ha^{-1}.

Lopes *et al.* (2016) tested five varieties of maize (IPR 114, PC 0402, PC 0404, BR 106 and BRS Angela) and the results showed that the variety PC 0404 was the most suitable for obtaining baby corn. The PC 0402 showed the best results for color parameters L*, a*, b*, C*, H* and the lowest weight loss during storage periods.

Kabir *et al.* (2019) reported that the 1000 seed weight (g) was statistically significant at 5% level of probability due to different variety which ranged from 318.20 to 328.50 g. The highest 1000 seed weight (328.50 g) was observed with the varietyPacific-559 which was statistically similar to that of BARI hybrid vutta-9 and the lowest 1000 seed weight (318.20 g) was observed in the BARI hybrid vutta-13.

Moshood *et al.* (2018) reported that the weight of 100 grains increased noticeably and significantly (p=0.05) across the varieties. Plots having 2000 Syn. EE-W QPM C0 recorded the highest weight of 100 grains (33.00).

2.7.10 Cob weight

Moshood *et al*. (2018) reported that the weight of cob increased noticeably and differed significantly (p=0.05) across the treatments. However, plots treated with TZEEY POP STRC4 recorded with highest number of cob (182.11) and the lowest weight of cob (131.22) was recorded with 99 TZEE-Y STR.

2.7.11 Grain yield

Maize (*Zea mays* L.) grain yield is determined by the growth and development of the maize plant, the amount of photosynthesis during the growing season, and how efficiently the photosynthate is partitioned into grain. Yield can also be considered to be the result of the interaction of genotype, management, and environmental factors (Fageria *et al*., 2006).

Macharia *et al*. (2010) conducted experiments on farmers' fields in a medium altitude ecosystem in Western Kenya to determine agronomic and financial implications of using farm-saved seed selected from advanced open pollinated generations of certified maize hybrids. First generation of certified seed (G1) of two commercial hybrids (H513 and H614), a local maize variety-Ababari and their respective advanced open pollinated generations two and three (G2 and G3) were evaluated with and without inorganic fertilizer. Significant differences (P<0.05) in maize grain yield were observed with the G1 consistently yielding more than their respective G2 and G3 generations.

Eyasu *et al*. (2018) conducted a field experiment at Ofa district-Geleko irrigation site during the off-season of 2016/17 cropping season with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize using three maize varieties ('BH-540', Lemu 'P3812W'and Jabi 'PHB 3253'). Significantly the highest grain yield was produced by maize variety Lemu grown at row spacing of 65 cm, which is statistically similar with variety BH-540.

Tripathi *et al*., (2016) reports on research finding on 117 maize hybrids of 20 seed companies assessed for grain yield and other traits at three sites in winter season of 2011 and 2012to identify superior maize hybrids suitable for winter time planting in eastern, central and inner Terai of Nepal. Across sites highly significant effect of genotype and genotype × environment interaction (GEI) on grain yield of commercial hybrids were noticed. The topmost yielders were identified from the tested hybrids which were P3856 (10515 kg ha^{-1}), Bisco prince (8763 kg ha^{-1}) as well as Shaktiman (8654 kg ha^{-1}) in the first year, while 3022 (8378 kg ha^{-1}), Kirtimanmanik (8323 kg $ha^{-1.}$) and Top class (7996 kg ha^{-1}) in the second year.

Abera *et al.* (2017) tested different maize varieties and found that the maize varieties BH-661 > BH-660 > BH-540 > BH-543 > BH-140 were in order producing higher grain yield. That is, BH-661 followed by BH-660 significantly produced higher combined mean grain yield and was recommended for farmers to produce in the selected areas. They then concluded that the farmers should use maize varieties BH-661 > BH-660 > BH-540 > BH-543 > BH-140, importance in descending order for alternative options.

Alom *et al*. (2009) carried out an experiment at Regional Agricultural Research Station, Bangladesh Agricultural Research Institute (BARI), Jessore to evaluate the performance of different varieties of hybrid maize under intercropping systems with groundnut in rabi seasons in the consecutive two years (2004 and 2005). Pacific-11 showed higher maize equivalent yield of 13.56 t ha^{-1} in 2003- 04 while 15.34 t ha^{-1} in 2004-05). Higher grain yield was observed sole maize var. Pacific-11. BARI Hybrid Maize-1 (BHM-1) was lower yielder in monoculture (T9).

Bhuiyan *et al*. (2015) carried out trials to have the performance of some maize varieties (V) and obtained the maximum yields from V1I3 (7.92 t ha^{-1}) which was statistically identical to V_4I_3 (7.83 t ha^{-1}), V_2I_3 (7.45 t ha^{-1}), V_1I_2 (7.40 t ha^{-1}), V_2I_2 (6.87 t ha^{-1}) and V_4I_2 (6.80 t ha^{-1}), respectively.

Ghimire *et al*. (2016) set a field experiment in farmer's field of Maina Pokhar and Deudakala Village Development Committee in Bardiya District of Nepal. The objective of study was to identify the appropriate combination of variety and cultivation practice of maize in spring season. Two maize varieties Rajkumar (hybrid) and Arun2 (Open Pollinated Variety-OPV) were sown at the field of 6 different farmer's field. Results showed that the Rajkumar variety produced the highest average grain yield of 5.13 t ha^{-1}. The variety Arun2 produced the mean grain yield 2.52 t/ha. Hybrid maize technology has made significantly yield advances and increased productivity in both developed and developing countries (Katuwal, 2012).

Sutresna *et al*. (2018) made a study with farmer's active participation approach (on farm) examining the Superior Variety Sukmaraga and Lamuru, BISI 18 Hybrids, Pioner Hybrids, BISI Hybrids 2, Arjuna Superior, NK 22 Hybrids, Seraye Local Cultivar, and Bima Local Cultivar. The results showed that the highest yield was obtained by the Pioner hybrid. Again, the yield of Sukmaragawas higher and different than those of Arjuna, Lamuru, Population C_2, Seraye and Bima.

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The irrigation and the variety exerted insignificant influences on the grain yield of maize. The highest grain yield (8.57 t/ha) was obtained under I_3 and the lowest (7.62 t ha) was obtained under I_0. These results were in agreement with those of Talukder *et al*. (1999), Niazuddin *et al*. (2002) and Hossain *et al.* (2011). An increasing trend in grain yield was observed due to the lowering of water stress. The V_3 provided the highest grain yield (8.60 t ha^{-1}) and V_2 provided the lowest (7.31 t ha^{-1}) yield. The interaction effects between the irrigation and maize variety revealed that the highest grain yield (9.31 t ha) was obtained under the treatment combination I_4V_3 and the lowest (6.34 t/ha) was under I_0V_2. Similar effect of water regimes and variety on the grain yield of maize was also reported by Hossain *et al.* (2011).

Shrestha and Kunwar (2014) from two-year observation recorded that there was significant variation in eighteen maize hybrids for flowering and grain yield. Tripathi *et al.* (2016) testing some varieties of maize showed that five top yielding genotypes produced more than 10000 kg ha^{-1} grain yields but lowest five provided 4515-6364 kg ha^{-1} with trial mean yield 7783 kg ha^{-1} in 2010-11. On the other hand, top five genotypes provided 7814-8378 kg ha^{-1} and lowest five gave 3517-4078 kg ha^{-1} with trial mean of 6048 kg ha^{-1} in 2011-12. High yielding genotype produced more than 35 to 38 percent higher than average grain yield in the first year and second year respectively. It also indicated that the lowest yielding genotype produced nearly 50 percent greater yield than the national average (2501 kg ha^{-1}) of 2012.

Kabir *et al*. (2019) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from December 2017 to April 2018 to study the yield performance of some maize varieties as influenced by irrigation management at different growth stages on three varieties viz. V_1= (BARI hybrid vutta-9), V_2= (BARI hybrid vutta-13), V_3= (pacific-559). The grain yield (t ha^{-1}) for different varieties ranged from 5.55 to 5.87 t/ha. The highest grain yield (5.87 t ha^{-1}) was observed with the variety Pacific-559 and the lowest (5.55 t ha) $^{-1}$) with BARI hybrid vutta-13.

2.7.12 Stover yield

Kabir *et al*. (2019) reported that the stover yield for different varieties ranged from 8.04 to 8.66 t ha^{-1}. The highest stover yield (8.66 t ha^{-1}) was observed with the variety Pacific-559 and the lowest stover yield (8.04 t ha^{-1})) was observed in the BARI hybrid vutta-13.

Describing the results of some of the old works of Izhar and Wallace (1967); Heichel and Musgrave (1969) and Moss and Dpwney (1971); and recently Sun *et al*., (2018) stated that as leaves were the photosynthetic factory of the plant, the amount of photosynthate available for biomass production is related both to the current leaf area and photosynthetic rate of the leaves. Therefore, crop stover yield is a result of accumulated daily carbon gains from photosynthesis throughout the growing season. Leaf photosynthetic rates have sometimes been correlated with dry matter potential among genotypes. The period from silking to physiological maturity is uniform and averages from 50 to 55 days for most hybrids. Pollination generally occurs within one to three days after silking and sufficient soil moisture levels, and optimum temperatures are critical for pollination.

2.7.12 Biological yield

Kabir *et al*. (2019) carrying out an experiment reported that the biological yield (t/ha) of some maize varieties were statistically significant at 1% level of probability due to different variety. The biological yield for different varieties ranged from 13.60 to 14.54 t ha^{-1}. The highest biological yield (14.54 t ha^{-1}) was observed with the variety Pacific-559) and the lowest biological yield (13.60 t ha^{-1}) was observed in the BARI hybrid vutta-13.

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that the highest biological yield (10.58 t ha^{-1}) while the most stressed treatment, I_0, produced the lowest (8.32 t ha^{-1}) yield, both yields were however statistically similar. The biological yield was the utmost (9.12 t ha) for V_1 and the least (8.35 t ha) for V_2. The maize varieties also did not significantly influence the straw yield. The interaction effects of irrigation and maize variety however employed significant influences on the biological yield. The highest (10.69 t ha) and lowest (5.26 t ha) biological yields were obtained under $I_1V_3$and I_4V_2, respectively.

2.7.13 Harvest index

Kabir *et al*. (2019) reported that the harvest index (%) for different varieties ranged from 40.39 to 40.83%. The highest harvest index (40.83%) was observed with the variety BARI hybrid vutta-13 that was statistically similar to that of BARI hybrid vutta-9 and the lowest harvest index (40.39%) was observed in Pacific-559).

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that the highest harvest index (55.89%) was obtained under I_1 and the lowest (50.87%) was obtained under I_3, both values were statistically similar. The three maize varieties also provided similar harvest indices. The v_3 provided the highest harvest index (52.16%) and V_2 provided its lowest (51.45%) value. The interaction effects of the irrigation and maize variety on harvest index were significant. The highest harvest index (57.65%) was obtained under $I_2V_3$and the lowest (46.20%) was obtained under I_3V_1.

2.8 Effect of water regimes

Pre-anthesis drought stress reduced the kernel row number and the number of kernels per row thus reducing the kernel number as well (Moser *et al*., 2006). Eck (1986) also found that water deficit during the vegetative growth stages reduced kernel numbers and had little effect on kernel weight. Kernel weights and yield were reduced due to reduced photosynthesis and translocation of dry matter to the grain, and an acceleration in leaf senescence.

Eck (1986) indicated that when kernel numbers have been reduced by water stress in the vegetative growth stages kernel weight may increase in order to compensate for the lower kernel number. This increase might be attributed to the shortening of the ear and elimination of some of the smaller kernels (Eck, 1986). Moser *et al*. (2006) reported low 1000-kernel weights due to pre-anthesis drought stress. It was concluded that this reduction in kernel weight was due to the reduced capacity of assimilate production and storage during grain filling. It has been observed stress before pollination may lead to failure of ear development and a reduced kernel number stress immediately after pollination reduces kernel number as well (Claasen and Shaw, 1970; Harder *et al*., 1982).

Stress occurring after 2 or 3 weeks after pollination no longer affects the number of kernels plant^{-1} but rather reduces kernel weight (Eck, 1986). Drought is the most important factor limiting maize crop productivity in many areas of the world, and large yield losses can occur when maize is exposed to drought conditions around flowering (Bänziger *et al*., 2002). Edmeades *et al*. (1999) reported that 34-40% of the inter-annual variability of the yields in the principal maize-growing region of the tropics was explained by variations in rainfall. Drought stress had its most devastating impact when it occured around flowering (Banziger *et al*., 2002). These facts have led to an interest in developing drought-tolerant genotypes for water-limited regions (Bruce *et al*., 2002). Yield gains for drought close to flowering have been useful, but gain under seedling drought stress and terminal drought stress has been poor (Banziger *et al.,* 2002).

Genetic variation in nitrogen uptake and its relation to the production of grain in maize have been reported (Pollmer *et al*., 1979). Maize plants differ in their ability to absorb nutrients and this is an inherited characteristic (Jones and Crsskston, 1973) concluded that accumulation of nutrient elements is under genetic control. Screening crop varieties, such as screening maize for tolerance to acid or alkaline conditions (Mortvedt, 1976), or for efficiency in the use of nutrients (Clark and Brown, 1974), has been used to select varieties that are more adapted to certain soil conditions.

An improved understanding of the interaction between a crop, fertilization and precipitation is essential for efficient utilization of the scarce water resource in crop production (Ahmad *et al.* 2002). This is important in ensuring sustainable food production under rain-fed cropping systems currently threatened by climate change (Fan *et al.,* 2005). Shariot-Ullah *et al*., (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that V_3 (Pacific 984) produced the highest (8.60 t ha) and V_2 (BHM-7) produced the lowest (7.31 t ha^{-1}) grain yield.

The highest water use efficiencies for grain was 7.64 kg/ha/cm and biomass (14.98 kg ha^{-1} cm^{-1}) production were obtained under I_0. The lowest water use efficiencies for grain (2.67 kg $^{-1}$ ha $^{-1}$ cm^{-1}) and biomass (4.93 kg^{-1}ha^{-1} cm^{-1}) reductions were obtained under I_4. The water use efficiency, WUE, for grain production differed significantly among the irrigation treatments.

Niazuddin *et al*. (2002) and Hossain *et al*. (2011) also reported comparable effects of irrigation treatments on WUE. The highest WUE for grain production (4.90 kg^{-1} ha^{-1} cm^{-1}) was obtained under V_1 and the lowest (4.41 kg^{-1} ha^{-1} cm^{-1}) was obtained under V_2. For biomass production, the highest (9.39 kg ha^{-1} cm^{-1}) and lowest (8.60 kg^{-1} ha^{-1} cm^{-1}) water use efficiencies were obtained under V_1 and V_2, respectively. The water use efficiencies, both for grain and biomass productions, were however statistically similar.

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of

IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that considering the interaction effects, WUE varied significantly between the treatment combinations. The highest WUE for grain production (8.86 kg^{-1} ha^{-1} cm^{-1}) was under I_0V_1 and the lowest (2.35 kg^{-1} ha^{-1} cm^{-1}) was under I_4V_3. The highest (16.04 kg^{-1} ha^{-1} cm^{-1}) and lowest (4.63 kg^{-1} ha^{-1} cm^{-1}) water use efficiencies for biomass productions were also obtained under I_0V_1 and I_4V_3, respectively. The highest water use efficiencies for gain (7.64 kg^{-1} ha^{-1} cm^{-1}) and biomass (14.98 kg^{-1} ha^{-1} cm^{-1}) production were obtained underI_0. The lowest water use efficiencies for grain (2.67 kg/ ha/cm) and biomass (4.93 kg^{-1} ha^{-1} cm^{-1}) productions were obtained under I_4.

The water use efficiency, WUE, for grain production differed significantly among the irrigation treatments. Niazuddin *et al*. (2002) and Hossain *et al*. (2011) reported comparable effects of irrigation treatments on WUE. The highest WUE for grain production (4.90 ha^{-1} cm^{-1}) was obtained under V_1 and the lowest (4.41 kg^{-1} ha^{-1} cm^{-1}) was obtained under V_2. For biomass production, the highest (9.39 kg/ ha/cm) and lowest (8.60 kg^{-1} ha^{-1} cm^{-1}) water use efficiencies were obtained under V_1 and V_2, respectively. The water use efficiencies, both for grain and biomass productions, were however statistically similar. Considering the interaction effects, WUE varied significantly between the treatment combinations. The highest WUE for grain production (8.86 kg^{-1} ha^{-1} cm^{-1}) was under $I_oV_1$and the lowest (2.35 kg^{-1} ha^{-1} cm^{-1}) was under I_4V_3. The highest (16.04 kg^{-1} ha^{-1} cm^{-1}) and lowest (4.63 kg^{-1} ha^{-1} cm^{-1}) water use efficiencies for biomass productions were also obtained under I_oV_1 and I_4V_3, respectively.

But, proper growth and development of maize needs adequate soil moisture in the root zone. Inadequate water supply results in soil and plant water deficits, which reduce maize yield (Gordon *et al.,*1995). In relation to the yield, proper time and sufficient irrigation need to be realized in irrigation scheduling for the most effective use of available water in optimizing maize production. Shaozhong and Minggang (1993) identified the heading to milking stage of maize as the most sensitive period to water stress that has ultimate negative impact on grain yield.

Number of kernels ear^{-1} is the yield component that varies the most with water stress (Classen and Shaw, 1970). It has been found that yield reductions from water stress were mostly due to reduced kernel numbers and kernel weight with kernel number having the greatest correlation with yield reduction (Pandey *et al*., 2000; Moser *et al*., 2006).

Reductions in kernel numbers are highest when stress occurs during silking and early grain fill stages (Claasen and Shaw,1970; Harder *et al*., 1982; Eck, 1986). Stress during vegetative growth had an effect on kernel number due to the fact that the size of the ear and number of ovules formed were determined during this stage (Abendroth *et al*., 2011).

The yield component that has the highest correlation with grain yield per unit area as plant populations change is ears m^{-2} (Novacek *et al*., 2013; Novacek *et al*., 2014) or kernels m^{-2} (Coulter *et al*., 2010) depending on which component is measured. Hashemi *et al*. (2005) found that the primary yield component responsible for yield reduction at plant populations higher than the optimal plant population was kernels plant^{-1}. This was followed by the number of ears plant^{-1} and kernel weight. These results indicate that the optimal plant population for grain yield occurs at the point where the increase in ears m^{-2} no longer compensates for the decrease in the other yield components such as kernels ear^{-1} and kernel weight.

Eck (1986) found that water deficit during vegetative growth reduced the number of kernels ear^{-1} but had little effect on kernel weight. The number of kernels produced was not influenced by water deficit during grain fill but kernel weight was reduced (Eck, 1986; Grant *et al*., 1989).

Pandey *et al.* (2000) studied deficit irrigation and N rate influence on maize yield components. They found that larger water deficits and lower N rates reduced grain yield as well as the yield components: ears m^{-2}, kernels m^{-2}, and kernel weight.

2.9 Effect of antitranspirants

Antitranspirants can act as either physical or physiological barriers to water loss. The most popularly used antitranspirants are spray emulsions of latex, wax, or acrylic that form a film over the leaf surface and reduce water loss. Other physical barriers are solar reflectants, which reduce internal leaf temperature and thereby depress evapotranspiration. Physiological barriers are those chemicals that act as plant growth regulators and may close stomata or inhibit plant growth.

Reduced plant growth is not always disadvantageous. Experiments are now being conducted with antitranspirant sprays on oleanders planted in the median strips of California's freeways to reduce the frequency of irrigation - an expensive and hazardous operation.

Applying these substances to plant leaves can have a significant impact on normal physiological function. Film-forming antitranspirants prevent evaporation by covering and clogging leaf stomata – the tiny pores on leaf surfaces. These pores have two functions: they create a gradient for water movement throughout the plant and they allow gas exchange between the plant and the atmosphere. Each of these physiological functions is vital to a plant's survival.

Kaolin is white, soft, plastic clay mainly composed of the fine grained platy mineral kaolinite; a white hydrous aluminum silicate, $Al_2Si_2O_5(OH)_4$, containing 23.5% alumina, 46.5% silica, and 14% water. It is soft, with a moderate refractive index of 1.56, and occurs as extremely small hexagonal-shaped crystals of micron and submicron size. It is used in the manufacturing of white-ware ceramics, and the main use now is in the filling and coating of paper. It is also used as filler in paints, rubber, plastics and many other productions. Natural material, unobjectionable, environment-friendly both in production and prospective liquidation as well, 100% recyclable (Yasin *et al*., 2015).

Khalil *et al*. (2011) stated that the antitranspirants are chemical compounds whose role is to train plants by gradually hardening them to stress as a method of reducing the impact of drought. There are different types of antitranspirants: film-forming which stops almost all transpiration; stomatic, which only affects the stomata; reflecting materials (Nasraui, 1993). Reducing transpiration can play a useful role in this respect by preventing the excessive loss of water to the atmosphere via stomata (Khalil, 2006).

Antitranspirant are substances involved in increasing drought resistance by tending to cause xeromorphy and/or stabilizing cell structure (Ouda *et al.,* 2007). Kaolin is a non-toxic aluminosilicate ($Al_4Si_4O_{10}(OH)_8$) clay mineral; kaolin spray decreased leaf temperature by increasing leaf reflectance and reduced transpiration rate more than photosynthesis in plants (Ibrahim and Selim, 2010). Magnesium carbonate (MgCO3) is considered to be an antitranspirant that closes stomata and thus affects metabolic processes in leaf tissues (Nermeen and Emad, 2011).

Khalil *et al*. (2012) conducted an investigation in a greenhouse during the two consecutive summer seasons to investigate the effects of three soil moisture levels (85, 55, and 25% depletion of the available soil water), and four antitranspirant treatments (control, 6% kaolin, 6% $MgCO_3$, and 6% kaolin + $MgCO_3$) which were sprayed twice during the plant's life (the first after 60 days from planting and the second 4 weeks later). Results indicated that increasing water stress significantly retarded growth attributes and RWC%. On the contrary, increasing severity of drought caused a significant increase in osmotic pressure, content and percentage carbohydrates.

Increasing water stress significantly retarded stem and root elongation. There was a negative relation between shoot height and root length with increasing water stress. Leaf area and leaf number were also significantly reduced by increasing water stress. Furthermore, a negative relation was observed between weight and dry weight of the whole plant and increasing water stress. The most significant increases in all growth parameters were evident under the highest soil moisture level, i.e., W_3. The reduction in these growth parameters under the lowest soil moisture level (i.e., W_1) may be attributed to losses of tissue water which inhibited cell division and enlargement, or possibly to a decrease in the activity of meristematic tissues responsible for elongation (Siddique *et al*., 1999).

Soil drying also decreased leaf growth, thereby reducing leaf water status in addition to accumulating organic solutes, hence enabling osmotic adjustment and inhibiting the incorporation of small substrate molecules into the polymers needed in the growth of new cells (Ali *et al*., 1999). In addition, decreasing leaf area under drought stress may be caused by decreasing cell division and expansion (Lieberman and Wang. 1982). Moreover, total FW and DW decreased due to exposure to injurious levels of drought which might have resulted from a reduction in chlorophyll content and consequently, photosynthetic efficiency (Khalil *et al.,* 2010).

Farrag and El-Nagar (2005) indicated that increasing water stress caused a significant decrease in the growth of cucumber (*Cucumis sativus*) plants. In addition, Ibrahim and Selim (2007) found that inadequate irrigation strongly negatively affected the growth of early summer squash (*Cucurbita pepo*) plants. Bafeel and Moftah (2008) showed that decreasing water stress significantly increased the weight and dry weight of eggplant (*Solanum melongena*).

Khalil *et al*. (2012) conducted an investigation in a greenhouse during the two consecutive summer seasons to investigate the effects of three soil moisture levels (85, 55, and 25% depletion of the available soil water), and four antitranspirant treatments used 6% Kaolin either sole or mixed with 6% $MgCO_3$ which were sprayed twice during the plant's life (the first after 60 days from planting and the second 4 weeks later). The use of kaolin + $MgCO_3$ resulted in the highest significant increase in all growth parameters compared with the control followed by $MgCO_3$; the lowest values were obtained for kaolin-only spray. In addition, kaolin + $MgCO_3$ increased plant height, leaf number plant^{-1}, root length, leaf area, plant FW and DW by 55.60, 51.32, 75.42, 44.35, 103.16, and 74.71%, respectively.

The increases in growth parameters as a result of antitranspirant treatments may be due to the reduction in transpiration rate as result of stomata closure (Pennazio and Roggero, 1984). Antitranspirants application may also increase plant growth, possibly by increasing photosynthesis as a result of the improvement of the water status of the plant (Samirm, 1988).

Ouda *et al*. (2007) noted that reflecting antitranspirants helped to reduce the heat load on leaves and increased the penetration of solar radiation into the canopy, increasing photosynthesis. The same finding was made by Gaballah and Moursy (2004) and El-Kholy *et al.* (2005b). Ibrahim and Selim (2010) suggested that a foliar spray with kaolin reduced the transpiration rate, which in turn maintained a higher water content in plant tissues, possibly favoring plant metabolism, physiological processes, photosynthetic rate, carbohydrate metabolism and many other important functions that directly affect plant growth. Jain and Srivastava (1981) also reported that low concentrations of antitranspirant stimulated the growth of maize (*Zea mays* L.) seedlings.

Furthermore, Metwally *et al.* (2002) concluded that the application of antitranspirants significantly increased plant height, number of branches, and number of leaves/ plant as well as fresh weight and dry weight of roselle (*Hibiscus sabdariffa*) plants. Khalil (2006) reported that all antitranspirants (film-forming, stomata and reflecting) significantly increased all growth parameters of sesame (*Sesamumindicum*) plants compared with the control treatment. Bafeel and Moftah (2008) suggested that a foliar spray with kaolin could lead to a reduction in the transpiration rate, which in turn maintained a higher water content in the plant tissues, thus directly affecting plant growth. Cantore *et al*. (2009) and Ibrahim and Selim (2010) concluded the same thing.

The highest values in growth parameters due to the interaction between the highest soil moisture level (W_3) and the kaolin + $MgCO_3$ treatment (i.e., $W_3 \times A_3$) might be due to the effect of supplemental irrigation, which may have increased the absorption of some nutrients (Ibrahim and Selim, 2007), consequently improving the photosynthetic capacity of leaves, in turn enhancing plant growth. Moreover, the use of antitranspirants decreases the loss in moisture content through transpiration (Nakano and Uehara 1996; Ibrahim and Selim 2010).

Davenport *et al.* (1974) stated that the film antitranspirants showed to affect growth adversely by reducing photosynthesis and favourably by increasing plant water potential. Abdullah *et al*., (2015) investigated the use of film-forming antitranspirants (AT) to reduce transpiration and alleviate the adverse effects of late season drought on wheat, growth and yield. Two experiments were conducted in a controlled temperature glass house from April to November 2014, to compare two watering regimes (well-watered and water-deficit) and three AT treatments (unsprayed control, sprayed before boot swollen and sprayed before anthesis complete). It was observed that drought stress reduced daily water use, transpiration rate, stomatal conductance and leaf turgor in wheat plants after about four days. In contrast, these measurements rapidly declined soon after AT application in both well-watered and water-deficit plants. Nevertheless, once soil moisture deficit increased markedly, AT-treated water-deficit plants maintained significantly higher levels of photosynthesis than untreated plants. Drought stress reduced grain yield in unsprayed control plants by more than 40%, compared to well-watered control plants, mainly due to fewer grains spike^{-1}. In contrast, drought stress with AT application prior to the most drought sensitive boot stage reduced yield by only 14%. These results suggest that AT has the potential to improve wheat yields with late season drought, as is common in semi-arid regions, although, more research is required to test the wider applicability of these results in field conditions.

CHAPTER III

MATERIALS AND METHODS

To achieve the goals mentioned in the research objectives of the present study, eight 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 in three consecutive rabi seasons of 2015-16, 2016-17 and 2017-2018.

3.1 General methodology

3.1.1 Experimental site

The experiments were conducted in three different sites of which one at Agronomy field of Sher-e-Bangla Agricultural University (SAU) which is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level. This site belongs to the Agro-ecological zone (AEZ) of 'The Modhupur Tract' (AEZ-28). Location map have been given in Appendix-I. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (BARI, 2014). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I. Three sites had distinct soil series where Sher-e-Bangla Agricultural University (SAU) farm which was situated at Dhaka (central Bangladesh) which has the soil series – Chiatta. The second site 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 site was at the Fakurpara village of Rangpur Sadar district in the northern Bangladesh having soil series - Gangachara.

Dhamrai's geographical position is within 23°49' and 24°03' N 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 site is Rabi- Jute-T. aman wherein the test was made during the winter season of 2015-16. Rangpur (central) site is located in between 25°39' and 25°50' N 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.

3.1.2 Climate

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of Sher-e-Bangla Agricultural University was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka.

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 (BBS, 2016)). Dhamrai is about 39 kilometers away from Dhaka and its rainfall data are not separately available.

Rangpur lies on 37m above sea level. Its climate is classified as warm and temperate. The summers are much rainier than the winters in Rangpur. According to Köppen and Geiger, this climate is classified as Cwa. The average temperature in Rangpur is 24.9 °C and the annual rainfall is 2192 mm. The least amount of rainfall occurs in December, while the greatest amount of precipitation occurs in June, with an average of 481 mm. In Rangpur, the wet season is hot, oppressive, and mostly cloudy and the dry season is warm and mostly clear. Over the course of the year, the temperature typically varies from *51°F* to *95°F* and is rarely below 7.77*°C* or above *38.89 °C*.
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 sowing dates varied due to the varying nature of the cropping pattern of the respective sites and the attaining field capacity time of the soil. At SAU site, the land elevation is high which can be used for dry land crop production after the recession of monsoon rain in the month of October. The Dhamrai soil was medium high wherein the rainy season rice (T. aman) is harvested in the month of November and thereafter the winter crop can be sown. In Rangpur the land was medium high wherein the test was made and its cropping pattern was short duration winter rice-potato-maize. Based on these cropping patterns of the respective sites, the trials were made on October 30 2015 at SAU, December 7 of 2015 at Dhamrai and February 9 of 2016 at Rangpur site.

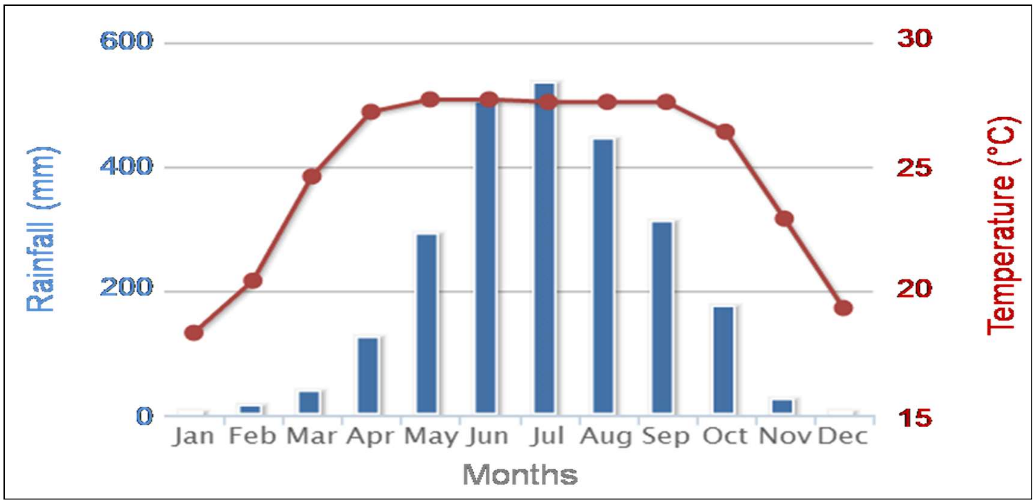


Figure 3.1. Average monthly temperature and rainfall for Bangladesh from 1900-2009 (source: www. research gate. net)

3.1.3 Soil

The soil of the SAU experimental field belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4-5.6. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from the experimental field. Prior to the initiation of the experiments the soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil of the three experimental sites are presented in Table 3.1, 3.2 and 3.3. The secondary data regarding the soil status of Rangpur site have been collected from elsewhere (Shil *et al*., 2016).

From the soil analysis reports (Table 3.1 and 3.2), 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. The soil of the Dhaka was heavier than that of Dhamrai. The soil of Dhaka was more acidic having pH of 4.8 as compared to that of 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%).

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

Texture		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 Framgate, Dhaka

Although it is an obvious fact that organic maters are more available in the rural areas compared to those at the urban areas. However, higher organic matter of Sher-e-Bangla Agricultural University farm might be due to the application of organic matter to the field regularly. 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 of Dhamrai soil (0.054%) which was obvious as the Dhaka soil had more added organic matter than that of 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 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 3.2 Soil analysis results of Dhamrai farm during pre-Rabi season 2016-17

Textural class	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 Framgate, Dhaka

The soil of Rangpur (AEZ 3) was sandy clay loam in texture (Table 3.3) having sand, silt and clay of 51, 27 and 22% respectively which was much lighter than those of the other two sites. The pH was 4.9 which was a bit higher than that of Dhamrai and organic matter 1.3% which was remarkably higher than other two sites. The Rangpur site was basically in a rural area nearby city corporation area 'Rangpur' wherein a number of poultry and dairy farms are available. 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 kg^{-1} and these two nutrients were also low in comparison to those at Dhamrai. The sulphur content at Rangpur was 10.96 mg kg^{-1}. The amount of the exchangeable bases such as K, Ca, Mg and Na were 0.16, 2.50, and 0.36 meq 100^{-1} g soil, respectively. It may be mentioned that N, P, K. S, Zn and B are 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%	Potassiu m %	Calcium %	Magnesiu m %	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)	Manganes e (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 Framgate, Dhaka

Before planting, the land was harrowed four times and followed by laddering. At final land preparation the soil was fertilized with N, P, K, S, Zn and B from urea, triple super sulphate, muriate of potash, gypsum, zinc sulphate and boric acid as per the treatments based on the recommended dose of BARI (2014). Urea was splited at 30 and 45 days after sowing at equal rates just after irrigation when leaves were dried and no standing water on the soil surface. The trial was conducted in randomized complete block design with three replications maintaining row to row distance of 60 cm and plant to plant distance within each row 25 cm. Two seeds in each hill were sown, seeds germinated four days after sowing. The germinated weaker seedling was removed 15 days after emergence to maintain single seedling $hill^{-1}$. Weeding was done twice at 30 and 45 days after sowing. Irrigation was provided at 30, 45, 60, 90 and 120 days after sowing. Other agronomic operations were done following the recommended packages of BARI (2014). Seeds were sown in furrows after having treated with Sevin 5G to protect seeds from soil borne pests.

3.2 Plant materials

For the investigation eight white maize hybrid varieties were used. The names and origin of the eight white maize hybrid varieties are given in Table 3.4.

Table 3.4 Name and origin of the white maize varieties used in the study

Treatment	Variety name	Origin
V_1	PSC-121	India
V_2	KS-510	India
V_3	Changnuo-1	China
V_4	Q- Xiangnuo-1	China
V_5	Changnuo-6	China
V_6	Yangnuo-3000	China
V_7	Yangnuo-7	China
V_8	Yangnuo-30	China

3.2.1 Varietal descriptions

1. PSC-121 (V_1)

PSC-121 variety was developed by Proline seed company, India. It is double cross hybrid variety and maturity period ranges from 110-120 days. The variety is ideal for kharif season and stays green at maturity, good crop standibility and drought tolerant. The seeds are white coloured, flint type with 100 seed weight of 32-33 g.

2. KS-510 (V_2)

KS-510 was developed by Proline seed company, India. It is also a double cross hybrid variety and maturity period ranges from 110-120 days. The variety is especially characterized that every plant bears two cobs but the lower cob remains unfilled. The variety is ideal for kharif season and good crop standibility. The seeds are white coloured, flint type with 100 seed weight of 27-28 g.

3. Changnuo-1 (V_3)

The variety Changnuo-1 was imported from Chongqing Zhong Yi Seed Co. Ltd of China to grow in the dry season. The plants are moderate statured with the plant height range of 260 to 262 cm. The leaves are semi erect with a bold stem base. The variety flowers in 69-71DAS and can be harvested in 117-119 days. The seeds are white coloured, dent type with 100 seed weight of 33-34 g.

4. Q- Xiangnuo-1 (V_4)

The variety Q- Xiangnuo-1 was also imported from Chongqing Zhong Yi Seed Co. Ltd of China to grow in the dry season. The plants have moderate height with the range of 215 to 217 cm. The leaves are semi erect with a bold stem base. The variety flowers in 66-68DAS and can be harvested in 116 days. The seeds are white coloured, dent type with 100 seed weight of 34-36 g.

5. Changnuo-6 (V_5)

The Changnuo -6 was imported from Chongqing Zhong Yi Seed Co. Ltd of China which has been released to grow in the dry season. The plants have moderate height with the range of 264 to 268 cm. The leaves are semi erect with a bold stem base. The variety flowers in 64-66 DAS and can be harvested in 114-116 days. The seeds are white coloured, dent type with 100 seed weight of 33-34 g.

6. Yangnuo-3000 (V_6)

The Yangnuo-3000 is a Chinese white grain maize variety. It was also imported from Chongqing Zhong Yi Seed Co. Ltd of China which has been released to grow in the dry season. The plants have moderate height with the range of 225 to 227 cm. The leaves are semi erect with a bold stem base. The variety flowers in 68-70 DAS and can be harvested in 120 days. The seeds are white coloured, dent type with 100 seed weight of 25-27 g.

7. Yangnuo-7 (V_7)

The Yangnuo-7 was also imported from Chongqing Zhong Yi Seed Co. Ltd of China which has been released to grow in the dry season. The plants have moderate height with the range of 183 to 188 cm. The leaves are semi erect with a bold stem base. The variety flowers in 58-60 DAS and can be harvested in 108-111 days. The seeds are white coloured, dent type with 100 seed weight of 28-29 g.

8. Yangnuo-30 (V_8)

The Yangnuo-30 was also imported from Chongqing Zhong Yi Seed Co. Ltd of China which has been released to grow in the dry season. The plants have moderate height with the range of 245 to 248 cm. The leaves are semi erect with a bold stem base. The variety flowers in 71-73 DAS and can be harvested in 128 days. The seeds are white coloured, dent type with 100 seed weight of 30-31g.

3.3 Seed Collection

Healthy seeds of V_1= PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4= Q- Xiangnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30 were collected from private organizations. The seeds of the V_1 and V_2 were collected from Indian Proline Seed Company Ltd. while others were imported from Chongqing Zhong Yi Seed Co. Ltd of China.

3.4 Time of initiation of the experiments

The trials were made in the rabi seasons both at the SAU farm and in the farmers' fields of Dhamrai and Rangpur. In total eight experiments were carried out of which four were made in the farmers' fields and others at the SAU farm. The initiation date of the experiments varied depending on the cropping patterns of the individual sites. The SAU trials were initiated from November to December, while those in the farmers' fields were initiated in the month of December to January.

3.5 Land preparation

The plot selected for the experiment was opened in the last week of November, 2015 with a power tiller and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross- ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed.

3.6 Fertilizer 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^{-1}, 250 kg ha^{-1}, 220 kg ha^{-1}, 220 kg ha^{-1}, 12.5 kg ha^{-1}, and 6 kg ha^{-1} [253, 49.1, 132, 39.6, 31.25 and 0.9 kg of N, P, K, S, Zn and B respectively] (BARI, 2014) were used for the experiments. All the fertilizers and $1/3^{rd}$ 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 4-6 leaf stage (30-35 DAS) and 10-12 leaf stage (pre tasselling stage) (BARI, 2014). In addition, cow dung was also applied @ 5 t ha^{-1} at the time of final land preparation.

3.7 Seed sowing

Seeds were sown in lines maintaining a line to line distance of 60 cm and plant to plant distance of 25 cm having 2 seeds $hole^{-1}$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.

3.8 Intercultural operations

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

3.8.1 Thinning

One healthy seedling $hill^{-1}$ was kept and rest one was thinned out before 15 DAS (BARI, 2014).

3.8.2 Weed control

During plant growth period two weedings were done. First weeding was done before 30 DAS and the second one was done before 45 DAS (BARI, 2014).

3.8.3 Earthing up

Two earthing up operations were done on 30 DAS and 45 DAS respectively (BARI, 2014).

3.9 Irrigation and drainage

Irrigation was done at five different growth stages to meet up crop's water demand providing at 30 DAS, 45 DAS, 60 DAS, 90 DAS and 120 DAS. Proper drainage system was also developed for draining out excess water. However, for pot experiment (Expt. 7) water were given in every morning and evening by a mug (approx. one liter) according the treatments and for antitransperent experiment (Expt. 8) only three irrigations e.g. 15-20 DAS, 30-35 DAS, 60-70 DAS were given.

3.10 Crop protection

In some plots stem borer and aphids were traced in the field at 8 to 10 leaves stage of maize plant. Marshal (25% EC formulation of Carbosulfan) was applied against the stem borer and aphids which was applied in all part of leaf at 40 and 60 DAS. The fall armyworm (*Spodoptera frugiperda*) was also observed sporadic eating the tip twig at the pre-tasseling stage. As the attack was not so remarkable no control measure was taken against it. During the entire growing period the crop was observed carefully to take protection measures.

3.11 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 12% moisture and weighed carefully with digital balance and ten cobs grain were recorded in gram and converted into metric tons hectare^{-1} (t ha^{-1}). Stalks obtained from ten plants were oven-dried and final stalk weight were recorded in gram and converted into metric tons hectare^{-1} (t ha^{-1}).

3.12 Collection of experimental data

The details procedures to determine the growth, phonological characters, yield and yield contributing characteristics were followed have been discussed below:

3.12.1 Crop growth characters

i. Plant height (cm) at 30, 60, 90 days after sowing (DAS) and at harvest
ii. Number of leaves plant-^{1} at 30, 60, 90 DAS and at harvest
iii. Leaf area index at 30, 60, 90 DAS and at harvest
iv. Dry matter weight plant^{-1} (g) at 60, 90 DAS and at harvest

3.12.2 Phenological parameters

i. Days to first tasseling
ii. Days to maturity

3.12.3 Yield contributing characters and yield data

i. Cob length (cm)
ii. Cob breadth (cm)
iii. Number of rows cob-^{1}
iv. Number of grains row-^{1}
v. Total grains cob-^{1}
vi. 100 grains weight (g)
vii. Grain yield (t ha-^{1})
viii. Stover yield (t ha-^{1})
ix. Biological yield (t ha-^{1})
x. Harvest index (%)

3.12.4 Procedure of recording data

A brief outline on data recording procedures followed during the study have been given below:

3.12.4.1 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 and plant height was measured in cm.

3.12.4.2 Number of leaves plant^{-1}

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.

3.12.4.3 Leaf area per plant

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.

3.12.4.4 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

3.12.4.5 Dry matter weight plant^{-1}(g) at different DAS (60, 90 DAS and at harvest)

Three plants were uprooted randomly from each plot. Then the stem, leaves and roots were separated. The shoot sample (stem and leaves) was sliced into very thin pieces and put into envelop and placed in oven maintaining 70°C for 72 hours. The final weight of the sample was taken. It was done at 60, 90 DAS and at harvest and finally converted to g plant-^{1}.

3.12.4.6 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.

3.12.4.7 Days to maturity

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

3.12.4.8 Cob length (cm)

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.

3.12.4.9 Cob breadth (cm)

Cob breadth was measured by means of measuring tape at the middle of each cob from ten randomly selected plants plot-^{1} and averaged to cm.

3.12.4.10 Number of rows cob^{-1}

Ten cobs from each plot were selected randomly and the number of rows cob^{-1} was counted and then the average values were recorded.

3.12.4.11 Number of grains row^{-1}

Number of grains row^{-1} was counted from each cob from ten randomly selected cobs individually and then averaged.

3.12.4.12 Number of grains cob^{-1}

Ten cobs from each plot were selected randomly and the total number of grains cob^{-1} was counted and then the average result was recorded.

3.12.4.13 100-grain weight (g)

From the seed stock of each plot 100 grains were counted and the weight was measured by an electronic balance that recorded in gram.

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

From each plot, three linear meter lines were harvested, cobs were removed and kernels were separated from the cobs and oven dried (at 70 ºC for 48 hours) up to a constant weight. The dry weight obtained was then adjusted to 12.5% moisture content to find out the values in tons per hectare^{-1}.

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

From each sub plot, three linear meter lines were harvested. Total dry matter (DM) was determined drying the plants at 70 ºC for 72 hours up to a constant weight and then the weight was adjusted in to 12.5% moisture and the data were converted into tons hectare^{-1}.

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

Biological yield of a crop was calculated summing up of grain yield and stover yield using the following formula. The biological yield was measured for each plot and expressed in ton hectare^{-1}.

Biological yield = (Grain yield + Stover yield)

3.12.4.17 Harvest index (%)

Harvest index is the ratio of economic (grain) yield and biological yield. It was calculated by dividing the economic yield of the harvested area by the biological yield of the same area and multiplying by 100.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield (t/ ha)}}{\text{Biological yield (t/ ha)}} \times 100$$

3.13 Nutritional components analyses

For nutritional component traits, protein, fiber, fat, ash and carbohydrate and moisture content of white maize grains were estimated from the grinding powder of 100g of dry grain seeds of different white maize varieties. Quantitative determination of moisture, protein, fiber, fat, ash and carbohydrate of dry seeds (100.0 g) were done following the protocols described by the association of official analytical chemist (AOAC, 1995).

- Protein (%) = 5.7 × {[(ml HCL for Sample – mL HCL for Blank) × NHCl× 0.014] × 100} ÷ Weight of sample (mg)
- Fiber (%) = 100 × Weight of the crude fiber ÷ Weight of sample
- Fat (%) = 100 × (Final weight of the test tube - Initial weight of the test tube) ÷ Weight of sample
- Ash (%) = 100 × {Weight of ash (g) ÷ Weight of the sample (g)}

- Carbohydrate (%) = 100 - (moisture + ash + fat + protein + fiber).
- The moisture content of the maize flour sample was determined by drying at 105°C overnight in an electric oven.
- AAC = Apparent Amylose content
- GI = Glycemic Index

3.14 Statistical analysis

Data recorded for growth, phonological, yield and yield contributing characters were compiled and tabulated using MS excel. The collected data were analyzed statistically using the Statistix 10 software. Least Significant Difference (LSD) technique at 5% level of significance was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

3.15 Details of each experimentation:

3.15.1 Year: 1st Year (2015-2016 Rabi Season)

3.15.1.1 Location: In the 1st year three experiments (Expt. 1, Expt. 2, and Expt. 3) were conducted in three locations, e.g., SAU Research Farm, Dhamrai Upazila, Dhaka and Rangpur District. The seeds of the respective experiment were sown on 01.12.2015 at SAU, on 07.12.2015 at Dhamrai and on 22.12.2015 at Rangpur.

3.15.1.2 The details on the three experiments (Expt. 1, Expt. 2, and Expt. 3) are describe below:

Experiment 1:	:	Yield and yield attributes of different white maize varieties at SAU during Rabi 2015-2016
Experiment 2:	:	Yield and yield attributes of different white maize varieties at DhamraiUpazila during Rabi 2015-2016
Experiment 3:	:	Yield and yield attributes of different white maize varieties at Rangpur during Rabi 2015-2016
Experimental Design	:	Randomized Complete Block Design (RCBD)
Treatments:	:	Eight (8) varieties: V_1=PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 =Q-Xiangnuo-1, V_5=Changnuo-6, V_6=Yangnuo-3000, V_7 =Yangnuo-7 and V_8=Yangnuo-30
No. of Replications	:	Three (3)
Total No. of Plots	:	24
Plot Size	:	14.7 m^2 (3.5 m × 4.2 m)
Plot to plot distance	:	70 cm
Replication to replication distance	:	1 m
Spacing	:	60 cm × 25 cm
Statistical analysis	:	The data were analyzed by Statistix 10 software and treatment means were compared by LSD at 5% level of probability

Parameters studied :

i. Plant height (cm)
ii. Number of leaves plant^{-1}
iii. Leaf area index
iv. Days to first tasseling
v. Days to maturity
vi. Cob length (cm)
vii. Cob breadth (cm)
viii. Number of rows cob^{-1}
ix. Number of grains row^{-1}
x. Total number of grains cob^{-1}
xi. 100 grains weight (g)
xii. Grain yield plant^{-1}(g)
xiii. Stover yield plant^{-1}(g)
xiv. Grain yield (t ha^{-1})
xv. Stover yield (t ha^{-1})
xvi. Biological yield (t ha^{-1})
xvii. Harvest index (%)

3.15.2 2nd Year (2016-2017 Rabi Season)

3.15.2.1 Location: In the 2nd year three experiments (Expt. 4, Expt. 5, and Expt. 6) were conducted in three locations, e.g., SAU Research Farm, Dhamrai Upazila, Dhaka and Rangpur District. The seeds of the respective experiment were sown on 16.11.2016 at SAU, 17.12.2016 at Dhamrai and 1.11.2016 at Rangpur.

3.15.2.2 The details of three experiments (Expt. 4, Expt. 5, and Expt. 6) are describe below:

Experiment 4:	:	Yield and yield attributes of different white maize varieties at SAU during Rabi 2016-2017
Experiment 5:	:	Yield and yield attributes of different white maize varieties at Dhamrai Upazila during Rabi 2016-2017
Experiment 6:	:	Yield and yield attributes of different white maize varieties at Rangpur during Rabi 2016-2017
Experimental Design	:	Randomized Complete Block Design (RCBD)
Treatments:	:	Seven (7) varieties e.g. V_1=PSC-121, V_3=Changnuo-1, V_4 =Q- Xiangnuo-1, V_5=Changnuo-6, V_6=Yangnuo-3000, V_7 =Yangnuo-7 and V_8=Yangnuo-30

No. of Replications	**:**	Three (3)
Total No. of Plots	**:**	21
Plot Size	**:**	14.7 m^2 (3.5 m × 4.2 m)
Plot to plot distance	**:**	70 cm
Spacing:	**:**	60 cm × 25 cm
Statistical analysis	**:**	The data were analyzed by Statistix 10 software and treatment means were compared by LSD at 5% level of probability

Parameters studied :

i. Plant height (cm)
ii. Number of leaves $plant^{-1}$
iii. Leaf area index
iv. Days to first tasseling
v. Days to maturity
vi. Cob length (cm)
vii. Cob breadth (cm)
viii. Number of rows cob^{-1}
ix. Number of grains row^{-1}
x. Total number of grains cob^{-1}
xi. 100 grains weight (g)
xii. Grain yield $plant^{-1}$(g)
xiii. Stover yield plant $^{-1}$(g)
xiv. Grain yield (t ha^{-1})
xv. Stover yield (t ha^{-1})
xvi. Biological yield (t ha^{-1})
xvii. Harvest index (%)

3.15.3 3rd Year (2017-2018 Rabi Season)

In the 3rd year one experiment (Expt. 7) was conducted under the bamboo-polythene shade house at SAU Research Farm, Dhaka-1207 and another experiment was conducted to test antitranspirant on two white maize varieties (Expt. 8). The seeds of the Expt.7 were sown on 12.11.2017 and Expt. 8 were sown on 1.12.2017.

3.15.3.1 Pot preparation for Expt. 7: Silt soil was used in the experiment. The upper edge diameter of the pots was 20 inches (50.8 cm). Each pot was filled with 20 kg soil.

3.15.3.2 Fertilizer application for Expt. 7: The soil of the pots was mixed with fertilizers at the recommended dose of 500-250-200-250-15-5 kg ha^{-1} urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid following (BARI, 2014). While filling with soil, the upper one inch of the pot was kept vacant so that irrigation can be provided using a hose pipe. As such the diameter of the upper soil surface was 16 inch (40.64 cm) and the area of the upper soil surface was πr^2 = 3.14x0.406 x 0.406 = 0.518 m^2. Fertilizer was calculated following the above mentioned rate and was mixed with the soil before sowing the seeds.

3.15.3.3 Crop management: Seed sowing, thinning, weeding and other agronomic management were done as was described in section 3.5. However, the irrigation was provided as per the water regime treatments.

3.15.3.4 Induction of drought stress for Expt. 7: To study the yield performance of white maize varieties under different drought stress conditions, six varieties of white maize were grown in the soil pots under bamboo-polythene house. Two drought stress treatments and a control (normal irrigated condition) were used for this experiment. The drought stress conditions were induced through withdrawal of watering from 80 DAS and 100 DAS till harvesting of the crop in the drought treatments namely, S_1 and S2, respectively. While in control treatment (S_c) the plants were given normal water till harvesting of the crop for proper growth and development of the crop to compare of the treated plants with S_1 and S2 drought stresses treated plants.

3.15.3.5 Details of Expt. 7

Title:	:	**Yield performance of white maize varieties under varying soil moisture regimes**
Experimental Design	:	Completely Randomized Design (CRD) (Factorial)
Treatments		
Factor 1 :	:	Six (6) Varieties: V_1= PSC, V_3 = Changnuo-1, V_5= Changnuo-6, V_6 = Yungnuo-3000, V7 = Yungnuo-7, V_8 = Yungnuo-30.
Factor 2:	:	Three (3) different moisture stresses: S_1 = No watering from 80 DAS to harvest S_2 =No watering from 100 DAS to harvest S_C = Control with no irrigation stress
No. of Replications	:	Four (4)
Total No. of treatment	:	6 × 3 = 18
Total no. of pots	:	18×4 = 72
Pots Size in volume (L)	:	Earthen pots of having 20 inches diameter, 20 inches height with a hole at the center of the bottom were used.
Replication to replication distance	:	2 m
Statistical analysis:	:	The data were analyzed by Statistix 10 software and treatment means were compared by LSD at 5% level of probability.
Parameters studied	:	i. Plant height (cm) ii. Number of leaves plant^{-1} iii. Leaf area index iv. Cob length (cm) v. Number of grains row^{-1} vi. Total number of grains cob^{-1} vii. Grain yield plant^{-1}(g) viii. Stover yield plant^{-1}(g) ix. Grain yield (t ha^{-1}) x. Stover yield (t ha^{-1}) xi. Biological yield (t ha^{-1}) xii. Harvest index (%)

3.15.3.6 Details of Expt. 8

Title	:	**Effect of antitranspirant (Kaolin) application at tasseling stage on the growth and yield of white maize**
Experimental Design	:	Randomized Complete Block Design (RCBD) (Factorial)
Treatments:		
Factor 1	:	Two (2) varieties e.g. V_1= PSC-121 and V_2=Changnuo-1
Factor 2	:	Four (4) different concentrations of Kaolin antitranspirant i. **C_O** = 0% concentration of Kaolin (i.e. no Kaolin but only water) ii. **C_1**=2% concentration of Kaolin iii. **C_2**=4% concentration of Kaolin iv. **C_3**=6% concentration of Kaolin
Spreading of Kaolin		At tasseling stage
No. of Replications	:	Three (3)
Total No. of treatments	:	2 × 4 = 8
Total No. of Plots	:	8 × 3 = 24
Plot Size	:	4.0 m^2 (2.66 m × 1.5 m)
Spacing	:	60 cm × 25 cm
Plot to plot distance	:	70 cm
Replication to replication distance	:	1 m
Statistical analysis:	:	The data are analyzed by Statistix 10 software and treatment means were compared by LSD at 5% level of probability
Parameters studied	:	i. Plant height (cm) ii. Number of leaves plant^{-1} iii. Cob length (cm) iv. Cob breadth (cm) v. Number of rows cob^{-1} vi. Number of seeds row^{-1} vii. Number of grains cob^{-1} viii. 100 grains weight (g) ix. Grain yield plant^{-1}(g) x. Stover yield plant (g) xi. Grain yield (t ha^{-1}) xii. Stover yield (t ha^{-1}) xiii. Biological yield (t ha^{-1}) xiv. Harvest index (%)

CHAPTER IV

RESULTS AND DISCUSSION

4.1 Experiment 1: Yield and yield attributes of different white maize varieties at SAU during Rabi 2015-2016

The objectives of this trial were to evaluate the performance of eight hybrid white maize varieties under different locations in Bangladesh. The experiment was conducted to find out the effect of varieties on the growth, phenology and yield performance of white maize. Data on different growth parameters, phenological parameters, yield contributing characters and yield were recorded.

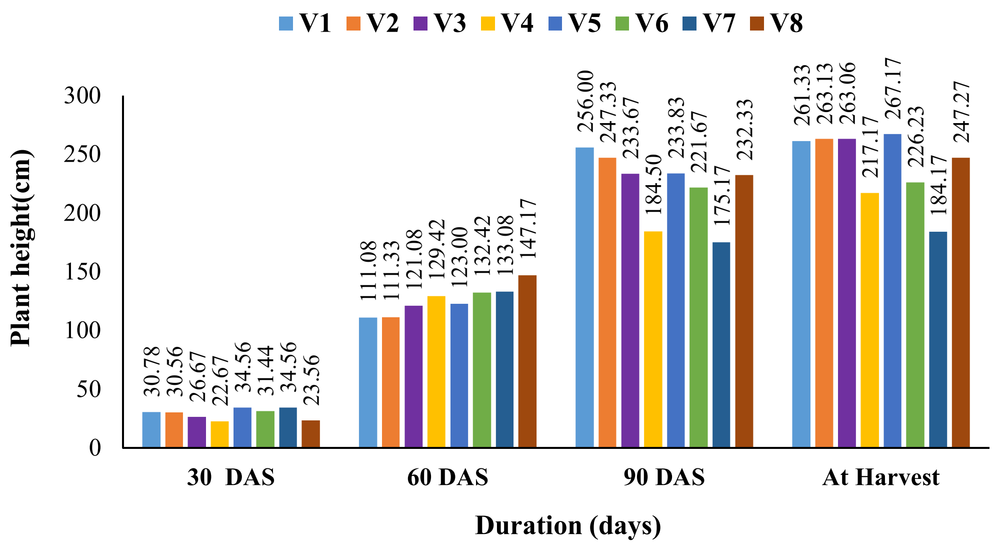
4.1.1 Growth parameters

4.1.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that plant height was significantly influenced by eight examined white maize hybrid varieties. The varieties had significant difference on plant height. At 30 DAS, significantly the maximum plant height (34.56 cm) was seen in the variety V_5 and V_7 which was identically similar. Variety V_4 (22.67 cm) was the lowest performer but there had no significant difference between the variety of V_8 (23.56) (Figure 4.1.1). Likewise, V_6 (31.44 cm) produced medium category of plant height but there was no significant difference between V_1 (30.78 cm), V_2(30.56 cm) and V_3 (26.67 cm).

At 60 DAS, the longest plant height was produced with the variety of V_8 (147.17 cm) (Figure 4.1.1). The lowest plant height was V_1 (111.08 cm) which was statistically similar to variety V_2 (111.33 cm). The second longest height plant height was grown by V_7 (133.08 cm) which was statically similar to V_6 (132.42 cm). At 90 days, V_1 showed the highest plant height but there had no significant difference between the variety of V_2 (247.33 cm), V_3 (233.67 cm), V_5 (233.83 cm), V_6 (221.67 cm), V_7 (175.17 cm) and V_8 (232.33 cm). The lowest highest was given by V_7 (175.17) which was statistically similar to V_4 (184.50) cm (Figure 4.1.1).

At Harvest, it was observed that the longest plant height showed by V_2 (263.13cm) and the lowest by V_7 (184.17 cm). The V_2 (263.13cm) had the highest plant height but there was no significant difference with the plant height of V_1 (261.33 cm).



V_1 = PSC-121, V_2=KS-510, V_3 =Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30.

Figure 4.1.1. Effect of variety on plant height at 30, 60, and 90 DAS and at harvest at SAU during Rabi 2015-2016 ($LSD_{0.05}$ =1.609, 3.212, 35.68 and 4.051 at 30, 60, 90 DAS and at harvest respectively).

Kabir *et al*. (2019) carrying out an experiment on varietal performance of maize in Bangladesh reported that the plants height at harvest was statistically significant at 1% level of probability due to different variety of maize which ranged from 96.33 to 132.80 cm. The highest plant height (132.80 cm) was observed with the variety Pacific-559 and the lowest plant height (96.33 cm) was observed in BARI hybrid vutta-13.

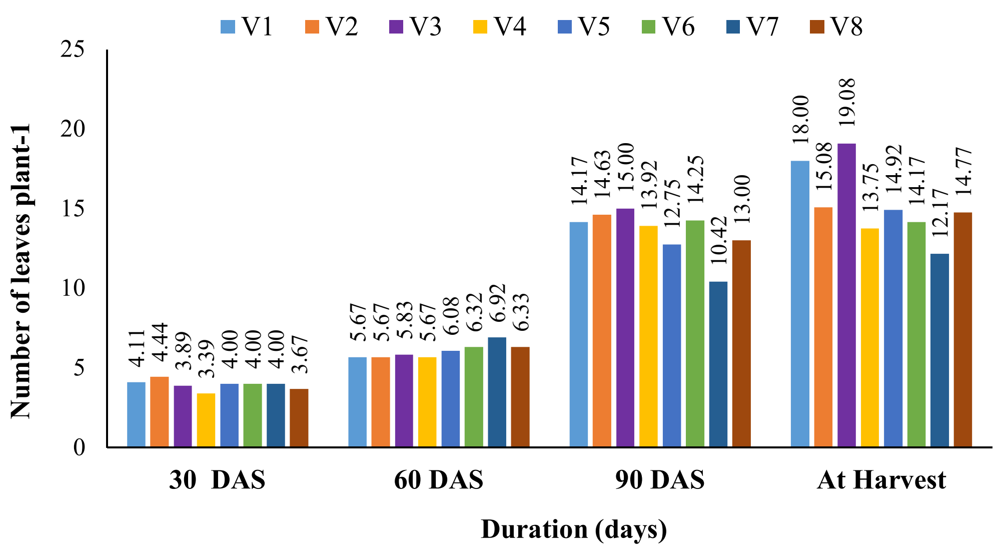
The variation of plant height with the variation in varieties has also been reported by the previous workers. These results are in the line with Gozubenli *et al*. (2001) and Konuskan (2000) who found that there was a considerable varietal variation for the plant height. Dawadi and Sah (2012) also observed that plant height was significantly influenced by the densities and varieties. Variation in varieties and luxury consumption of nutrient enhanced the plant height.

4.1.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties. Number of leaves is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that number of leaves was significantly influenced by eight examined white maize hybrid varieties

At 30 DAS, number of leaf had significant effect and significantly the maximum number of leaves (4.44) was produced by the variety V_2. Variety V_4 (3.39) was the lowest performer but there had no significant difference between the variety of V_3 (3.88), V_7 (4.00), V_6 (4.00), V_5 (4.00) and V_1 (4.11) (Figure 4.1.2).

At 60 DAS, no significant difference observed among the varieties. Numerically the highest number of leaves was produced from the variety V_7 (6.92) and the lowest number of leaf was V_1 that similar to V_2 (5.67) (Figure 4.1.2). At 90 DAS, significant difference was found among the varieties. The V_5 (14.92) showed the highest number of leaf and lowest was by V_7 (10.42) might be due to tasseling stage.



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.1.2 Effect of variety on number of leaves plant^{-1} at 30, 60, 90 DAS and at harvest at SAU during Rabi 2015-2016 ($LSD_{0.05}$ = 0.578, 1.297, 1.444 and 1.463 at 30, 60, 90 DAS and time of at harvest, respectively)

At Harvest, significantly the maximum number of leaves plant^{-1} (19.08) was produced by the variety V_3 which was statistically similar to V_1 (18.00) and V_7 variety was the lowest performer (12.16). Although the lowest leaves plant^{-1} was V_7 (12.16) but there was no significant difference with the varieties V_8 (13.00) and V_5 (12.75). Likewise, V_2 produced medium number of leaves plant^{-1} (15.083) but there was no significant difference between V_4 (13.75) and V_6 (14.16).

The variation in number of leaves plant^{-1} was also been manifested by the previous researchers. Kabir *et al*. (2019) carrying out an experiment and reported that the number of leaves/plant at harvest was statistically significant at 1% level of probability due to the variety. The number of leaves plant^{-1} for different varieties ranged from 14.44 to 17.44. The highest number of leaves plant^{-1} (17.44) was observed with the variety Pacific-559 and the lowest number of leaves plant^{-1} (14.44) was observed in BARI hybrid vutta-13. However, the number of leaves plant^{-1}at harvest was statistically not significant due to interaction effects of different water management treatments and variety.

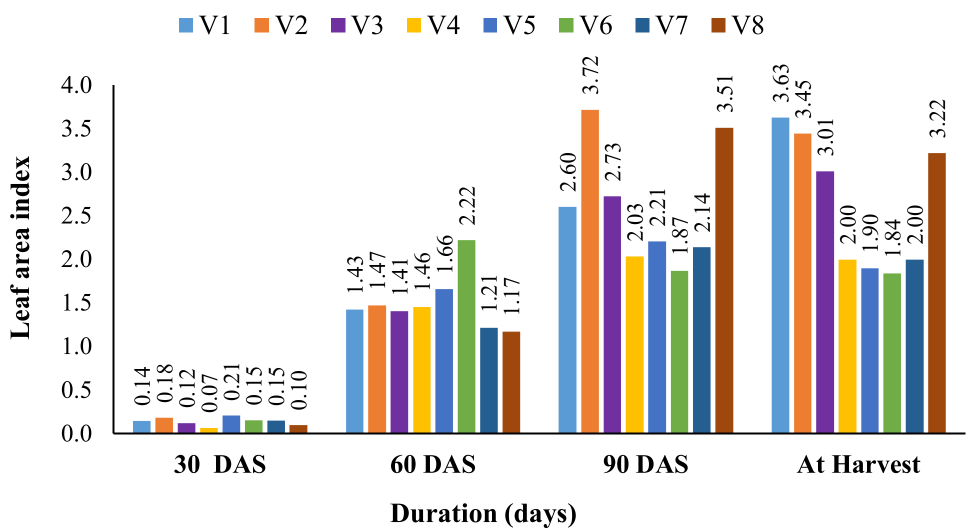
.

4.1.1.3 Leaf area index (LAI)

Leaf area index is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that leaf area index was significantly influenced by eight examined white maize hybrid varieties.

At 30 DAS, leaf area index had significant effect among the eight varieties. Significantly the maximum leaf area index (0.20) was produced by the variety V_5 (Figure 4.1.3). Variety V_4 (0.06) was the lowest performer. Likewise, V_2 (0.19) showed medium valued of leaf area index. In 60 DAS, the highest leaf area index was observed by the variety V_6 (2.22) (Figure 4.1.3). The lowest Leaf area index was in V_3 (1.406). At 90 DAS, Leaf area index had significant effect among the eight varieties where V_2 (3.72) showed the highest leaf area index height and the lowest leaf area index was found in V_6 (1.87).

During harvesting, it was observed that the verities had significant difference on leaf area index. The highest leaf area index showed by V_1 (3.63) and the lowest was V_6 (1.84) (Figure 4.1.3). The V_1 (3.63) showed the highest leaf area index but there was no significant difference with V2 (3.45), V_3 (3.01) and V_8 (3.22). The lowest leaf area index was in V_6 (1.85) which had no significant difference among the varieties of V_7 (2.44), V_5 (1.90).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30.

Figure 4.1.3. Effect of variety on leaf area index at 30, 60, 90 DAS and at harvest at SAU during Rabi 2015-2016 ($LSD_{0.05}$ =0.017, 0.190, 0.061 and 0.620 at 30, 60, 90 DAS and time of at harvest respectively).

The above mentioned finding revealed the leaf area index changes with the change of varieties that also been reported by Abera *et al*. (2017) who conducted a field experiment using five maize varieties (BH-540, BH-543, BH-661, BH-660, and BH-140) and reported that higher leaf area and leaf area index of 7246 cm^2 and 3.86 were found respectively from BH-661 followed by BH-660.

4.1.2 Phenological parameters

Phenological attributes of maize plant is affected by varieties along with the variation in other plant parameters. Ebuka (2018) stated that the heritability in different varieties was found to vary having the the range of 28.82 - 89.53% in the most of the studied agronomic attributes such as plant stands, days to 50% emergence, days to 50% tasseling, days to 50% silking, plant height, leaf area, ear height, stem girth, days to maturity, plant at harvest, cob length, number of rows cob^{-1}, number of grains cob^{-1}, grain weight cob^{-1}, field weight, grain yield indicating that about 28 – 89% of total phenotypic variations were heritable. They opined that the interactions of genotypes across several environments also need to be investigated in the selection of genotypes besides calculating the average performance of the genotypes under evaluation (Fehr, 1991; Gauch and Zobel, 1997).

4.1.2.1 Days to first tasseling

Eight white maize varieties were used to observe their effects on days to tasseling. It was found that days to tasseling was significantly influenced by varieties. Among the treatments, V_8 variety took significantly maximum days to tasseling (73.00 days) followed by V_2 (70.33 days), V_4 (70.00 days), V_1 (68.67 days), V_6 (68.67 days), V_4 (67.33 days) and V_5 (63.33 days), while V_7 (59.34 days) took significantly minimum days to tasseling (Figure 4.1.4).

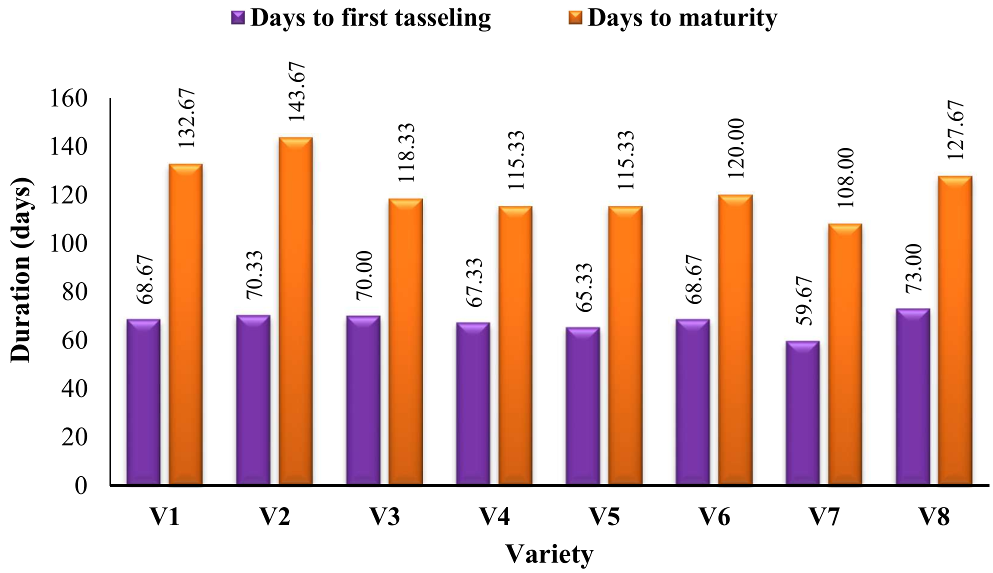
Days to phenological development varies depending on the variety and even on the sowing time that affect the phenology of a certain crop plant. Significantly earlier tasseling and shorter physiological maturity was observed in the variety V_7. Early tasseling and short physiological maturity of V_7 might be due to its genetic characteristics. Azam *et al*. (2007) reported different tasseling days for different maize varieties.

Tripathi *et al*. (2016) reported that the days to silking ranged from 113-127 with mean 119 days in the first year of the experimentation and 108-123 days in the next year with mean of 116 days in different maize varieties. It indicated that days to flowering differed by two weeks between the early and late genotypes so that maturity period differed by one month between the early and late maturing genotypes.

4.1.2.2 Days to maturity

The verities had significant difference on days to maturity. The highest maturity duration was found in V_2 (143.67 days) and the lowest was in V_7 (108.00 days). V_2 (143.67) had the highest days to maturity followed by V_1 (132.67 days), V_8 (127.67

days), V_6 (120.00days), V_3 (118.33 days), V_5 (115.67 days), V_4 (115.33 days) (Figure 4.1.4).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30.

Figure 4.1.4. Effect of variety on days to first tasseling and days to maturity at SAU during Rabi 2015-2016 ($LSD_{0.05}$ = 3.60, 2.08 at first tasseling and days to maturity days respectively)

4.1.3 Yield contributing characters and yield

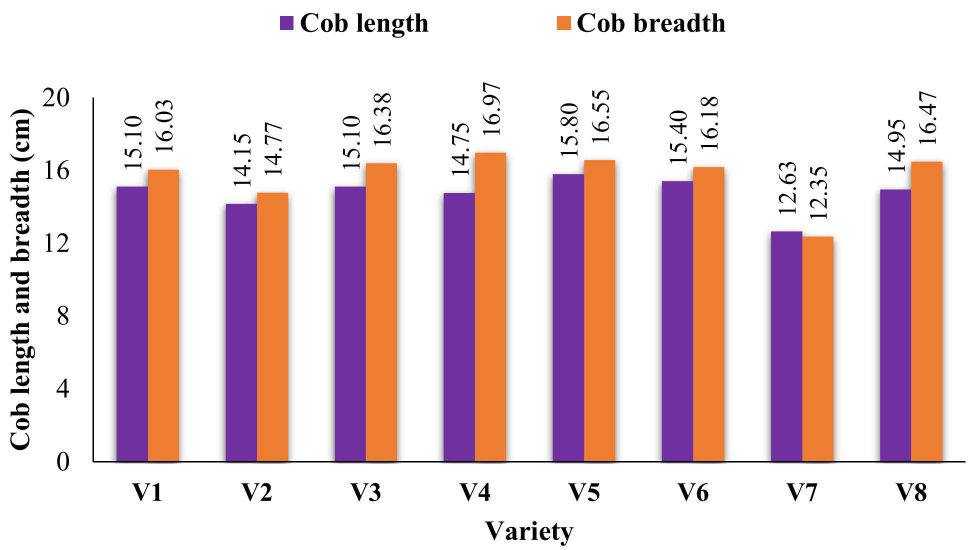
Giri and Bandyopadhyay (2016) evaluating some maize varieties in the consecutive two years and reported that out of three varieties of maize such as V_1- Pinnacle, V_2- DKC- 9081 and V_3- All-rounder the maximum yield attributes and yield were recorded from DKC- 9081.

4.1.3.1 Cob length (cm)

Eight varieties of edible maize were tested. Cob length ranged from 12.63-15.80 cm depending on varieties showing the highest by V_5 and the lowest by V_7 (Figure 4.1.5). Although the V_5 had the highest cob length but there was no significant difference with the cob length of V_6 (15.40 cm), V_1 (15.10 cm), V_3 (15.10 cm), V_8 (14.95 cm) and V_4 (14.75 cm) (Figure 4.1.5). The lowest cob length of 12.63 cm was found in V_7. This finding was in agreement with those of Kabir *et al*. (2019) who reported that the cob length (cm) was statistically significant at 1% level of probabilitydue to different variety ranging from 13.09 to 14.27 cm. The highest cob length (14.27 cm) was observed with the variety factor V3 Pacific-559 and the lowest cob length (13.09 cm) was observed in the BARI hybrid vutta-13.

4.1.3.2 Cob breadth (cm)

Among the varieties significant difference was found on the cob breadth. Maximum cob breadth (16.97 cm) was found in V_4but there has no significant difference between the variety of V_5 (16.55cm), V_8 (16.47 cm), V_3 (16.39 cm), V_6 (16.18 cm) and V_1 (16.03 cm) (Figure 4.1.5). The minimum (12.35 cm) cob breadth was significantly achieved with V_7.

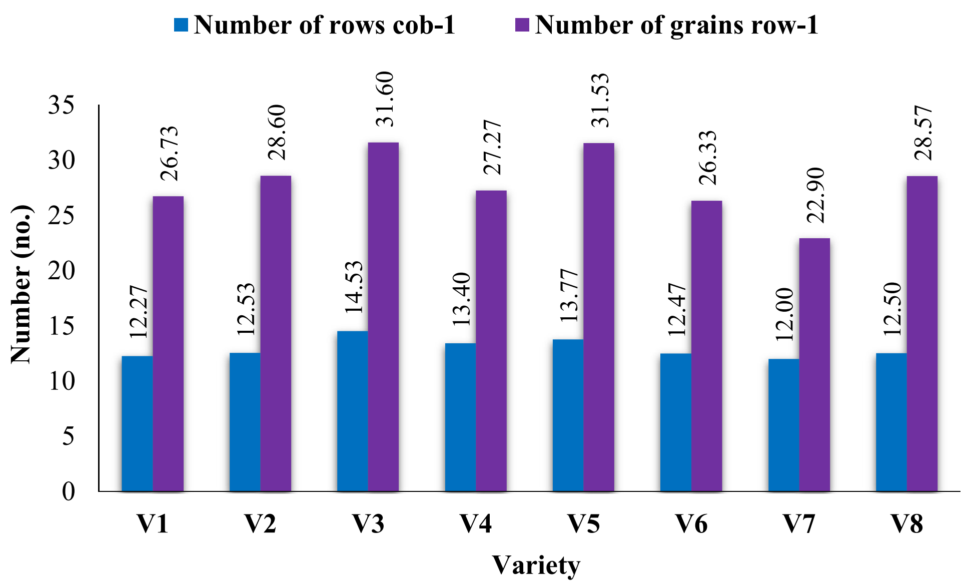


Here, V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30.

Figure 4.1.5. Effect of variety on cob length and cob breadth at SAU during Rabi 2015-2016 ($LSD_{0.05}$ = 1.116 and 1.103 at cob length, cob breadth respectively)

4.1.3.3 Number of rows cob^{-1}

Number of rows cob^{-1} was significantly influenced by varieties. Among the varieties, the maximum number of rows cob^{-1} was found in V_3 (14.53) which was statistically similar to V_4 and V_5 (13.80 and 13.77 respectively) whereas V_7 (12.00) showed the lowest performance (12.25) (Figure 4.1.6). Although V_7 gave the lowest number of rows cob^{-1} performer bur there was no significant difference between V_1 (12.27), V_6 (12.46), V_2 (12.53) and V_8 (12.50). Eyasu *et al*. (2018) observed that the variety Lemu produced the highest kernel rows ear^{-1} (16.34) at 75 cm row spacing, whereas the variety Jabi showed significant increase in number of kernel rows cob^{-1} as the plant row spacing increased from 45 cm to 75 cm with significant difference between row spacing's.



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30.

Figure 4.1.6. Effect of variety on Number of rows cob^{-1}, Number of grains row^{-1} at SAU during Rabi 2015-2016 ($LSD_{0.05}$ = 0.994 and 4.010 Number of row cob^{-1}, Number of grain row^{-1} respectively)

4.1.3.4 Number of grains row^{-1}

The verities had significant difference on number of grain row^{-1}. The highest number of grains row^{-1} was found in V_3 (31.60) and the lowest was in V_7 (22.90) (Figure 4.1.6). The V_3 had the highest grains row^{-1} but there was no significant difference between V_5 (31.53), V_2 (28.60) and V_8 (28.57). The second highest number of grains row^{-1} V_4 (27.27) which was statistically similar to V_1 (26.73) and V_6 (26.33).

4.1.3.5 Number of grains cob^{-1}

Total number of grains cob^{-1} contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. The verities had significant difference on number of grains cob^{-1}. The highest number of grains cob^{-1} was found in V_3 (413.00) and the lowest was in V_4 (323.00) (Table 4.1.1). The V_3 had the highest grains cob^{-1} but there was no significant difference between number of grain per cob of V_8 (412.69). The second highest number of grains cob^{-1} was found in V_2 (408.44). Such results were in agreement with the previous reports. Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2 = BHM-7, V_3 = Pacific-984) and reported that the highest number of grains cob^{-1} (547) was obtained with V_3 (552) while V_1 provided the lowest (510) number of grains cob^{-1}.

Khan *et al*. (2017) while conducting an experiment on four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) showed that maximum number of grains ear^{-1} (531.30) was found in PS-1 which was statistically at par with grains ear^{-1} (518.7) of PS-2, however significantly lower number of grains ear^{-1} (424.3 and 439.0) were produced by Iqbal (check) and PS-3 respectively (Ali, 1994) reported similar results that hybrid produced more grains ear^{-1} as compared to synthetic varieties due to difference in genetic makeup.

4.1.3.6 100-grain weight (g)

Grains weight is an important factor directly contributing to final grain yield of crop. Greater grain weight of hybrid might be due to the genetical character of a varietiy. In this study the varieties influenced the weight of 100-grain in white maize. Varieties had significant difference on number of grain row^{-1}. The highest 100-grain weight was obtained with V_4 (36.00 g) and the second highest 100- grain weight was found in V_5 (34.00 g) which is statistically identical to V_3 (32.66 g) (Table 4.1.1**)**. The lowest 100 grain weigh was found to V_6 (26.66 g) but there had no significant difference between the variety of V_2 (28.00 g). The same results were also reported by (Ali, *et al.,* 1999; Jong *et al*., 2003).

The above mentioned findings agreed well with those other researchers as the individual kernel mass (1000 sw) is one of the most important parameters for the total grain yield in maize (Severini *et al.,* 2011). Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) and found that the highest 100-seed weight of 32.10 g was obtained from V_3 while the lowest (30.60 g) from V_1. Eyasu *et al*. (2018) reported that the highest weight of 1000 kernels (456.33 g) was obtained from variety 'Lemu'.

Table 4.1.1 Effect of white maize varieties on the number of grains cob $^{-1}$ and 100 grain weight at SAU during Rabi 2015-2016

Variety	Number of grains cob^{-1}	100 grains weight(g)
PSC-121 (V_1)	377.17 e	31.33 cd
KS-510 (V_2)	408.44 b	28.00 fg
Chagnuo-1 (V_3)	413.00 a	32.66 bc
Q-Xiagnuo-1 (V_4)	323.00 g	36.00 a
Changnuo-6 (V_5)	382.10 d	34.00 b
Yangnuo-3000 (V_6)	394.44 c	26.66 g
Yangnuo-7 (V_7)	348.03 f	29.33 ef
Yangnuo-30 (V_8)	412.69 a	30.66 de
LSD $_{(0.05)}$	1.094	1.450
CV (%)	0.16	5.01

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

Khan *et al*. (2017) conducted an experiment using four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) and reported that the thousand grains weight of maize varieties differed significantly giving greater thousand grains weight (330 g) in PS-2, which was statistically similar with thousand grains weight (327 g) of the PS-1. Lower thousand grains weight (265 and 270 g) was recorded in PS-3 and Iqbal (check) respectively.

4.1.3.7 Stover yield plant^{-1}

The verities had significant difference on stover yield plant^{-1}. The highest stover yield plant^{-1} was found in V_1 (135.43 g) and the lowest was V_7 (93.83 g) (Table 4.1.2). V_1 had the highest stover yield plant^{-1} but there was no significant difference between the variety of V_2 (133.67 g). The second highest stover yield plant^{-1} produced byV_8 (123.07 g) which was statistically identical to V_3 (128.73 g).

4.1.3.8 Grain yield plant^{-1}

The varieties had significant difference on grain yield plant^{-1}. The highest grain yield plant^{-1} was found in V_3 (130.98 g) and the lowest was in V_7 (92.11 g) (Table 4.1.2). The V_3 had the highest grain yield plant^{-1} but there was no significant difference between the variety of V_5 (129.03 g). The second highest grain weight plant^{-1} produced by V_5 (129.03 g) which was statistically similar to V_8 (125.19 g). The lowest grain yield plant^{-1} was found in V7 (92.11 g) which was statistically different from other varieties.

Table 4.1.2 Effect of white maize varieties on stover weight and grain weight at SAU during Rabi 2015-2016

Variety	Stover yield plant^{-1} (g)	Grain yield plant^{-1} (g)
PSC-121 (V_1)	135.43 a	123.57 c
KS-510 (V_2)	133.67 ab	108.52 d
Chagnuo-1 (V_3)	128.73 bc	130.98 a
Q-Xiagnuo-1 (V_4)	114.73 e	107.28 d
Changnuo-6 (V_5)	126.10 cd	129.03 ab
Yangnuo-3000 (V_6)	103.50 f	105.86 d
Yangnuo-7 (V_7)	93.83 g	92.11 e
Yangnuo-30 (V_8)	123.07 d	125.19 bc
LSD $_{(0.05)}$	5.270	4.077
CV (%)	2.51	2.02

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

4.1.3.9 Grain yield ha^{-1}

Grain yield in maize is a product of three components; number of ears per unit area, unit grain weight and the number of kernels ear^{-1} (Gardner *et al*., 1985). Increasing or decreasing any of these components will influence the final grain yield (Devi and Muhammad, 2001).

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Eight varieties of edible maize were tested where yield ranged from 6.16-8.62 t ha^{-1} depending on varieties and the highest yield by V_3 and the lowest by V_7 (Table 4.1.3). Although the V_3 had the highest yield, there was no significant difference observed with the yield of V_8 (8.35 t ha^{-1}), V_5 (8.52 t ha^{-1}), V_1 (8.26 t ha^{-1}), V_4 (7.18 t ha^{-1}), and V_2 (7.10 t ha^{-1}). The lowest yields of V_7 (6.16

$t ha^{-1}$) but there was no significant difference between the variety of V_4 (7.18 t ha^{-1}) and V_6 (7.05 t ha^{-1}).

Khan *et al.* (2017), while carrying out an experiment on the seed yield performance of different maize (*Zea mays* L.) genotypes (PS-1, PS-2, PS-3 and Iqbal check) showed that number of ear $plant^{-1}$ was statistically similar in PS-1, PS-2 and PS-3 (1.20), however comparatively lower number of ear $plant^{-1}$ (1.0) was observed in Iqbal (check). The ear $plant^{-1}$ is a genetically controlled character and yield of less ear plant-1 is higher due to lower competition for nutrients. These results are in contrast with (Ali, 1994). However, in this study the tested varieties were hybrid ones, mostly developing a single ear on each plant. They observed that in the study the varieties PS-1 and PS-2 produced similar grain yield of 5495 and 5261 kg ha^{-1} respectively; however, the yield was higher as compared to Iqbal (check) (4128 kg ha^{-1}) and PS-3 (4202 kg ha^{-1}). Grain yield variation might be due to the diverse genetic background of these varieties and their response to agro-ecology of the experimental area. Earlier it has been reported that genotypic variations effect grain yield of maize considerably (Ali *et al*., 2018; Ahmad *et al*., 2011).

In an another report Moshood *et al*. (2018) examining four varieties of maize showed that among the varieties TZEE-Y POP STRC4, EV99QPM, 2000SynEE-W QPM C0 and 99TZEE-Y STR, the TZEE-Y POP STRC4 had the best potential for increased grain yield due to having a wide genetic base irrespective of soil and environmental difference. The said that the variety was also resistant to a wide range of biotic and a biotic stress.

Grain yield differed depending on the variation in the genetic makeup of a certain crop varieties in consecutive two years. Tripathi *et al*. (2016) experimenting at different locations of different maize varieties revealed that the effect of GEI (genotype x environmental interaction) on grain yield was highly significant with the relatively greater proportion of total variation contributed by GEI in both the years. In the meantime, a large yield variation was experienced by environments and GEI than genotype. It indicates that environment and GEI effect was more important for grain yield in hybrid maize. They also opined that the existing heterogeneity among the evaluated hybrids and growing environment clearly reflected on days to silking, plant height, and grain yield performance of commercial hybrid maize.

4.1.3.10 Stover yield ha^{-1}

Stover yield showed difference among the varieties and ranged from (6.26 t ha^{-1} -9.03 t ha^{-1}) where The highest yield was given by V_1 and the lowest by V_7 (Table 4.1.3). V_1 showed the highest yield but no significant difference with the Stover yield of V_2 (8.91 t ha^{-1}). The second significantly highest stover yield was given by V_3 (8.45 t ha^{-1}) that significantly similar to V_5 (8.41 t ha^{-1}) and V_8 (8.20 t ha^{-1}). This finding agreed well with that of Kabir *et al.* (2019) who reported that the stover yield for different varieties ranged from 8.04 to 8.66 t ha^{-1} and the highest stover yield (8.66 t ha^{-1}) was observed with the variety Pacific-559 and the lowest stover yield (8.04 t ha^{-1}) from BARI hybrid vutta-13.

4.1.3.11 Biological yield ha^{-1}

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.

Eight varieties of edible maize were tested where biological yield ranged from 12.37 - 17.27 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7 (Table 4.1.3). The V_1 showed the highest biological yield but there was no significant difference of V_3 (17.05 t ha^{-1}). The second height biological yield was found in V_8 (16.55 t ha^{-1}) which was statistically similar to V_2 (16.15 t ha^{-1}). The V_7 (12.37 t ha^{-1}) showed significantly the lowest biological yield. This finding was in agreement with the works of Kabir *et al*. (2019). They carrying out an experiment and reported that the biological yields of some maize varieties were statistically significant at 1% level of probability due to different variety.

The biological yield for different varieties ranged from 13.60 to 14.54 t ha^{-1}. The highest biological yield (14.54 t ha^{-1}) was observed with the variety Pacific-559 and the lowest biological yield (13.60 t ha^{-1}) was observed in the BARI hybrid vutta-13. Shariot-Ullah *et al*. (2013) testing three varieties (V_1=BHM-5, V_2=BHM-7,

V_3=Pacific-984) reported that the straw yield was the highest (9.12 t ha^{-1}) for V_1 and the least (8.35 t ha^{-1}) for V_2.

Table 4.1.3 Effect of white maize varieties on yield and yield attributes at SAU during Rabi 2015-2016

Variety	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
PSC-121 (V_1)	8.26 ab	9.03 a	17.27 a	46.71 c
KS-510 (V_2)	7.10 d	8.91 a	16.15 b	43.80 d
Chagnuo-1 (V_3)	8.62 a	8.45 b	17.05 a	49.43 a
Q-Xiagnuo-1 (V_4)	7.18 abc	7.65 c	14.80 c	47.34 bc
Changnuo-6 (V_5)	8.52 a	8.41 b	17.01 a	49.57 a
Yangnuo-3000(V_6)	7.05 bcd	6.90 d	13.96 d	49.57 a
Yangnuo-7 (V_7)	6.16 cd	6.26 e	12.40 e	48.53 ab
Yangnuo-30 (V_8)	8.35 ab	8.20 b	16.55 b	49.43 a
LSD $_{(0.05)}$	1.64	0.33	0.42	1.27
CV (%)	1.80	1.75	1.55	1.51

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

Khan *et al*. (2017) conducted an experiment to evaluate the biological yield of four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) and observed that the tested maize varieties differed significantly. The highest biological yield (12679 kg ha^{-1}) was produced by PS-1, at par biological yield (12189 kg ha^{-1}) was produced by PS-2, while biological yield was lower (10649 kg ha^{-1}) with Iqbal (check). In the present study, maximum biological yield was recorded in maize hybrid because it produced taller plants and more stem diameter as compare to rest of the varieties. Taller plants produce more number of leaves, larger leaf area and more light interception, which result in more photosynthesis and higher biological yield (Masood *et al*., 2003; Echarte *et al*., 2004).

4.1.3.12 Harvest Index (HI)

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Harvest index was varied significantly due to varieties and V_5

showed the highest harvest index (49.57 %), which was statistically similar to V_3 (49.43 %), V_6 (49.57 %), V_7 (48.53%) and V_8 (49.43 %) (Table 4.1.3). The V_2 variety showed the lowest (43.80 %) harvest index. The varietal difference in HI was also reported by the previous scientists. Kabir *et al*. (2019) reported that the harvest index (%) for different varieties ranged from 40.39 to 40.83%. The highest harvest index (40.83%) was observed with the variety BARI hybrid vutta-13 which is statistically similar to that of BARI hybrid vutta-9 and the lowest harvest index (40.39%) was observed in Pacific-559). Khan *et al*. (2017) while carrying out an experiment reported that out of four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) significantly higher harvest index was obtained in PS-1 and PS-2 with harvest index of 43.3 and 43.2%, respectively. The lowest harvest index (38.9 and 39.0%) were calculated for Iqbal (check) and PS-3 respectively. Difference in harvest index was probably due to the change in genetic makeup of the tested varieties (Ajmal *et al*., 2000, Ali *et al*. 2006). Shariot-Ullah *et al*. (2013) investigated the three hybrids of maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) and reported that V3 provided the highest harvest index (52.16%) and V_2 provided its lowest (51.45%) value.

Varietal selection is one of the most important agronomic management to boost grain yields. It was reported by many researchers that using hybrid is more profitable than using local or open pollinated maize varieties. Because of higher yield potentiality and assurance market of maize grains, farmers' attraction towards hybrids cultivar increased radically now a day. It is established that the yield advantage of hybrid cultivar over traditional variety is a critical component for determining the attraction towards hybrid maize (Heisey *et al*., 1998).

Khan *et al*. (2017) conducted an experiment to evaluate the yield performance of different maize (*Zea mays* L.) genotypes (PS-1, PS-2, PS-3 and Iqbal check) and indicated that PS-1 and PS-2 produced tallest plants (212.1 and 201.7 cm), higher number of rows ear^{-1} (15.6 and 14.8), maximum number of grains ear^{-1} (531.3 and 518.7) and greater thousand grains weight (330 and 327 g) respectively. While genotype PS-1 had maximum ear height (88.7 cm) and higher moisture contents (31.7%) in the grain. Genotypes PS-1 and PS-2 produced higher but at par grain yield (5495 and 5261 kg ha^{-1}), biological yield (12679 and 12189 kg ha^{-1}) and higher harvest index of (43.3 and 43.2%) respectively. From the data obtained in this study, it can be concluded that genotypes PS-1 and PS-2 performed better as compared to genotypes PS-3 and Iqbal (check).

4.1.4 Nutritional analyses of different white maize varieties

Most of the researches on maize have been related to the varietal selection. Therefore, a study of the nutritional quality of white maize would be of great interest. The contents of different nutritional components e.g. protein, carbohydrate, fat, fiber, ash, moisture Apparent Amylose content (AAC) and Glysomic Index (GI) of the eight varieties of white maize were estimated. The components were significantly varied among the variety. Significantly the maximum fiber content was obtained with PSC-121 (2.92%) and carbohydrate with Changnuo-1 (75.13%) (Table 4.1.4). The maximum Apparent Amylose content (AAC) was contained by Changnuo-1 (24.41 %) significantly. The highest amount of Glycemic Index (GI) was obtained with significantly Yangnuo-7 (71.24 %) while the other varieties showed glycemic index a bit over 60% (61-64%).According to report (Ullah,2017) the protein content in white maize is higher than rice and even than the yellow maize. Consumers when habituated with using white maize will intake more protein which will be helpful intaking protein in Bangladesh.

Food staffs having low glycemic Index (GI) is safer for the diabetic patients in comparison to those with higher GI values. GI less than 55 is termed as 'good', between 56-70 as intermediate or medium, while greater than 70 is termed as high or bad. Smaller the number, lesser the impact of GI on blood sugar. Carbohydrates with a low GI value (55 or less) are more slowly digested, absorbed and metabolized and cause a lower and slower rise in blood glucose. It was reported that rice with lower amylose content had a higher glycemic index (75), while rice with the highest amylose content had a low glycemic index (50). Low fiber in rice was associated with a high glycemic index while rice with higher fiber had a lower glycemic index (Hoon *et al.*, 2010). In this study, white maize varieties had GI values ranging from 60 to 70 which is, in general, lesser than rice. The smaller the number, the less impact the food has on your blood sugar. Carbohydrates with a low GI value (55 or less) are more slowly digested, absorbed and metabolized and cause a lower and slower rise in blood glucose and, therefore usually, insulin levels. Generally, the rice with the lowest amylose content had a high glycemic index (75) while rice with the highest amylose content had a low glycemic index (50). Low fiber was associated with a high glycemic index while rice with higher fiber had a lower glycemic index (Hoon *et al*., 2010).

Table 4.1.4 Nutritional components analysis of different varieties of white maize

Variety	Protein (%)	Moisture (%)	Fat (%)	Fiber (%)	Ash (%)	Carbohydrate (%)	AAC (%)	GI (%)
V_1	8.17 bc	10.63 a	4.13 a	2.92 ab	1.47 ab	72.67 c	23.25 b	61.24 e
V_2	8.11 bc	10.60 a	3.43 b	2.90 ab	1.40 ab	70.17 d	22.06 c	62.22 d
V_3	7.11 d	10.21 b	3.95 ab	2.28 c	1.33 b	75.13 a	24.41 a	62.22 d
V_4	9.00 a	8.96 d	3.81 ab	2.56 bc	1.43 ab	73.86 b	22.05 c	64.24 b
V_5	7.73 cd	5.02 e	3.43 b	2.78 ab	1.55 ab	70.17 d	23.44 b	63.24 c
V_6	7.93 bc	9.84 c	3.96 ab	2.70 ab	1.52 ab	74.17 b	22.84 bc	63.11 c
V_7	8.48 ab	10.03 bc	3.90 ab	2.96 a	1.63 a	72.91 c	6.85 d	71.24 a
$LSD_{(0.05)}$	0.631	0.345	0.644	0.381	0.275	0.713	0.824	0.218
CV (%)	4.30	2.08	9.17	7.76	10.16	0.88	2.21	0.19

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

V_1 = PSC-121, V2= KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7; AAC = Apparent Amylose Content and GI = Glysomic Index

Ullah *et al*. (2018) compared the nutritional quality of some local, Suvra, exotic hyrids (Plough-01, Plough 02 and Changnuo-1) and a yellow hybrid maize and reported that Local white and Suvra had higher protein (10.26-10.31%) while the white hybrids had lesser (7.73-8.92%). When comparison was made between yellow and white maize, over 4% higher protein was obtained with a Chinese hybrid Changnuo-1 (7.73%) than that of the yellow one (7.42). Yellow maize had more nutrition along with carotenoid which was lacking in white maize. It is well known that wheat and maize are superior to rice from the nutritional point of view and wheat contains more protein, fiber, thiamine than maize, but maize is superior to wheat containing more fat, and energy (Hoon *et al*., 2010).

4.2 Experiment 2: Yield and yield attributes of different white maize varieties at Dhamrai during Rabi 2015-2016

The objectives of this trial were to evaluate the performance of eight hybrid white maize varieties under different locations of Bangladesh. The experiment was conducted to find out the effect of varieties on the growth, phenology and yield performance of white maize. Data on different growth parameters, phenological parameters, yield contributing characters and yield were recorded.

4.2.1 Growth parameters

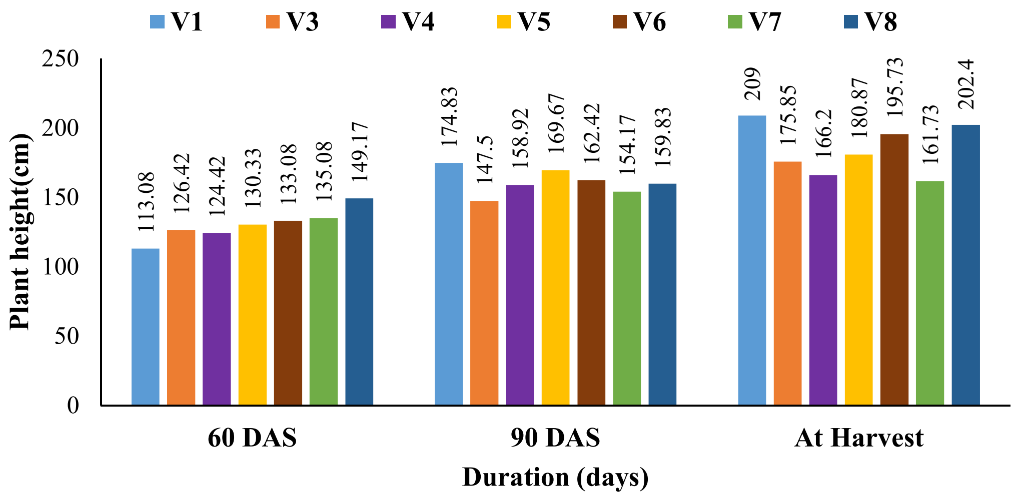
4.2.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that plant height was significantly influenced by eight examined white maize hybrid varieties.

At 60 DAS, significantly the maximum plant height (145.50 cm) was produced by the variety V_8 (Figure 4.2.1). Variety V_2 (109.00 cm) showed the lowest performance but there was no significant difference between the variety of V_1 (109.42 cm). Likewise, V_6 (131.42 cm) showed medium plant height but there was no significant difference between V_7 (130.75 cm). At 90 DAS, the longest plant height was produced from the variety V5 (219.42 cm) but there was no significant difference between the variety V_1 (217.92 cm). The lowest plant height was found in V_7 (169.50 cm). The second longest plant was shown by V_2 (212.67 cm) which was statically similar to V_3 (211.92 cm) and V_6 (211.75 cm).

At Harvest, V_1 showed the highest plant height that was 252.89 cm (Figure 4.2.1). The lowest plant height was with V_7 (192.53 cm). Likewise, V_2 (235.79 cm) had medium plant height but there was no significant difference between V_4 (235.06 cm). Tripathi *et al.* (2016) observed in two consecutive years experiment and reported that the plant height of different maize genotypes ranged from 153-222 cm with a mean of 187 cm in 2010-11 whereas it ranges from 149-189 cm with the mean 173 cm in 2011-12. The highest plant height observed in 30B11 which was then followed by

P3856 in the first year while, the varieties 'Top class' and 'Kirtiman Kundan' respectively showed the highest and lowest tall and dwarf variety in the second year.



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30

Figure 4.2.1 Effect of variety on plant height at 60 DAS, 90 DAS and at harvest of different white maize varieties at Dhamrai during Rabi 2015-2016 ($LSD_{0.05}$ = 3.992, 5.138, 4.159 at 60 DAS, 90 DAS and at harvest respectively)

4.2.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was not significantly influenced by varieties (Table 4.2.1). In 60 DAS, Number of leaf had not significantly varied though the maximum number of leaf (6.65) was produced in the variety V_7. Variety V_1 (5.67) and V_2 (5.67) were the least performers.

At 90 DAS, there was no significant difference observed among the varieties for leaf numbers. The numerically maximum number of leaf was seen in the variety of V_3 (15.00) and minimum number of leaf from V_7 (10.41). During At Harvest, significant differences were observed among the varieties where V_3 showed the highest number of leaf (15.92) and the lowest was in V_7 (11).

Table 4.2.1 Effect of variety on number of leaves plant^{-1} of different white maize varieties at Dhamrai during Rabi 2015-2016

Variety	Number of leaves plant^{-1}		
	60 DAS	**90 DAS**	**At Harvest**
PSC-121 (V_1)	5.67 a	14.17 a	15.08 a
KS-510 (V_2)	5.67 a	14.63 a	14.50 a
Changnuo-1 (V_3)	5.83 a	15.00 a	15.92 a
Q-Xiangnuo-1 (V_4)	5.67 a	13.92 a	13.25 ab
Changnuo-6 (V_5)	6.08 a	14.92 a	14.75 ab
Yangnuo-3000 (V_6)	6.39 a	14.25 a	14.59 a
Yangnuo-7 (V_7)	6.65 a	10.42 b	11.00 b
Yangnuo-30 (V_8)	6.33 a	14.17 a	14.00 a
LSD $_{(0.05)}$	1.691	1.445	1.956
CV (%)	12.86	5.92	8.04

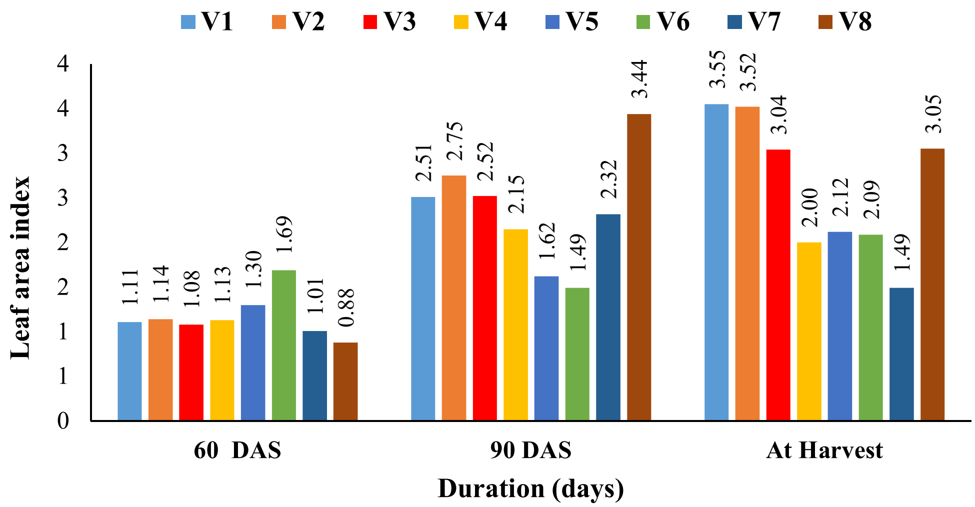
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.2.1.3 Leaf area index

Leaf area index is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that leaf area index was significantly influenced by eight examined white maize hybrid varieties.

At 60 DAS, leaf area index had significant effect on the eight varieties. The highest leaf area index (1.69) was shown in the variety V_6. The variety V_8 (0.88) was the poorest performer but there was no significant difference between V_7 (1.02) (Figure 4.2.2). Likewise, V_5 had medium value of leaf area index (1.30) but had no significant difference between V_2 (1.14) and V_4 (1.13).

At 90 DAS, leaf area index had significant effect among the eight varieties where the V_1 showed significantly the highest leaf area index (3.55) and the significantly lowest leaf area index was in V_7 (1.49) (Figure 4.2.2). The V_2 (3.22) showed the medium type of performance. During harvest, it was observed that verities had significant difference on leaf area index. The highest leaf area index (3.00) showed V_8 which had no significant difference among the variety of V_2 (2.75), V_1 (2.50). The lowest was found in V6 (1.49) which had no significant difference with V_5 (1.62), V_4 (1.75) and V_7 (2.32).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30

Figure 4.2.2 Effect of variety on leaf area index of different white maize varieties at 60 DAS, 90 DAS and at harvest in Dhamrai during Rabi 2015-2016 ($LSD_{0.05}$ =0.182, 0.447, 0.471 at 60 DAS, 90 DAS and at harvest respectively)

4.2.2 Phenological parameters

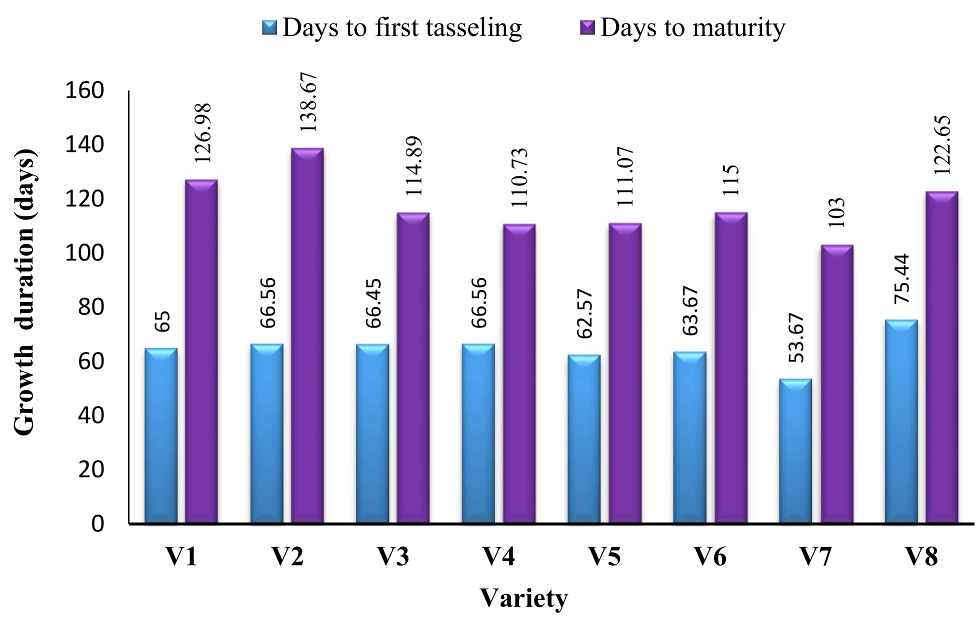
4.2.2.1 Days to first tasseling

Eight varieties were used to observe their effects on days to tasseling of white maize. It was found that days to tasseling was significantly influenced by varieties. Among the treatments, V_8 variety took significantly maximum days to tasseling (75.44 days) followed by V_2 (66.56 days), V_3 (66.45 days), V_1 (65 days), V_6 (63.67 days), V_4 (66.56 days) and V_5 (62.56 days) while V_7 (53.67 days) took significantly minimum days to tasseling (Figure 4.2.3).

The phenology of maize plants is greatly influenced by both variety and the growing environment. The phenology of maize is visually noticed by tasselling followed by silking which is greatly affected by the surrounding temperature of the season which may be delayed due to cold stress if flowering happens in winter. It was observed that the cold stress increases the gap between tasseling, anthesis and silking that obstructs fertilization, and ultimately reduced the kernel number ear^{-1}. (Abendroth *et al*., 2011; Thomison & Nielson, 2002).

4.2.2.2 Days to maturity

The verities had significant difference indays to maturity. The latest maturity was found in V_2 (138.67 days) while the earliest was withV_7 (103.00 days) (Figure 4.2.3). The V_2 (138.70days) had the highest days to maturity followed by V_1 (126.98 days), V_8 (122.65 days), V_6 (115.00 days), V_3 (114.89 days) V_5 (111.07 days) and V_4 (110.73 days).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30

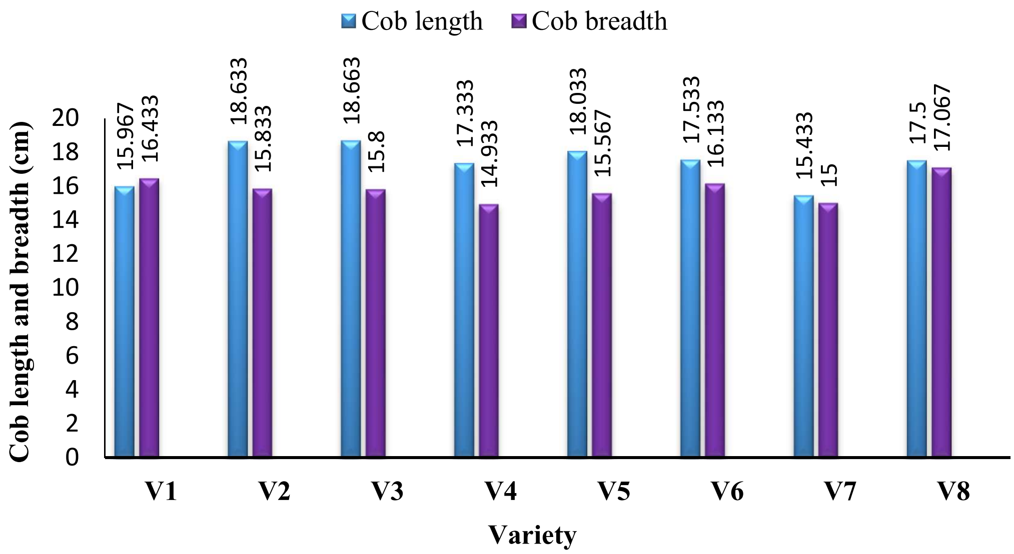
Figure 4.2.3 Effect of variety on the days to first tasseling and maturity of different white maize varieties at Dhamrai during Rabi 2015-2016 ($LSD_{0.05}$ =3.415, 1.272 at the days to first tasseling and days to maturity respectively).

4.2.3 Yield contributing characters and yield

4.2.3.1 Cob length (cm)

Eight varieties of edible maize were tested. Cob length ranged from 15.43-18.67 cm depending on varieties showing the highest by V_3 and the lowest by V_7 (Figure 4.2.4).

Although the V_3 had the highest cob length but there was no significant difference with the cob length of V_2 (18.63 cm), V_5 (18.03 cm), V_8 (17.50 cm), V_4 (17.33 cm) and V_6 (17.53 cm). The lowest cob length was V_7 (15.43) but there was no significant difference between V_1 (15.97). This result agreed well with the findings of Eyasu *et al*. (2018) who observed variation of cob length among the maize varieties where the highest ear length (33.84 cm) was recorded in Jabi while the lowest (30.03 cm) was recorded for name the variety.



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30

Figure 4.2.4 Effect of variety on the days to cob length and cob breadth of different white maize varieties at Dhamrai during Rabi 2015-2016 ($LSD_{0.05}$ = 1.364,1.335 to cob length and cob breadth, respectively).

4.2.3.2 Cob breadth (cm)

Cob breadth was significantly affected by varieties. Among the varieties significant difference was found in cob breadth. Maximum cob breadth (17.07 cm) was found in V_8 but there had no significant difference between the varieties of V_1 (16.43 cm), V_6 (16.13 cm), V_2 (15.83 cm) and V_3(15.80cm) (Figure 4.2.4). The minimum (14.93 cm) was found with V_4 which had no significant difference when compared with V_7 (15.00), V_5 (15.57 cm), V_6 (16.13 cm), V_2 (15.83 cm) and V_3 (15.80 cm).

4.2.3.3 Number of rows cob^{-1}

Number of rows cob^{-1} was significantly influenced by varieties. Among the varieties, the highest number of rows cob^{-1} was found in V_3 (14.53) which was statistically similar to V_4 and V_5 (13.40 and 13.77), whereas V_7 (12.00) was the least performer (12.25) (Table 4.2.2). Although V_7 (12.00) was the lowest performer but there was no significant difference between V_1 (12.27), V_6 (12.47), V_2 (12.53) and V_8 (12.50).

4.2.3.4 Number of grains row^{-1}

The varieties had significant difference on number of grains row^{-1}. The highest number of grains row^{-1} was found in V_3 (31.60) and the lowest was V_7 (22.90) (Table 4.2.2). The V_3 had the highest grain row^{-1} that was not significantly different with V_5 (31.53), V_2 (28.60) and V_8 (28.57). The next highest number of grains row^{-1} observed in V_4 (27.27) which was statistically similar to V_1 (26.73) and V_6 (26.33).

4.2.3.5 Number of grains cob^{-1}

Total number of grains cob^{-1} contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. The varieties had significant difference on number of grains cob^{-1}. The highest number of grains cob^{-1} was found in V_6 (518.40) and the least was in V_4 (294.00) (Table 4.2.2). The V_6 had the highest grains cob^{-1} but there was no significant difference with V_2 (475.47) and V_5 (455.33). The next highest number of grains cob^{-1} was found in V_1 (434.40) which had no significant differencewithV_3 (433.33) and V_5 (455.33).

Kabir*et al*. (2019) reported that the number of kernels cob^{-1} was statistically significant among different varieties. The number of kernels cob^{-1} for different varieties ranged from 261.00 to 310.40. The highest number of kernels/cob (310.40) was observed with the varietal factor V_3 (Pacific-559) and the lowest number of kernels cob^{-1} (261.00) was observed in the factor V_2 (BARI hybrid butta-13).

4.2.3.6 100-grain weight (g)

100-grain weight is an important yield contributing characters, which plays an important role in showing the potentiality of a variety. The varieties influenced the weight of 100-grain in white maize. The heaviest grain was found with V_5 (32.00 g) but there was no significant difference between V_3 (31.33 g), V_4 (30.67 g) and V_8

(30.67 g) (Table 4.2.2). The next heaviest grain was found in V_1 (29.00 g) which was statistically higher thanV_2 (28.00 g). The lowest 100 grain weight was found withV_7 (26.00 g) but there was no significant difference in the variety V_6 (27.34 g). Moshood *et al*. (2018) reported that the weight of 100 grains increased noticeably and significantly (p=0.05) across the varieties. Plots having 2000 Syn. EE-W QPM C_0 recorded the highest weight of 100- grains (33.00).

Table 4.2.2 Effect of variety on Number of rows cob^{-1}, Number of grain row^{-1}, Number of grain cob^{-1} and 100 grains yield of different white maize varieties at Dhamrai during Rabi 2015-2016

Variety	Number of rows cob^{-1}	Number of grains row^{-1}	Number of Grains cob^{-1}	100 grains weight(g)
PSC-121 (V_1)	12.27 b	26.73b	434.40 bc	29.00 b
KS-510 (V_2)	12.53 b	28.60 ab	475.47 a	28.00 bc
Changnuo-1 (V_3)	14.53 a	31.60 a	433.33 bc	31.33 a
Q-Xiangnuo-1(V_4)	13.80 a	27.27 b	294.00 e	30.67 a
Changnuo-6 (V_5)	13.77 a	31.53 a	455.33 ab	32.00 a
Yangnuo-3000 (V_6)	12.47 b	26.33 b	418.40 c	27.33 cd
Yangnuo-7 (V_7)	12.00 b	22.90 c	332.00 d	26.00 d
Yangnuo-30 (V_8)	12.50 b	28.57 ab	403.87 c	30.67 a
LSD $_{(0.05)}$	0.994	4.010	33.260	1.598
CV (%)	4.37	8.12	0.24	5.00

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

4.2.3.7 Grain yield plant^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Eight varieties of edible maize were tested. Yield ranged from 90.67 – 136.93 g plant^{-1} depending on varieties showing the highest withV_5 and the lowest withV_7 (Table 4.2.3). The V_5 had significantly the highest grain yield plant^{-1} which was significantly higher than all other varieties of V_2 (132.13 g),

V_1 (128.80 g), V_3 (123.60 g), V_6 (123.60 g), V_8 (117.73 g), V_4 (101.73 g) and V_7 (90.67 g) (Table 4.2.3). Significantly the lowest grain yield was found in V_7 (90.67 g).

4.2.3.8 Stover yield plant^{-1}

The varieties had significant effect on stover yield plant^{-1}. The heaviest stover was found in V_1 (155.30 g) and the lowest with V_7 (93.06 g) (Table 4.2.3). The V_1 (155.30 g) had significantly highest stover yield plant^{-1} and having significantly higher values over the other varieties of V_2 (148.03 g), V_5(134.28 g), V_6 (121.63 g), V_3 (127.26 g), V_4 (102.23 g), V_8 (124.87 g) and V_7 (93.06 g). Significantly lightest stover yield plant^{-1} was found in V_7 (93.06 g) (Table 4.2.3).

Table 4.2.3 Effect of variety on grain yield and stover yield of different white maize varieties at Dhamrai during Rabi 2015-2016

Variety	Grain yield plant^{-1} (g)	Stover yield plant^{-1} (g)
PSC-121 (V_1)	128.80 c	155.30 a
KS-510 (V_2)	132.13 b	148.03 b
Changnuo-1 (V_3)	123.60 d	127.26 d
Q-Xiangnuo-1 (V_4)	101.73 f	102.23 e
Changnuo-6 (V_5)	136.93 a	134.28 c
Yangnuo-3000 (V_6)	123.60 d	121.63 d
Yangnuo-7 (V_7)	90.67 g	93.06 f
Yangnuo-30 (V_8)	117.73 e	124.87 d
LSD $_{(0.05)}$	2.523	6.251
CV(%)	0.18	4.76

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

4.2.3.9 Grain yield ha^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Eight varieties of edible maize were tested. Yield ranged from 6.05 - 9.13 t ha^{-1} depending on varieties showing the highest by V_5 and the lowest by V_7 (Table 4.2.4). The V_5 had the highest yield which was significantly superior among the other varieties of V_2 (8.81 t ha^{-1}), V_1 (8.59 t ha^{-1}) , V_3 (8.24 t ha^{-1}), V_6 (8.24 t ha^{-1}), V_8 (7.85 t ha^{-1}) V_4 (6.79 t ha^{-1}) and V_2 (6.05 t ha^{-1}).Significantly the lowest yield was found in V_7 (6.05 t ha^{-1}).The varietal difference in respect of seed yield also reported by Eyasu *et al*. (2018) who conducted a field experiment at a district Ethiopia during the off-season of 2016-17 and found the highest grain yield in variety Lemu that statistically similar to BH-540.

4.2.3.10 Stover yield ha^{-1}

Stover yield showed difference among the varieties. That ranged from 6.20 t ha^{-1}- 11.43 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7 (Table 4.2.4). The V_1 (11.43 t ha^{-1}) had significantly the highest stover yield among the varieties of V_2 (9.87 t ha^{-1}), V_5 (8.95 t ha^{-1}), V_6 (8.09 t ha^{-1}), V_3 (8.49 t ha^{-1}), V_4 (6.81 t ha^{-1}) and V_8 (8.33 t ha^{-1}). Significantly lowest was found in V_7 (6.20 t ha^{-1}).

Table 4.2.4 Effect of white maize varieties on yield and yield attributes at Dhamrai during Rabi 2015-2016

Variety	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})
PSC-121 (V_1)	8.59 c	11.43 a	20.01 a
KS-510 (V_2)	8.81 b	9.87 b	18.68 b
Chagnuo-1 (V_3)	8.24 d	8.49 cd	16.72 c
Q-Xiagnuo-1 (V_4)	6.79 f	6.82 e	13.60 d
Changnuo-6 (V_5)	9.13 a	8.95 c	18.08 b
Yangnuo-3000 (V_6)	8.24 d	8.09 d	16.33 c
Yangnuo-7 (V_7)	6.05 g	6.20 e	12.25 e
Yangnuo-30 (V_8)	7.85 e	8.33 cd	16.17 c
LSD $_{(0.05)}$	0.188	0.688	0.698
CV (%)	4.44	4.68	2.42

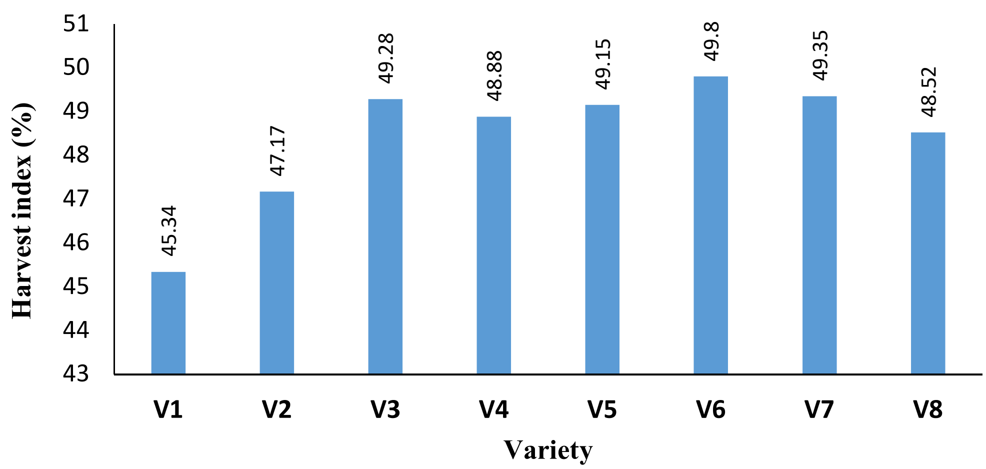
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

4.2.3.11 Biological yield ha^{-1}

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. Eight varieties of edible maize were tested where biological yield ranged from 12.25 - 20.01 t ha^{-1}. The highest biological yield was given by V_1 and the lowest by V_7 (Table 4.2.4). The V_1 (20.01 t ha^{-1}) was significantly highest but had no difference with the variety V_2 (18.68 t ha^{-1}). Significantly the second height biological yield was found in V_2 (18.68 t ha^{-1}) and V_7 had the significantly lowest yield (12.25 t ha^{-1}).

4.2.3.12 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among economic yield and biological. The varieties had a significant effect on harvest index and the highest harvest index was found in V_6 (49.80 %) and the lowest was V_1 (45.34 %) (Figure 4.2.5).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.2.5 Effect of variety on harvest index of different white maize varieties at Dhamrai during Rabi 2015-2016 ($LSD_{0.05}$ = 1.779)

The V_6 had the highest harvest index but there was no significant difference with V_3 (49.28 %), V_4 (48.88 %), V_5 (49.15 %) and V_7 (49.35 %). The second highest harvest index was found in V_8 (48.52 %) which had no significant difference with V_3 (49.28 %), V_4 (48.88 %), V_5 (49.15 %) and V_7 (49.35 %). Significantly the lowest harvest index was V_1 (45.34 %).

4.3 Experiment 3: Yield and yield attributes of different white maize varieties at Rangpur during Rabi, 2015 -2016

The objectives of this trial were to evaluate the performance of eight hybrid white maize varieties under different location in Bangladesh. The experiment was conducted to find out the effect of varieties on the growth, phenology and yield performance of white maize at Rangpur region. Data on different growth parameters, phenological parameters, yield contributing characters and yield were recorded.

4.3.1 Growth parameters

4.3.1.1 Plant height (cm)

Determination of growth attained during the growing period plant height is an important component. It was revealed from the results that plant height was significantly influenced by eight examined white maize hybrid varieties. Among the varieties, the V_6 showed significantly the tallest plant (224.22 cm) whereas, V_7 showed the shortest (185.33 cm) (Table 4.3.1). Significantly the tallest height (224.22 cm) was found in V_6 that was similar to V_5 (222.22 cm). The next highest plant height was found in V_8 (217.44 cm) which had no difference with V_5 (222.22 cm) (Table 4.3.1). The lowest highest (185.33 cm) was achieved in V_7. Such variation of plant height among different maize varieties was also obtained in the previous findings where Abera *et al*. (2017) conducted trials on some varieties and reported that the mean plant height of maize varieties was significantly affected by variety. In comparison to others significantly higher plant heights were recorded from BH-661, BH-660, and BH-543 in descending order.

4.3.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties. Significantly the highest number of leaves plant^{-1} (13.89) was found in the variety V_1 which was statistically similar to V_2 (13.56), V_3 (13), V_4 (12.78), V_8 (12.78) and V_6 (12.67). The V_7 variety showed the lowest number of leaves (10.33) (Table 4.3.1).

Table 4.3.1 Effect of variety on plant height and number of leaves plant^{-1} of white maize varieties at Rangpur Sadar during Rabi 2015-2016

Variety	Plant height(cm)	Number of leaves plant^{-1}
PSC-121 (V_1)	211.89 d	13.89 a
KS-510 (V_2)	215.44 cd	13.56 a
Changnuo-1 (V_3)	215.89 cd	13.00 a
Q-Xiangnuo-1 (V_4)	212.11 d	12.78 a
Changnuo-6 (V_5)	222.22 ab	12.78 a
Yangnuo-3000 (V_6)	224.22 a	12.67 a
Yangnuo-7 (V_7)	185.33 e	10.33 b
Yangnuo-30 (V_8)	217.44 bc	12.78 a
LSD $_{(0.05)}$	5.280	2.315
CV(%)	3.13	8.38

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

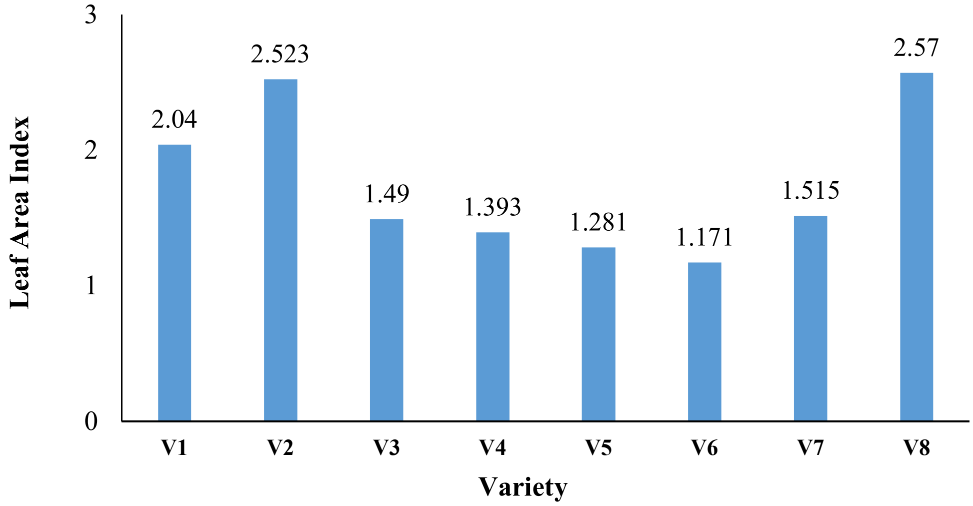
4.3.1.3 Leaf area index

Among the important component, Leaf area index is an important parameter which helps in the determination of growth attained during the growing period. It was revealed from the results that Leaf area index was significantly influenced by eight examined white maize hybrid varieties. Significantly the highest Leaf area index was found in V_8 (2.57) and the lowest Leaf area index was found in V_6 (1.17) (Figure 4.3.1). Significantly the highest Leaf area index was found in V_8 (2.57) which had no significant difference with V_2 (2.58). The lowest Leaf area index was given by V_6 (1.17) which had no significant difference with V_3 (1.49), V_4 (1.39) and V_5 (1.28).

4.3.2 Phenological parameters

4.3.2.1 Days to first tasseling

Eight varieties of white maize were used to observe their effects on days to tasseling. It was found that days to tasseling was significantly influenced by varieties. Among the treatments, V_2 (KS-510) took significantly longest days to tasseling (58 days) but there was no significant difference between the varieties of V_7 (57.67 days), V_3 (57 days) and V_5 (56.67 days) (Figure 4.3.2). Significantly the shortest days to tasseling was in V_6 (54.33 days) which was not significantly different with V_1 (54.67 days), V_4 (55.33 days) and V_8 (56 days).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.3.1 Leaf Area Index of white maize at Rangpur Sadar as influenced by different varieties during Rabi, 2015-2016 ($LSD_{0.05}$ = 0.337 Leaf Area Index respectively)

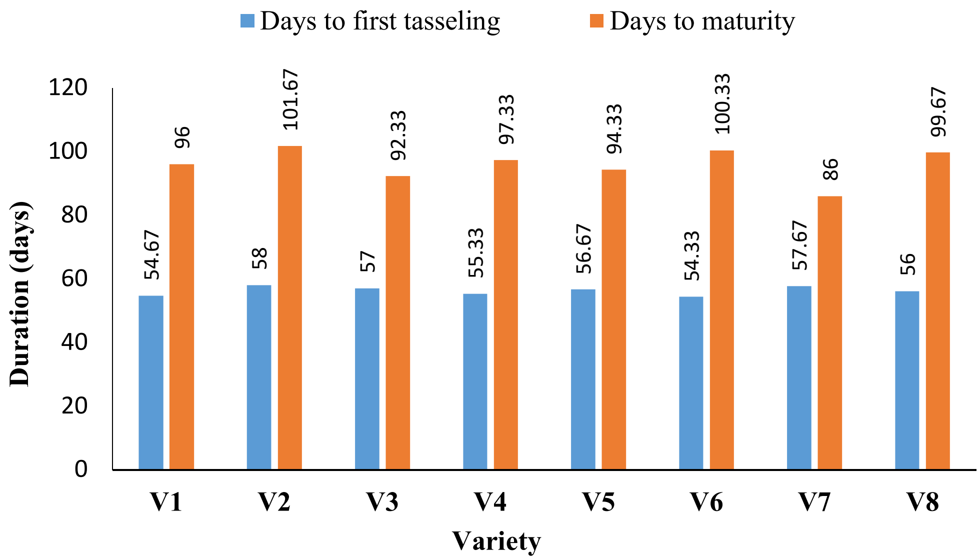
4.3.2.2 Days to maturity

The varieties, showed significantly positive effect on days to maturity where V_2 (KS-510) variety took significantly longest time to be matured (101.67 days) which was statistically similar to V_6 (100.33 days). Significantly the shortest days to maturity was found in V_7 (86 days) (Figure 4.3.2).

4.3.3 Yield contributing characters and yield

4.3.3.1 Cob length (cm)

Cob length ranged from 16.00-19.07 cm depending on varieties and the highest cob length withV_6 and the lowest by V_7. Although the V_6 had the highest cob length but there was no significant difference with those ofV_3 (18.60 cm), V_4 (18.00 cm) and V_8 (17.67 cm) (Table 4.3.2). The lowest cob length was found with the treatment V_7 (16.00) but there was no significant difference between V_1 (17.50 cm), V2 (16.80 cm), V_5 (16.40 cm) and V_8 (17.67 cm).



V_1 = PSC-121, V_2=KS-510, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000,V_7 = Yangnuo-7,V_8= Yangnuo-30.

Figure 4.3.2 Effect of variety on the days to first tasseling and days to maturity of different white maize varieties at Rangpur Sadar during Rabi 2015-2016 ($LSD_{0.05}$ = 1.94 and 1.77 to first tasseling and days to maturity respectively)

The results were in agreement with the works of Shariot-Ullah *et al.* (2013) who investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0). The results showed that the maize variety, V_3 provided the longest cobs (17.67 cm) and V_2 provided the shortest cobs (16.78 cm). Niazuddin *et al*. (2002) and Gab-Alla *et al.* (1995) also reported similar effects of water regimes on the cob length of maize. The combined effects of irrigations and varieties however caused significant differences in cob length.

4.3.3.2 Cob breadth (cm)

Cob breadth was significantly affected by varieties. The widest cob breadth (17.07 cm) was found in V_8 but there has no significant difference observed among the variety of V_1 (16.43 cm), V_6 (16.13 cm), V2 (15.83 cm) and V_3 (15.80 cm) (Table 4.3.2). The narrowest cob (14.93 cm) was found with V_4 which however, was not significantly different with those of V_7 (15.00 cm), V_5 (15.57 cm), V_6 (16.13 cm), V2 (15.83 cm) and V_3 (15.80 cm).

Table 4.3.2 Effect of variety on Cob length, Cob breadth and Number of rows cob^{-1} of white maize varieties at Rangpur Sadar during Rabi 2015-2016

Variety	Cob length (cm)	Cob breadth (cm)	Number of rows cob^{-1}
PSC-121 (V_1)	17.50 bcd	16.43 ab	13.17 ab
KS-510 (V_2)	16.80 cd	15.83 abc	12.58 bc
Changnuo-1 (V_3)	18.60 ab	15.80 abc	13.00 ab
Q-Xiangnuo-1 (V_4)	18.00 abc	14.93 c	12.80 abc
Changnuo-6 (V_5)	16.40 d	15.57 bc	14.07 a
Yangnuo-3000 (V_6)	19.07 a	16.13 abc	12.80 abc
Yangnuo-7 (V_7)	16.00 d	15.00 c	13.77 ab
Yangnuo-30 (V_8)	17.67 a-d	17.07 a	11.60 c
LSD $_{(0.05)}$	1.556	1.336	1.393
CV(%)	4.99	4.81	6.13

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

4.3.3.3 Number of rows cob^{-1}

Number of rows cob^{-1} was significantly influenced by varieties. Among the varieties, the maximum number of rows cob^{-1} was found in V_5 (14.07) which however, was statistically similar to those of V_1 (13.17), V2 (12.58), V_3 (13.00), V_4 (12.80), V_6 (12.80) and V_7 (13.77) (Table 4.3.2). The treatment V_8 (11.60) had the lowest number of rows per cob.

The result found similarity with the work of Nielsen (1995) who noted that the number of rows cob^{-1} was highly dependent on the genetic make-up of a variety, more than it was influenced by the environmental conditions. Khan *et al*. (2017) reported higher grains rows ear^{-1} in the variety PS-2 (14.8) and lower number of grain rows ear^{-1} (13.9 and 13.6) were observed in PS-3 and Iqbal (check) respectively. These results were in line with (Ahmad, 2000) who reported that hybrid cultivar produced more number of grain rows. This finding coincides with that of Kabir *et al.* (2019) who reported that the number of rows cob^{-1} was the highest (13.24) with the variety Pacific-559 and the lowest with BARI hybrid vutta-13.

4.3.3.4 Number of grains row^{-1}

The varieties had significant difference in containing number of grain row^{-1}. The highest number of grains row^{-1} was found withV_3 (32.00) while the lowest with V_1 (25.30) (Table 4.3.3). Significantly the lowest grains row^{-1} was observed with V_1 (25.30) but there was no significant difference among the number of grains row^{-1}of the treatments V_2 (26.58), V_4 (26.33) and V_7 (27.07). Andrade *et al*., (1999) identified the number of kernels row^{-1} as one of the main components which directly influenced the total grain yield in maize.

4.3.3.5 Number of grains cob^{-1}

Total number of grains cob^{-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. The maximum number of grains cob^{-1} (418.87) was reported from the treatments V_3 which was then followed by V_1 (336.52), V_2 (334.33), V_4 (337.55), V_5 (393.69), V_6 (380.43) and V_7 (370.71) and V_8 was the lowest performer among others (326.21) (Table 4.3.3). Statistically V_1 (336.52), V_2(334.33) and V_4 (337.55) was the similar performer.

4.3.3.6 100-grain weight (g)

100-grain weight is an important yield contributing factor, which plays an important role in showing the potentials of a variety. The varieties influenced the weight of 100-grain in white maize. The heaviest grains were observed with V_4 (28.67 g) which was statistically similar with V_5 (27.33 g) (Table 4.3.3). The second highest 100- grain weigh was obtained with V_5 (27.33 g) which was statistically higher than those of V1 (26.00 g), V_3 (26.00 g), V_7 (26 .00 g) and V_8 (.00 g). The lightest 100 grain weigh was found withV_2 (22.00 g). Such finding agreed well with the finding of Kabir *et al*. (2019) who reported that the 1000 seed weight (g) ranged from 318.20 to 328.50 g and was the highest (328.50 g) with the variety Pacific-559 which was statistically similar to that of BARI hybrid vutta-9 and the lowest 1000 seed weight (318.20 g) was observed in the BARI hybrid vutta-13.

Table 4.3.3 Effect of variety on number of grain cob-1 and 100 seed weight of different white maize varieties at Rangpur Sadar during Rabi 2015-2016

Treatment (Variety)	Number of grains row^{-1}	Number of grains cob^{-1}	100 seed weight (g)
PSC-121 (V_1)	25.30 d	336.52 e	26.00 b
KS-510 (V_2)	26.58 cd	334.33 e	22.00 d
Changnuo-1 (V_3)	32.00 a	418.87 a	26.00 b
Q-Xiangnuo-1 (V_4)	26.33 cd	337.55 e	28.67 a
Changnuo-6 (V_5)	28.20 bc	393.69 b	27.33 ab
Yangnuo-3000 (V_6)	29.73 b	380.43 c	24.00 c
Yangnuo-7 (V_7)	27.07 cd	370.71 d	26.00 b
Yangnuo-30 (V_8)	27.40 c	326.21 f	26.00 b
LSD ($_{0.05}$)	1.939	8.025	1.371
CV (%)	3.98	5.16	1.89

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

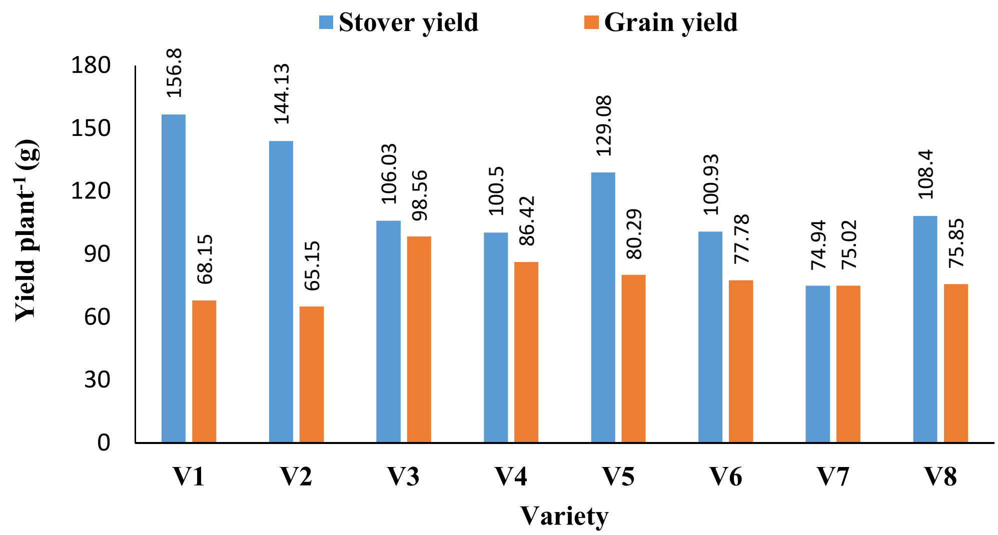
4.3.3.7 Grain yield Plant^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Eight varieties of maize were tested. Yield ranged from (65.15 – 98.56) gplant^{-1} depending on varieties showing the highest by V_3 and the lowest by V_2 (Figure 4.3.3). The V_3 had significantly highest grain yield plant^{-1} among the varieties of V_1 (68.15 g plant^{-1}), V_4 (86.42 g plant^{-1}), V_5 (80.29 g plant^{-1}), V_6 (77.78g plant^{-1}), V_7 (75.02 g plant^{-1}) and V_8 (75.85 g plant^{-1}). Significantly lowest was found in V_2 (65.15 g plant^{-1}).

4.3.3.8 Stover yield plant^{-1}

The verities had significant effect on stover yield plant^{-1}. The highest stover yield plant^{-1} was found in V1 (156.80 g) and the lowest was V_7 (74.94 g) (Figure 4.3.3). V1 had significantly the highest stover yield plant^{-1} (156.80 g plant^{-1}) over other varieties such as, V_2 (144.13 g plant^{-1}), V_3 (106.03 g plant^{-1}), V_4 (100.50 g plant^{-1}), V_5 (129.08

g plant^{-1}), V_6 (100.93 g plant^{-1}) and V_8 (108.40 g plant^{-1}) while, significantly lowest was found in V_7 (74.94 g plant^{-1}).



V_1 = PSC-121, V_2=KS-510, V_3 =Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7,V_8= Yangnuo-30.

Figure 4.3.3 Effect of variety on stover yield plant^{-1} and grain yield plant^{-1} of different white maize varieties at Rangpur Sadar during Rabi 2015-2016 (LSD$_{0.05}$ = 4.905 and 3.366 of stover yield plant^{-1} and grain yield plant^{-1} respectively)

4.3.3.9 Grain yield ha^{-1}

Yield ranged from 4.54-6.35 t ha^{-1} depending on varieties showing the highest withV_3 and the lowest by V_1 (Table 4.3.4). The V_3 had the highest yield which was significantly highest among the varieties such as V_2 (4.66 t ha^{-1}), V4 (6.14 t ha^{-1}), V_5 (5.40 t ha^{-1}), V_6 (5.43 t ha^{-1}), V_7 (5.00 t ha^{-1}) and V_8 (5.06 t ha^{-1}). While, significantly the lowest yield was in V_1 (4.54 t ha^{-1}). Such finding is in coordination with that of Tripathi *et al*. (2016) who the top most yielders P3856 (10515 kg ha^{-1}), Bisco prince (8763 kg ha^{-1}) and Shaktiman (8654 kg ha^{-1}) in the first year, while 3022 (8378 kg ha^{-1}), Kirtimanmanik (8323 kg ha^{-1}) and Top class (7996 kg ha^{-1}) in the second year. Alom *et al*. (2009) also published similar report stating that the variety Pacific-11 showed higher maize equivalent yield while the variety BARI Hybrid Maize-1 (BHM-1) was lower yielder in monoculture (T9).

4.3.3.10 Stover yield ha^{-1}

Stover yield showed difference among the varieties. Stover yield ranged from 5.01 t ha^{-1} – 10.45 t ha^{-1} depending on varieties showing the highest by V1 and the lowest by V_7 (Table 4.3.4). V_1 (10.45 t ha^{-1}) had significantly highest Stover yield among the variety of V_2 (9.60 t ha^{-1}), V_3 (7.07 t ha^{-1}), V_4 (6.70 t ha^{-1}), V_5 (8.60 t ha^{-1}), V_6 (6.73 t ha^{-1}) and V_8 (7.23 t ha^{-1}). Significantly the lowest stover yield was found in V_7 (5.01 t ha^{-1}).

4.3.3.11 Biological yield ha^{-1}

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 different varieties. Eight varieties of edible maize were tested. Biological yield ranged from (10.00 – 15.17 t ha^{-1}) depending on varieties showing the highest by V_1 and the lowest by V_7 (Table 4.3.4). The V_1 (15.17 t ha^{-1}) had significantly highest biological yield among the varieties of V_2 (13.49 t ha^{-1}), V_3 (13.64 t ha^{-1}), V_4 (12.46 t ha^{-1}), V_5 (13.96 t ha^{-1}), V_6 (11.91 t ha^{-1}) and V_8 (12.28 t ha^{-1}). The second highest biological yield was with V_5 (13.98 t ha^{-1}) which had no significant difference with those of V_3 (13.64 t ha^{-1}). V_7 (10.00 t ha^{-1}) had significantly the lowest yield.

Table 4.3.4 Effect of white maize varieties on yield and yield attributes at Rangpur Sadar during Rabi 2015-2016

Variety	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
PSC-121 (V_1)	4.54 e	10.45 a	15.17 a	31.09 g
KS-510 (V_2)	4.66 e	9.61 b	13.485 c	28.76 h
Chagnuo-1 (V_3)	6.35 a	7.07 d	13.64 bc	48.18 b
Q-Xiagnuo-1 (V_4)	6.14 b	6.70 e	12.46 d	46.23 c
Changnuo-6 (V_5)	5.40 c	8.61 c	13.96 b	38.35 f
Yangnuo-3000 (V_6)	5.43 c	6.73 e	11.91 e	43.52 d
Yangnuo-7 (V_7)	5.01 d	4.99 f	10.00 f	49.93 a
Yangnuo-30 (V_8)	5.06 d	7.23 d	12.29 de	41.17 e
LSD $_{(0.05)}$	0.190	0.256	0.384	0.935
CV (%)	2.00	1.91	1.70	1.31

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

4.3.3.12 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among biological and economic yield. White maize varieties had a significant effect on harvest index. The verities had significant difference on harvest index. Significantly the highest harvest index was found in V_7 (49.93 %) and the lowest was V1 (31.09 %) (Table 4.3.4). The second highest harvest index was found in V_3 (48.18 %).

Across the location the varieties responded differently in respect of growth and yield. The differences in grain yield across environments might be owing to variation in the genetic base of the hybrids, differing environmental conditions over sites, and GEI. Similar kind of observation was also reported by Sharma *et al*. (2008). The maize hybrids developed by different seed companies with various genetic backgrounds might be the major causes of variability in performance among genotypes. The variation in climatic parameters and soil type of experimental site might be also depicted on the performance of these commercial hybrids. Growth and development of crops influenced by temperature, radiation, photoperiod and water availability (Tsimba *et al*., 2013).

4.3.4 Conclusion over the first year's (2015-16) three experiments (Expt. 1-3) regarding the varietal selection

In the first three experiments, eight varieties e.g., PSC-121, KS-510, Changnuo-1, Q-Xiangnuo-1, Changnuo-6, Yangnuo-3000, Yangnuo-7, Yangnuo-30 of white maize were tested at three sites such as SAU, Dhamrai and Rangpur Sadar during rabi 2015-16. Results showed that out of eight varieties at SAU, five varieties were at par showing statistically similar seed yields (tha^{-1}) although there were marked differences among them, such as PSC-121 (8.26), Q-Xiangnuo-1 (7.17), Changnuo-1 (8.62), Changnuo-6 (8.52) and Yangnuo-30 (8.35). That is except Q-Xiangnuo-1, all of the five good performing varieties had grain yields over eight t ha^{-1}. At Dhamrai, four out of eight varieties showed significantly higher grain yields over others showing yields over eight t ha^{-1} such as PSC-121 (8.58), KS-510 (8.81), Changnuo-1 (8.24) and Changnuo-6 (9.13). But at Rangpur only two out of eight varieties yielded significantly higher grain yields such as Changnuo-1 (6.65) and Q-Xingnuo-1 (6.14). Over all, it was observed that the variety Changnuo-1 performed good at three sites. Other varieties except the KS-510 performed at least two sites, while KS-510 performed good only at Dhamrai.

4.4 Experiment 4: Yield and yield attributes of different white maize varieties at SAU during Rabi, 2016-2017

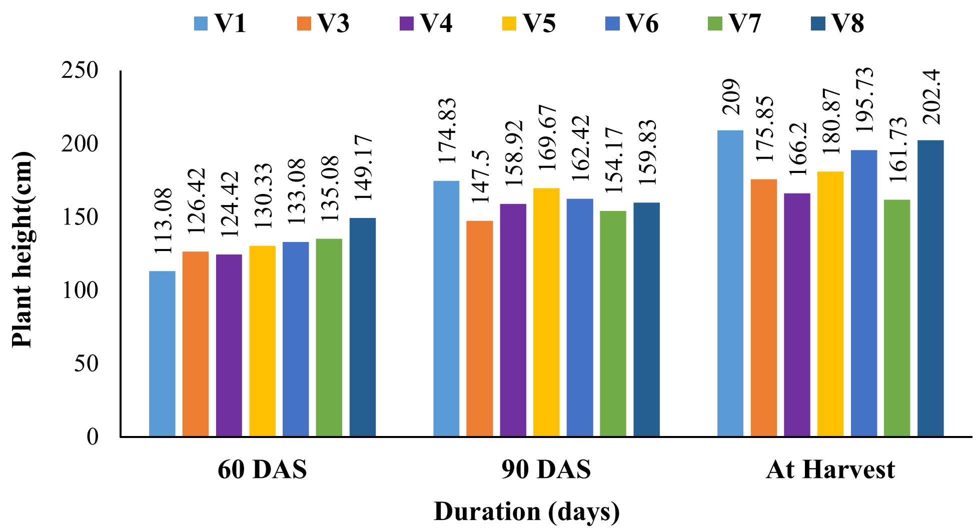
The objectives of this trial was to evaluate the performance of seven hybrid white maize varieties under different locations in Bangladesh to find out the effect of varieties on the growth and yield performance of white maize. Data on different growth parameters, yield, and yield contributing characters recorded. In this trial, V_2 that is, KS-510 was not included. Because in addition to its poorer performance in two sites, it was observed that this variety did not have synchrony in flowering and maturity. To have synchrony in all the experiments, the subscript with each symbol 'V' (meaning for variety) were kept same in this trial as were in the Expt. 1-3 of 2015-16.

4.4.1 Growth parameters

4.4.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that plant height was significantly influenced by seven examined white maize hybrid varieties. At 60 DAS, significantly the longest plants (149.17cm) were obtained with the variety V_8. The variety V_1 (113.08 cm) was the lowest performer (Figure 4.4.1). Likewise, V_7 (135.08 cm) showed medium plant height but there was no significant difference between V_6 (133.08 cm) and V_5 (130.33 cm).

At 90 DAS, V_1(174.83 cm) showed the height plant height but there was no significant difference between the variety of V_5 (169.67 cm), V_4 (158.92 cm), V_6 (162.42 cm), V_7 (154.17 cm), and V_8 (159.83 cm). The lowest was V_3 (147.50 cm) which was statically similar to V_5 (169.67 cm), V_4 (158.92 cm), V_6 (162.42 cm), V_7 (154.17 cm), and V_8 (159.83 cm) (Figure 4.4.1). During harvesting, significantly the longest plants (209.00 cm) were produced by the variety V_1 which however, was statistically similar to that of the variety V_8 (202.40 cm). Variety V_7 (161.73 cm) was the lowest performer but there was no significant difference between the variety of V_4 (166.20 cm). Likewise, V_6 (195.73 cm) produced medium tall plants.



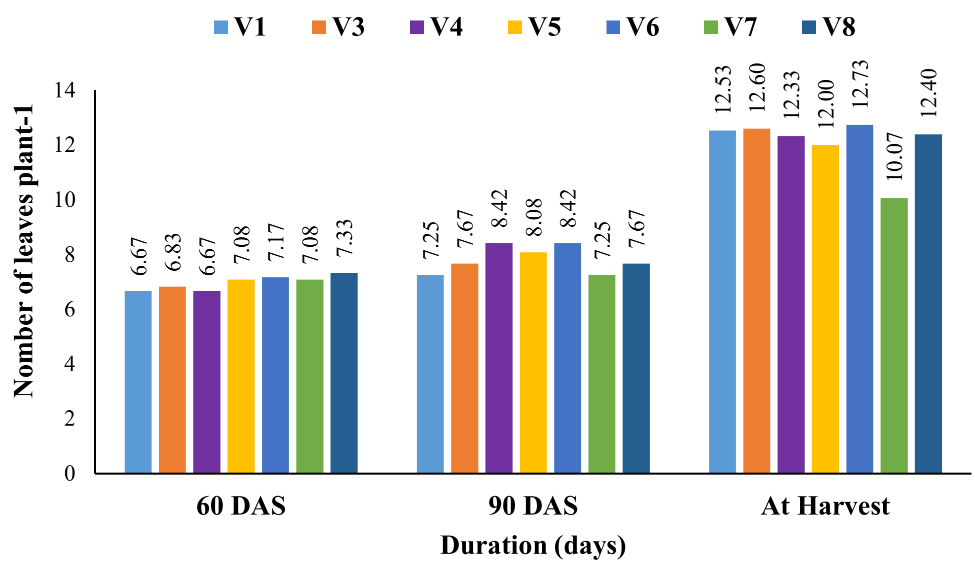
V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.4.1 Effect of white maize varieties on plant height in 60 DAS, 90 DAS and at harvest at SAU during Rabi, 2016-2017 ($LSD_{0.05}$ =6.362, 22.632, 11.439 on plant height in 60 DAS, 90 DAS and time at harvest respectively)

The above mentioned finding agreed well with that of Khan *et al*. (2017) who conducted an experiment to evaluate the different maize (*Zea mays* L.) genotypes under varying agro climatic conditions at Haripur of Pakistan. The experiment was sown on 17th May, 2015, at the Research Farm of the University of Haripur. Four different varieties of maize (PS-1, PS-2, PS-3 and Iqbal check) were tested in the experiment. Among the tested varieties, PS-1 produced the tallest plants (212.1 cm) which was followed by PS-2 (201.70 cm).

4.4.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties. Number of leaf is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that number of leaf was significantly influenced by seven examined white maize hybrid varieties. The verities had significant difference on number of leaf. At 60 DAS, no significant variations of leaf number observed among the tested varieties. The maximum number of leaf per plant (7.33) was produced by the variety V_8 (Figure 4.4.2). The variety V_1 and V_4 (6.67) showed significantly lower values in number of leaf. At 90 DAS there was no significant difference observed among the varieties. The highest number of leaf was produced by the variety V_4 and V_6 (8.42). The lowest number of leaf was produced by V_1 and V_7 (7.25) varieties. At Harvest, significantly the maximum number of leaves plant^{-1} (12.73) was produced by the variety V_6 which was statistically similar to V_1 (12.53), V_3 (12.60), V_4 (12.33), V_5 (12.00) and V_8 (12.40) and V_7 variety was the lowest performer (10.07).



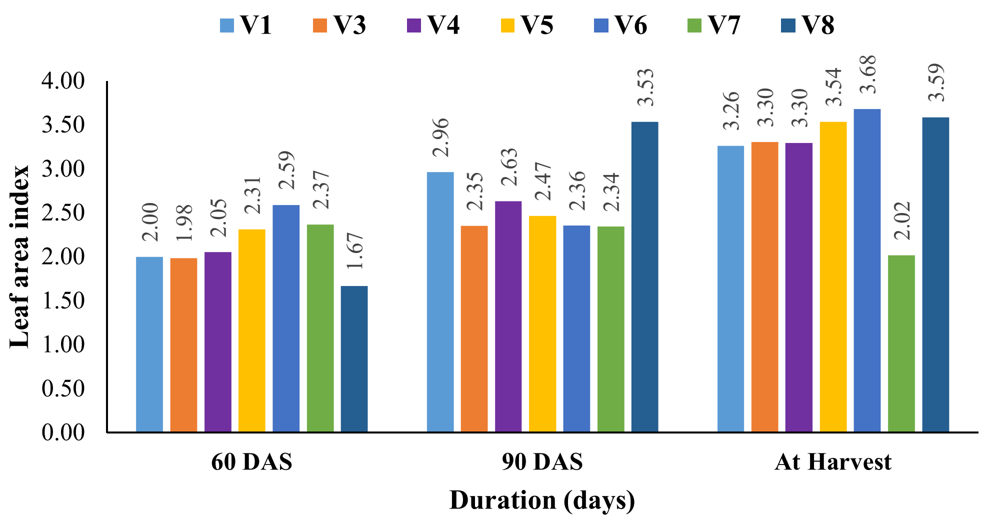
V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.4.2 Effect of white maize varieties on number of leaves plant^{-1} in 60 DAS, 90 DAS and at harvest at SAU during Rabi, 2016-2017 ($LSD_{0.05}$ =0.933,1.390 and 0.961 on number of leaves plant^{-1} in 60 DAS, 90 DAS and at harvest)

4.4.1.3 Leaf area index

Leaf area index is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that leaf area index was significantly influenced by seven examined white maize hybrid varieties. The varieties had significant difference on leaf area index. At 60 DAS, Leaf area index had significant effect among the seven varieties. The maximum leaf area index (2.59) was produced by the variety V_6 which had no significant difference among the variety of V_5 (2.31) and V_7 (2.37) (Figure 4.4.3). The variety V_8 (1.67) was the lowest performer. Likewise, V_7 (2.37) showed medium leaf area index.

At 90 DAS, it was observed that the varieties had significant difference on leaf area index. Highest Leaf area index showed V_8 (3.53) which had no significant difference among the varieties of V_1 (2.96). The lowest leaf area index was found in V_4 (2.62) (Figure 4.4.3). During harvesting, leaf area index had significant effect among the seven varieties. The V_6 (3.68) showed the highest leaf area index which had no significant difference among the varieties of V_1 (3.26), V_3 (3.30), V_4 (3.27), V_5 (3.54) and V_8 (3.59). Lowest leaf area index was V_7 (2.62).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.4.3 Effect of white maize varieties on leaf area index in 60, 90 DAS and at harvest at SAU during Rabi, 2016-2017 ($LSD_{0.05}$ =0.424,1.046 and 0.670 in 60, 90 DAS and at harvest respectively)

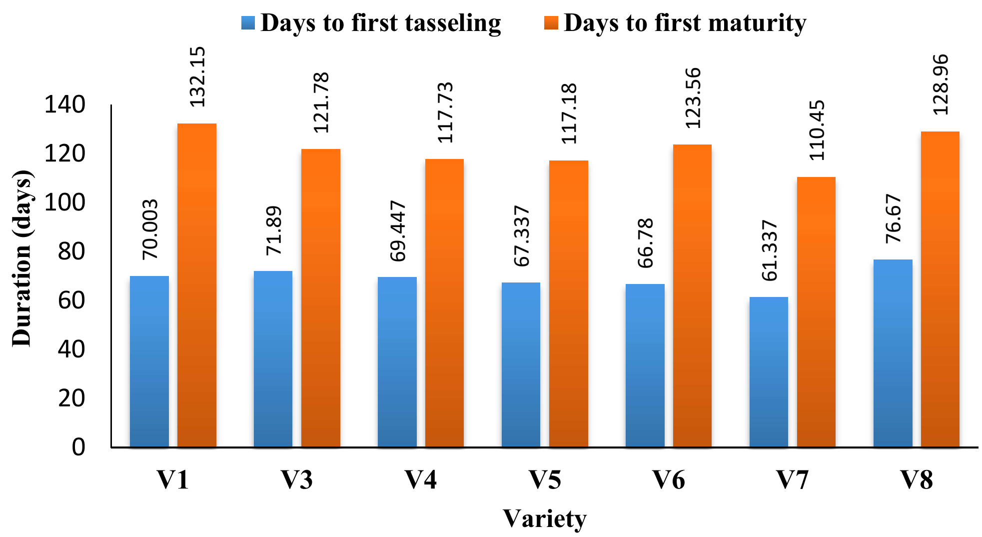
4.4.2 Phenological parameters

4.4.2.1 Days to first tasseling

Seven varieties were used to observe their effects on days to tasseling of white maize. It was found that a day to tasseling was significantly influenced by varieties. Among the treatments, V_8 variety took significantly maximum days to tasseling (76.00 days) followed by V_1 (70.00 days), V_3 (71.89 days), V_4 (69.45 days), V_5 (67.34 days), V_6 (66.78 days) and V_7 (61.34 days) while V_7 (61.34 days) took significantly minimum days to tasseling (Figure 4.4.4). Likewise, V_3 (71.890 days) had medium tasseling date which had no significant difference with the tasseling dates of V_1 (70.003 days) and V_4 (69.447 days).

4.4.2.2 Days to maturity

The varieties had significant difference on days to maturity. The highest days was found in V_1 (132.15 days) and the lowest was V_7(110.45 days). The V_1 (132.15) had the highest days to maturity but which had no significant difference among the maturity date of V_8 (128.96 days) (Figure 4.4.4). The V_1 (132.15) had the highest days to maturity followed by V_3 (121.78 days), V_4 (117.73 days), V_5 (117.18 days),V_6 (123.56 days) , V_7 (110.45 days) and V_8 (128.96 days).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30.

Figure 4.4.4 Effect of white maize varieties on days to first tasseling and days to maturity at SAU during Rabi, 2016-2017 ($LSD_{0.05}$ = 3.496,4.468 on days to first tasseling and days to first maturity).

4.4.3 Yield contributing characters and yield

4.4.3.1 Cob length (cm)

Seven varieties of edible maize were tested. Cob length ranged from 15.40 - 18.07 cm depending on varieties showing the highest by V_6 and the lowest by V_7. Although the V_6 had the highest cob length but there was no significant difference with the cob length of V_3 (17.73 cm) V_4 (17.57 cm), V_5 (16.67 cm) and V_8 (17.73 cm) (Table 4.4.1). The lowest cob length was found in V_7 which had no significant difference among the varieties of V_1 (16.30) and V_5 (16.67).

4.4.3.2 Cob breadth (cm)

Cob breadth was significantly affected by varieties. Among the varieties significant difference was found in the values of cob breadth. Maximum cob breadth (17.00 cm) was found in V_4 but there was no significant difference between the variety of V_1 (16.03 cm), V_5 (16.55 cm), V_6 (16.02 cm) and V_8 (16.41 cm) (Table 4.4.1). The minimum (12.35 cm) was significantly achieved with V_7. This result agreed well with other finding. Kabir *et al*. (2019) found that the cob diameter (cm) was statistically significant at 1% level of probability due to different variety which ranged from 11.58 to 12.21 cm. The highest cob diameter (12.21 cm) was observed with the variety V_3 (pacific-559) which was statistically similar to V_1 (BARI hybrid vutta-9) and the lowest cob diameter (11.58 cm) was observed in the V_2 (BARI hybrid vutta-13) treatment.

4.4.3.3 Number of rows cob^{-1}

Number of rows cob^{-1} was not significantly influenced by varieties. Among the varieties, the numerical maximum number of rows cob^{-1} was found in V_4 (13.40) and V_8 (12.73) was the lowest performer (Table 4.4.1).

Table 4.4.1 Effect of variety on Cob length, Cob breadth and Number of rows cob^{-1} and Number of grains row^{-1} of white maize varieties at SAU during Rabi, 2016-2017

Variety	Cob length (cm)	Cob breadth (cm)	Number of rows cob^{-1}	Number of grains row^{-1}
PSC-121 (V_1)	16.30 bc	16.03 a	13.07 a	32.53 a
Changnuo-1 (V_3)	17.73 ab	14.38 b	12.87 a	29.73 b
Q-Xiangnuo-1 (V_4)	17.57 ab	16.97 a	13.40 a	27.40 c
Changnuo-6 (V_5)	16.67 abc	16.55 a	12.93 a	30.87 a
Yangnuo-3000 (V_6)	18.07 a	16.02 a	13.33 a	32.00 a
Yangnuo-7 (V_7)	15.40 c	12.35 c	13.33 a	23.47 d
Yangnuo-30 (V_8)	17.73 ab	16.47 a	12.73 a	28.40 bc
LSD $_{(0.05)}$	1.724	1.420	NS	1.913
CV (%)	5.68	5.14	3.56	3.76

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

4.4.3.4 Number of grains row^{-1}

The varieties had significant difference on number of grains row^{-1}. The highest number of grains row was found in V_1 (32.53) and the lowest was V_7 (23.47) (Table 4.4.1). V_1 had the highest grain row^{-1} but there was no significant difference between V_5 (30.86) and V_6 (32.00). Significantly the second highest number of grains row^{-1} was V_3 (29.73) which was statistically similar to V_8 (28.40).

4.4.3.5 Number of grains cob^{-1}

Total number of grains cob^{-1} contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. The varieties had significant difference on number of grainscob^{-1}. The highest number of graincob^{-1} was found in V_1 (427.15) and the lowest was in V_7 (306.35) (Table 4.4.2). The V_1 had the highest graincob^{-1} but there was no significant difference observed with V_5 (419.35). The second highest number of grain cob^{-1} was found V_3 (387.73) which was statistically similar to V_4 (372.53).

4.4.3.6 100-grain weight (g)

The 100-grain weight is an important yield contributing factor, which plays an important role in showing the potential of a variety. The varieties influenced the weight of 100-grain of white maize. Significantly the highest 100-grain weight was observed with V_4 (42.67 g) which was not significantly different with the varieties of V_3 (40.33 g) and V_1 (40.00 g) (Table 4.4.2). Significantly the lowest 100 grain weigh was found with V_7 (34.33 g) but it was not significantly different when compared with the values obtained from the variety V_6 (35.67 g).

4.4.3.7 Grain yield plant^{-1}

The varieties had significant difference on grain yield. The highest grain yield plant^{-1} was found in V_1 (157.77 g) and the lowest was in V_7 (101.45 g) (Figure 4.4.5). Significantly the second highest grain yield plant^{-1} was V_5 (149.47 g) which was statistically similar to V_4 (149.20) and V_3 (148.29).

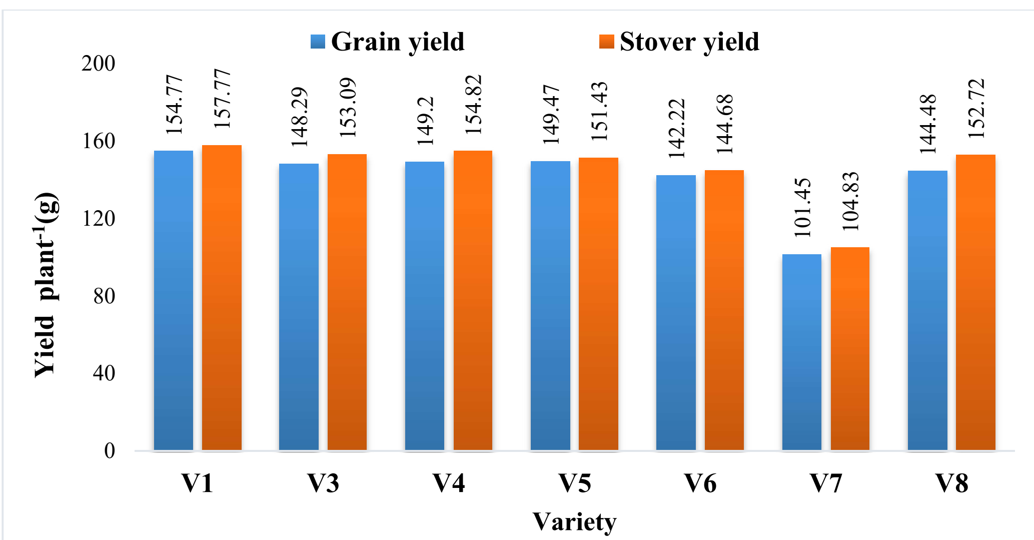
Table 4.4.2 Effect of white maize varieties on number of grain cob^{-1} and 100 seed weight at SAU during Rabi, 2016-2017

Variety	Number of grain cob^{-1}	100 seed weight(g)
PSC-121(V_1)	427.15 a	40.000 ab
Changnuo-1(V_3)	387.73 b	40.333 ab
Q-xingnuo-1(V_4)	372.53 bc	42.667 a
Changnuo-6(V_5)	419.35 a	38.333 bc
Youngnuo 3000(V_6)	346.85 d	35.667 cd
Yoyngnuo-7(V_7)	306.35 e	34.333 d
Youngnuo-30(V_8)	361.29 cd	38.333 bc
LSD $_{(0.05)}$	17.048	3.2557
CV (%)	8.55	3.99

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

4.4.3.8 Stover yield plant^{-1}

The varieties had significant difference on stover yield. The highest stover yield plant^{-1} was found in V_1 (157.77 g) and the lowest was V_7 (104.83 g) (Figure 4.4.5). Significantly the second highest stover yield plant^{-1} exhibited by V_8 (152,72 g).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q-Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30.

Figure 4.4.5 Effect of white maize varieties on grain yield plant^{-1} and stover yield plant^{-1} at SAU during Rabi, 2016-2017. ($LSD_{0.05}$ = 3.211, 2.0873 on grain yield plant^{-1}and stover yield plant^{-1} respectively)

4.4.3.9 Grain yield ha^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Seven varieties of white maize were tested. Yield ranged from 6.76-10.31 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7 (Table 4.4.3). The V_1 variety showed significantly maximum grain yield (10.31 t ha^{-1}) followed by V_3 (9.89 t ha^{-1}), V_4 (9.95 t ha^{-1}), V_5 (9.97 t ha^{-1}), V_6 (9.49 t ha^{-1}) and V_8 (9.63 t ha^{-1}) while V_7 (6.77 t ha^{-1}) took significantly minimum grain yield (Table 4.4.3). Statistically second highest grain yield was found in V_5 (9.97 t ha^{-1}) which was statistically similar to V_3 (9.886 t ha^{-1}) and V_4 (9.947 t ha^{-1}). Abera *et al*. (2017) tested different maize varieties and found variation among the maize varieties as BH-661 > BH-660 > BH-540 > BH-543 > BH-140 producing higher grain yield was reported due to having genetically variability among them.

4.4.3.10 Stover yield ha^{-1}

Stover yield showed difference among the varieties. That ranged of (6.98 -10.52 t ha^{-1}) depending on varieties showing the highest by V_1 and the lowest by V_7 (Table 4.4.3). Significantly V_1 showed the highest stover yield that followed by V_3 (10.21 t ha^{-1}), V_4 (10.32 t ha^{-1}), V_5 (10.10 t ha^{-1}), V_6 (9.65 t ha^{-1}), V_7 (6.99 t ha^{-1}) and V_8 (10.18 t ha^{-1}). Statistically the V_7 (6.99 t ha^{-1}) showed the lowest stover yield.

Table 4.4.3 Effect of white maize varieties on yield and yield attributes at SAU during Rabi, 2016-2017

Varieties	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
PSC-121 (V1)	10.31 a	10.51 a	20.82 a	49.49 a
Changnuo-1 (V3)	9.89 b	10.21 bc	20.09 bc	49.20 ab
Q-xingnuo1 (V4)	9.95 b	10.32 b	20.27 b	49.08 ab
Changnuo-6 (V5)	9.97 b	10.10 c	20.06 c	49.67 a
Youngnuo3000(V6)	9.48 c	9.65 d	19.13 e	49.57 a
Yoyngnuo-7 (V7)	6.76 d	6.99 e	13.75 f	49.18 ab
Youngnuo-30 (V8)	9.63 c	10.18 c	19.81 d	48.61 b
LSD $_{(0.05)}$	0.214	0.139	0.208	0.755
CV (%)	1.28	2.82	1.04	1.4

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

4.4.3.11 Biological yield ha^{-1}

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. Seven varieties of edible maize were tested. Biological yield ranged from 13.752-20.823 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7 (Table 4.4.3). Significantly V_1 (20.82 t ha^{-1}) showed the highest biological yield. The second height biological yield was 20.27 t ha^{-1} which was statistically similar with the variety V_3 (20.09 t ha^{-1}). Although the V_7 had the significantly lowest biological yield.

4.4.3.12 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Plant varieties had a significant effect on harvest index. Significantly V_5 showed the highest harvest index (49.67%) and V_8 variety was the lowest (48.61 %) (Table 4.4.3). Although V_5 showed significantly lowest harvest index but there was no significant difference among the variety of V_1 (49.49 %), V_3 (49.20 %), V_4 (49.08 %), V_6 (49.57 %) and V_7 (49.18 %). Significantly the lowest harvest index was in V_8 (48.61 %) which was statistically similar to V_7 (49.18 %).

4.5 Experiment 5: Yield and yield attributes of different white maize varieties at Dhamrai during Rabi, 2016-2017

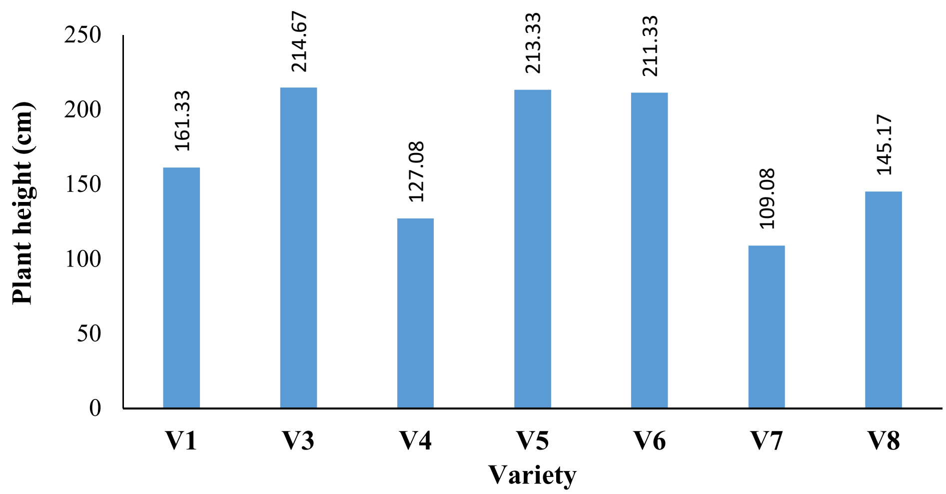
The objectives of this trial was to evaluate the performance of seven hybrid white maize varieties under different locations in Bangladesh to find out the effect of varieties on the growth and yield performance of white maize. Data on different growth parameters, yield, and yield contributing characters were recorded. In this trial the variety V_2 was not (KS-510) was not included, due to its poorer performance in two sites and this variety did not have synchrony in flowering and maturity. To have synchrony in all the experiments, the subscript with each symbol 'V' (meaning for variety) were kept same in this trial as were in the Expt. 1-3 of 2015-16.

4.5.1 Growth parameters

4.5.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that plant height was significantly influenced by seven examined white maize hybrid varieties. During harvesting, significantly the highest plant height (214.67 cm) was observed in the variety V_3 which had no difference with the variety V_5 (213.33) and V_6 (211.33) (Figure 4.5.1). On the other hand, the variety V_7 (109.08 cm) was the lowest performer but there was no significant difference with the variety of V_4 (127.08 cm). Likewise, V_1 (161.33 cm) showed medium plant height which was statistically similar to that of V_8 (145.17).

The finding of this study agreed well with that of the previous works. Khan *et al*. (2017) while performing a varietal trial on maize reported that the plant height was lower in both Iqbal (check) (196.3 cm) and PS-3 (197.3 cm) varieties. All maize varieties used in that study had diverse genetic background showing, varying plant heights ranging from 196.00 to 212.00 cm. The plant height of PS-1 was higher which was attributed to the vigorous growth in this variety in addition to the genetic makeup of the hybrid (Noor *et al*. 2010). Similar results were also reported earlier by Beyene *et al.* (2011) and showed variation of plant height in different maize varieties.



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30

Figure 4.5.1 Plant height of white maize at Dhamrai as influenced by different varieties during Rabi, 2016-2017 (LSD $_{0.05}$ = 27.444)

4.5.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties. Number of leaf is an important component which helps in the determination of growth attained during the growing period. It revealed from the results that number of leaf was significantly influenced by seven examined white maize hybrid varieties. During harvesting, significantly the highest number of leaves plant^{-1} (15.08) was produced by the variety V_1 which was statistically similar to that of V_8 (14.00) (Table 4.5.1). The V_7 variety was the lowest performer (10.333).

4.5.1.3 Leaf area index

Leaf area index is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that leaf area index was significantly influenced by seven examined white maize hybrid varieties. The V_1 (2.99) showed highest leaf area index which had no significant difference among the varieties of V_3 (2.50) and V_4 (2.66) (Table 4.5.1). The lowest leaf area index found in V_6 (1.73) which was similar to the varieties of V_5 (2.33), V_7 (2.08) and V_8 (1.92).

Table 4.5.1 Effect of white maize varieties on number of leaves plant^{-1} and leaf area index at Dhamrai during Rabi, 2016-2017

Variety	Number of leaves plant^{-1}	Leaf area index
PSC-121(V_1)	15.08 a	2.98 a
Changnuo-1(V_3)	13.00 b	2.50 abc
Q-xingnuo-1(V_4)	13.25 b	2.66 ab
Changnuo-6(V_5)	13.00 b	2.33 bcd
Yangnuo- 3000(V_6)	13.33 b	1.73 d
Yangnuo-7(V_7)	10.33 c	2.08 bcd
Yangnuo-30(V_8)	14.00 ab	1.91 cd
LSD $_{(0.05)}$	1.461	0.654
CV (%)	6.25	15.89

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

4.5.2 Phenological parameters

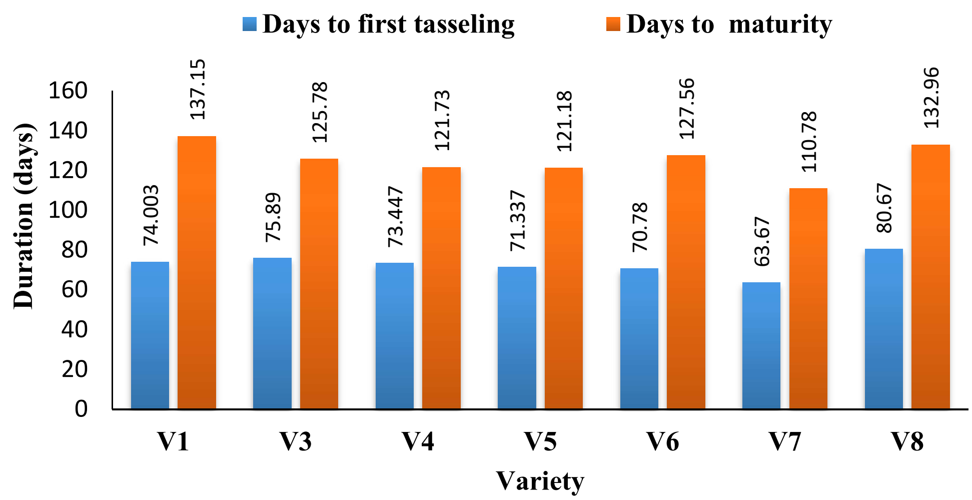
4.5.2.1 Days to first tasseling

Seven varieties were used to observe their effects on days to tasseling of white maize. It was found that days to tasseling was significantly influenced by varieties. Among the treatments, V_8 variety took significantly maximum days to tasseling (80.00 days) followed by V_1 (74.00 days), V_3 (75.89 days), V_4 (73.45 days), V_5 (71.34 days), V_6 (70.78 days) and V_7 (63.67 days) while V_7 (63.67 days) took significantly minimum days to tasseling (Figure 4.5.2). Likewise, V_3 (73.89 days) showed intermediate tasseling date which had no significant difference with V_1 (74.00 days) and V_4 (73.45 days).

4.5.2.2 Days to maturity

The varieties had significant difference on days to maturity. The highest maturity duration was found in V_1 (137.15 days) and the lowest was in V_7 (110.78 days). The V_1 (137.15) had the highest days to maturity which was not significantly differed with the maturity date of V_8 (132.96 days). The V_1 (137.15) showed the highest days to maturity followed by V_3 (125.78 days), V_4 (121.73 days), V_5 (121.18 days), V_6

(127.56 days), V_7 (110.78 days) and V_8 (132.96 days) (Figure 4.5.2). The V_7 (110.78 days) showed significantly the lowest days to maturity among the varieties.



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30

Figure 4.5.2 Days to first tasseling and days to first maturity of white maize at Dhamrai as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ = 3.201, 4.424 in Days to first tasseling and days to first maturity respectively)

4.5.3 Yield contributing characters and yield

4.5.3.1 Cob length (cm)

Seven varieties of edible maize were tested. Cob length ranged from 12.90 -18.93 cm depending on varieties showing the highest by V_3 and the lowest by V_1. Although the V_3 had the highest cob length but there was no significant difference with the cob length of V_4 (17.33 cm), V_6 (17.13 cm) and V_8 (17.50 cm) (Table 4.5.2). Significantly the lowest cob length was found in V_7 (12.90 cm).

4.5.3.2 Cob breadth (cm)

Cob breadth was significantly affected by varieties. The highest cob breadth (17.07 cm) was found in V_8 but it was not significantly differed with the variety of V_1 (16.43 cm), V_3 (15.80 cm) and V_6 (16.13 cm) (Table 4.5.2). Significantly the minimum (14.93 cm) cob breadth was found in V_7.

4.5.3.3 Number of rows cob^{-1}

The varieties had significant difference on number of rows cob^{-1}. The highest number of rows cob^{-1} was found in V_3 (13.40) and the lowest was V_7 (10.00). The V_3 had the highest rows cob^{-1} but (13.40) there was no significant difference between number of rows cob^{-1} of V_1 (11.67), V_4 (10.67), V_5 (13.07), V_6 (13.07), V_7 (10.00) and V_8 (11.40) (Table 4.5.2). Significantly the lowest rows cob^{-1} was found in V_7 (10.00) which was statistically similar to that of V_1 (11.67), V_4 (10.67) and V_8 (11.40).

4.5.3.4 Number of grains row^{-1}

The varieties had significant difference on number of grains row^{-1}. The highest number of grains row^{-1} was found in V_3 (35.17) and the lowest was V_7 (17.07) (Table 4.5.2). The V_3 had the highest grains row^{-1} that was not significantly differed with V_6 (32.53). Significantly the second highest number of grains row^{-1} was in V_6 (32.53) which were statistically similar to that of V_1 (29.73).

Table 4.5.2 Effect of variety on Cob length, Cob breadth and Number of rows cob^{-1} and Number of grains row^{-1} of white maize varieties at Dhamrai during Rabi, 2016-2017

Variety	Cob length (cm)	Cob breadth (cm)	Number of rows cob^{-1}	Number of grains row^{-1}
PSC-121 (V_1)	15.97 b	16.43 ab	11.67 ab	29.73 bc
Changnuo-1 (V_3)	18.93 a	15.80 abc	13.40 a	35.17 a
Q-Xiangnuo-1 (V_4)	17.33 ab	14.93 c	10.67 b	26.00 c
Changnuo-6 (V_5)	16.00 b	15.57 bc	13.07 a	27.33 c
Yangnuo-3000 (V_6)	17.13 ab	16.13 abc	13.07 a	32.53 ab
Yangnuo-7 (V_7)	12.90 c	15.00 bc	10.00 b	17.07 d
Yangnuo-30 (V_8)	17.50 ab	17.07 a	11.40 ab	26.00 c
LSD $_{(0.05)}$	2.084	1.441	2.096	4.861
CV (%)	7.08	5.11	9.83	9.87

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

4.5.3.5 Number of grains cob^{-1}

Total number of grains cob^{-1} contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. The varieties had significant difference on number of grains cob^{-1}. The highest number of grains cob^{-1} was found in V_3 (470.01) and the lowest was V_7 (204.21) (Table 4.5.3). The V_3 had the highest grains cob^{-1} but there was no significant difference among the number of grains cob^{-1} of V_1 (407.67) and V_6 (426.19).

Table 4.5.3 Effect of white maize varieties on number of grains cob^{-1} and 100 grain weight of white maize at Dhamrai as influenced by different varieties during Rabi, 2016-2017

Varieties	Number of grains cob^{-1}	100 grain weight (g)
PSC-121(V_1)	407.67 ab	30.00 ab
Changnuo-1(V_3)	470.01 a	31.33 a
Q-xingnuo-1(V_4)	289.51 c	27.85 ab
Changnuo-6(V_5)	359.95 bc	30.33 ab
Yangnuo - 3000(V_6)	426.19 ab	31.67 a
Yangnuo-7(V_7)	204.21 d	26.67 b
Yangnuo-30(V_8)	343.44 bc	28.78 ab
LSD (0.05)	84.705	4.249
CV (%)	13.33	8.09

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

4.5.3.6 100-grains weight (g)

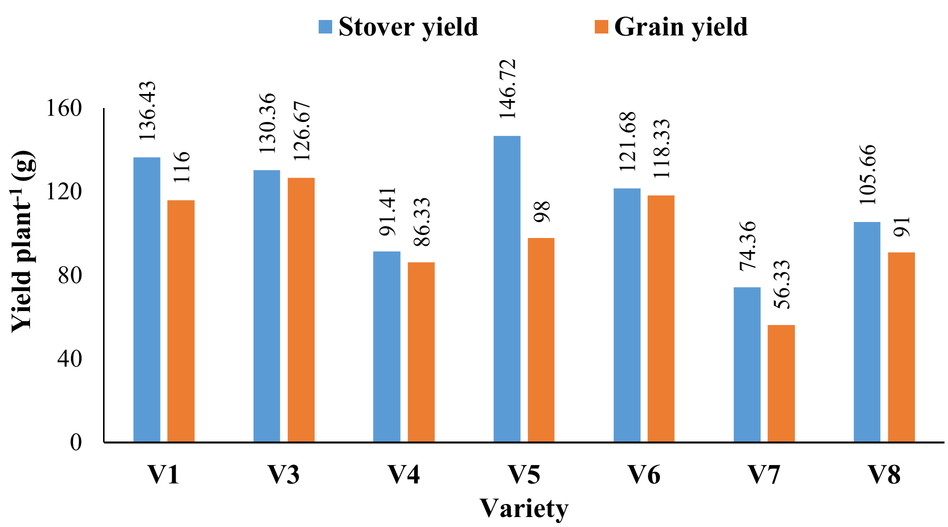
100-grain weight is an important yield contributing factor, which plays an important role to showing the potential of a variety. The varieties influenced the weight of 100-grain of white maize. The highest 100-grain weight was found in V_6 (31.67g) which was no significantly differed with the varieties of V_1 (30.00 g), V_3 (31.33 g), V_4 (27.85 g), V_5 (30.33 g) and V_8 (28.78 g) (Table 4.5.3). Significantly the lowest 100 grain weight was found to that of V_7 (26.67 g) but there was no significant difference between the variety of V_1 (30.00 g), V_4 (27.85 g), V_5 (30.33 g) and V_8 (28.78 g).

4.5.3.7 Stover yield plant^{-1}

The varieties had significant difference on Stover yield plant^{-1}. Significantly he highest number of Stover yield plant^{-1} was in found in V_5 (146.72g) and the lowest was V_7 (74.36 g) (Figure 4.5.3). Significantly the second highest stover yield plant^{-1} was experienced withV_1 (136.43 g).

4.5.3.8 Grain yield plant^{-1}

The varieties had significant difference on grain yield plant^{-1}. Significantly the highest grain yield plant^{-1} was found in V_3 (126.67 g) and the lowest was in V_7 (59.33 g) (Figure 4.5.3). The second highest grain yield plant^{-1} was found in V_6 (118.33 g) which was statistically similar to that of V_1 (116.00 g).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30

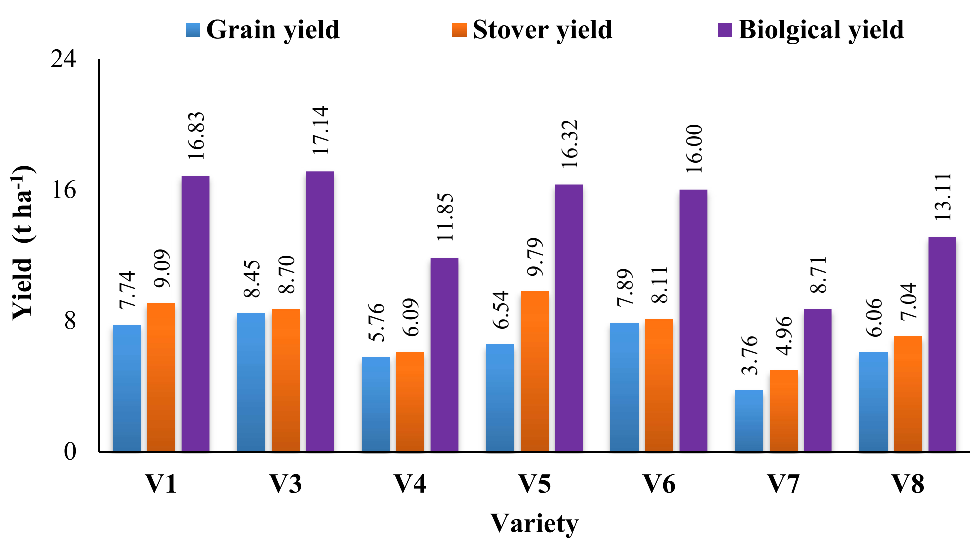
Figure 4.5.3 Grain yield plant^{-1} and Stover yield plant^{-1}of white maize at Dhamrai as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ =6.617, 5.142 in Grain yield plant^{-1} and Stover yield plant^{-1} respectively)

4.5.3.9 Grain yield ha^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Seven varieties of white maize were tested. Yield ranged from 3.76-8.44 t ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7 (Figure 4.5.4). V_3 variety took significantly maximum grain yield (8.44 t ha^{-1}) followed by V_1 (7.74 t ha^{-1}), V_4 (5.76 t ha^{-1}), V_5 (6.54 t ha^{-1}), V_6 (7.89 t ha^{-1}) and V_8 (6.06 t ha^{-1}) while V_7 (3.76 t ha^{-1}) took significantly minimum grain yield. Bhuiyan *et al*. (2015) in one study examined the yield performance of some maize varieties and obtained the maximum yields from V1I3 (7.92 t ha-1) which was statistically identical to V4I3 (7.83 t ha^{-1}), V2I3 (7.45 t ha^{-1}), V1I2 (7.40 t ha^{-1}), V2I2 (6.87 t ha^{-1}) and V4I2 (6.80 t ha^{-1}) respectively.

4.5.3.10 Stover yield ha^{-1}

Stover yield showed difference among the varieties. Stover yield ranged of 4.96 t ha^{-1} to 9.78 t ha^{-1} and the highest by V_5 and the lowest by V_7 (Figure 4.5.4). The V_5 showed significantly highest stover yield among the variety of V_1 (9.09 t ha^{-1}), V_3 (8.70 t ha^{-1}), V_4 (6.09 t ha^{-1}), V_6 (8.11 t ha^{-1}), V_7 (4.96 t ha^{-1}) and V_8 (7.04 t ha^{-1}). Statistically V_7 (4.96 t ha^{-1}) showed the lowest stover yield.



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30

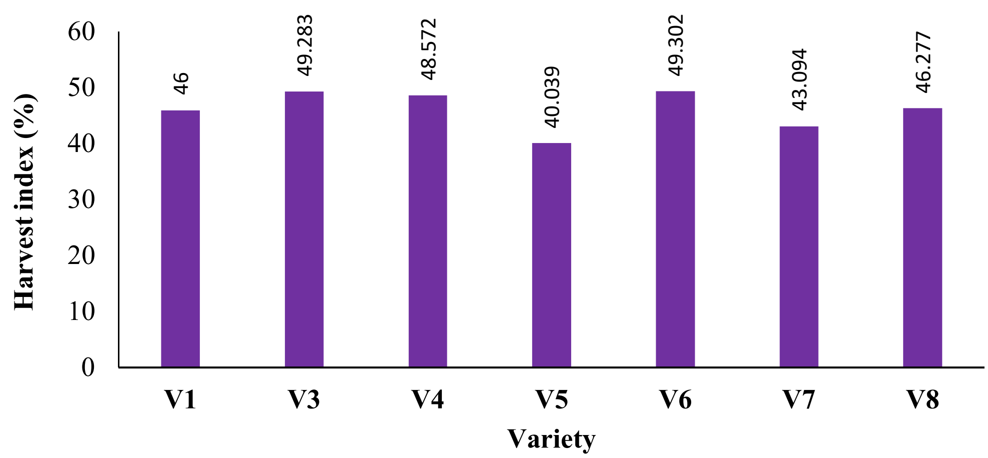
Figure 4.5.4 Stover yield ha^{-1}, grain yield ha^{-1} and biological yield ha^{-1} of white maize at Dhamrai as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ =0.4411, 0.3428 and 0.6502 in Stover yield ha^{-1}, grain yield ha^{-1}, biological yield ha^{-1} respectively)

4.5.3.11 Biological yield ha^{-1}

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. Seven varieties of edible maize were tested where biological yield ranged from (8.713 -17.135) tons ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7 (Figure 4.5.4). Significantly V_3 (20.83 t ha^{-1}) showed the highest biological yield but there was no significant difference with that of V_1 (16.83 t ha^{-1}). The second height Biological yield was found in V_1 (16.83 t ha^{-1}) which was statistically similar with the variety of V_5 (16.32 t ha^{-1}. Although the V_7 (8.71 t ha^{-1}) showed the significantly lowest biological yield.

4.5.3.12 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Plant varieties had a significant effect on harvest index. Harvest index was varied significantly due to varieties, Biological yield ranged from (40.039 - 49.283) tons ha^{-1} depending on varieties showing the highest by V_6 and the lowest by V_5(Figure 4.5.5).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8 = Yangnuo-30

Figure 4.5.5 Harvest index (%) of white maize at Dhamrai as influenced by different varieties during Rabi, 2016-2017 (LSD $_{0.05}$ =1.506)

Although V_6 showed significantly the lowest harvest index but there was no significant difference with those of the varieties of V_3 (49.28 %), and V_4 (48.57 %). Significantly the second highest harvest index was in V_8 (46.28 %) which was statistically similar to that of V_1 (45.95 %) and lowest harvest index was found in V_5 (40.04 %).

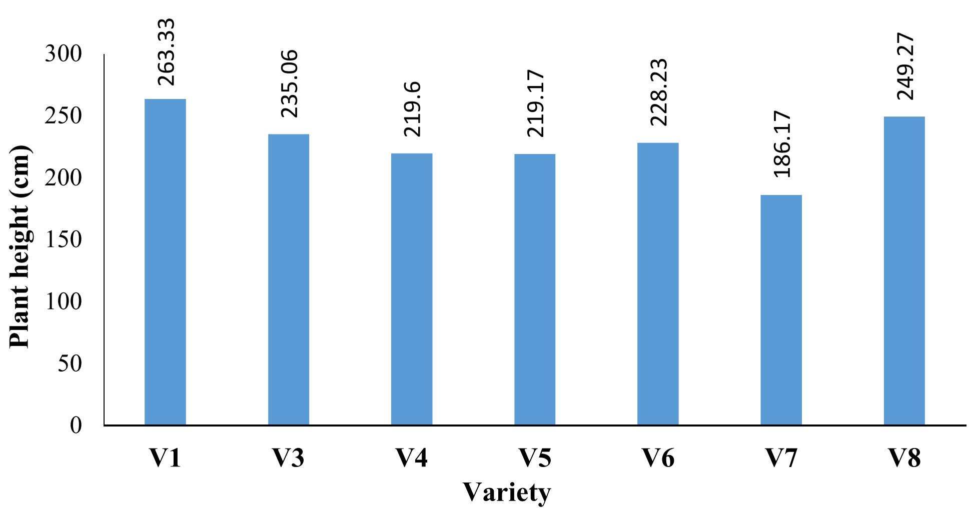
4.6 Experiment 6: Yield and yield attributes of different white maize varieties at Rangpur during Rabi, 2016-2017

The objectives of this trial was to evaluate the performance of seven hybrid white maize varieties under different locations of Bangladesh to find out the effect of varieties on the growth and yield performance of white maize. Data on different growth parameters, yield, and yield contributing characters were recorded. The V_2 (KS-510) was not included in this trial due to its poorer performance in two sites and non-synchrony of flowering and maturity. To have synchrony in all the experiments, the subscript with each symbol 'V' (meaning for variety) were kept same in this trial as were in the Expt. 1-3 of 2015-16.

4.6.1 Growth parameters

4.6.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that plant height was significantly influenced by seven examined white maize hybrid varieties. During the time of harvesting, significantly the highest plant height (263.33 cm) was recorded in V_1.



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.6.1 Plant height of white maize at Rangpur Sadar as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ = 1.874)

On the other hand, variety V_7 (186.17cm) showed the lowest performance (Figure 4.6.1). The V_1 (263.33 cm) was the highest performer among the variety of V_3(235.06 cm), V_4 (219.60 cm), V_5 (219.17 cm), V_6 (228.23 cm), V_7 (186.17 cm) and V_8 (249.27 cm). Likewise, V_8 (249.27 cm) showed medium plant height.

4.6.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties. Number of leaf is an important component which helps in the determination of growth attained during the growing period. It was revealed from the stady that number of leaves was significantly influenced by seven examined white maize hybrid varieties. The verities had significant difference on number of leaf. During harvest, significantly the highest number of leaves plant^{-1} (12.73) was produced by the variety V_6 which was statistically similar to those of V_1 (12.53), V_3 (12.60), V_4 (12.33), V_5 (12.00), V_7 (10.07) and V_8 (12.40) (Table 4.6.1). Significantly V_7 variety was the lowest performer (10.07).

Table 4.6.1 Effect of white maize varieties on number of leaves plant^{-1} and leaf area index at Rangpur Sadar during Rabi, 2016-2017

Variety	Number of leaves plant^{-1}	Leaf area index
PSC-121 (V_1)	12.53 a	2.54 b
Changnuo-1 (V_3)	12.60 a	1.99 c
Q-xingnuo-1 (V_4)	12.33 a	1.89 c
Changnuo-6 (V_5)	12.00 a	1.78 c
Yangnuo- 3000 (V_6)	12.73 a	1.67 c
Yangnuo-7 (V_7)	10.07 b	2.02 c
Yangnuo-30 (V_8)	12.40 a	3.07 a
LSD $_{(0.05)}$	0.962	0.369
CV (%)	4.47	9.71

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

4.6.1.3 Leaf area index

Leaf area index is an important component which helps in the determination of growth attained during the growing period. It was revealed from the results that leaf area index was significantly influenced by seven examined white maize hybrid varieties. During harvest, V_8 (3.07) showed significantly the highest leaf area index and the lowest leaf area index was in V_6 (1.68) (Table 4.6.1). Significantly lowest Leaf area index was V_6 (1.68) which had no significant difference among the varieties of V_3 (1.99), V_4 (1.99), V_5 (1.79) and V_6 (1.68).

4.6.2 Phenological parameters

4.6.2.1 Days to first tasseling

Seven varieties were used to observe their effects on days to tasseling of white maize. It was found that days to tasseling was significantly influenced by varieties. Among the treatments, V_8 variety took significantly maximum days to tasseling (82.67 days) followed by V_1 (76.00 days), V_3 (77.89 days), V_4 (75.45 days), V_5 (73.33 days),V_6 (72.68 days) and V_7 (65.67 days) (Figure 4.6.2). Significantly V_8 showed maximum days to tasseling but there was no significant difference among the variety of V_1 (76.00 days), V_3 (77.89 days) and V_4 (75.44 days). While V_7 (65.67 days) showed significantly lowest days to tasseling. Likewise, V_3 (77.89 days) showed intermediate tasseling date which had no significant difference among the tasseling date of V_1 (76.00 days).

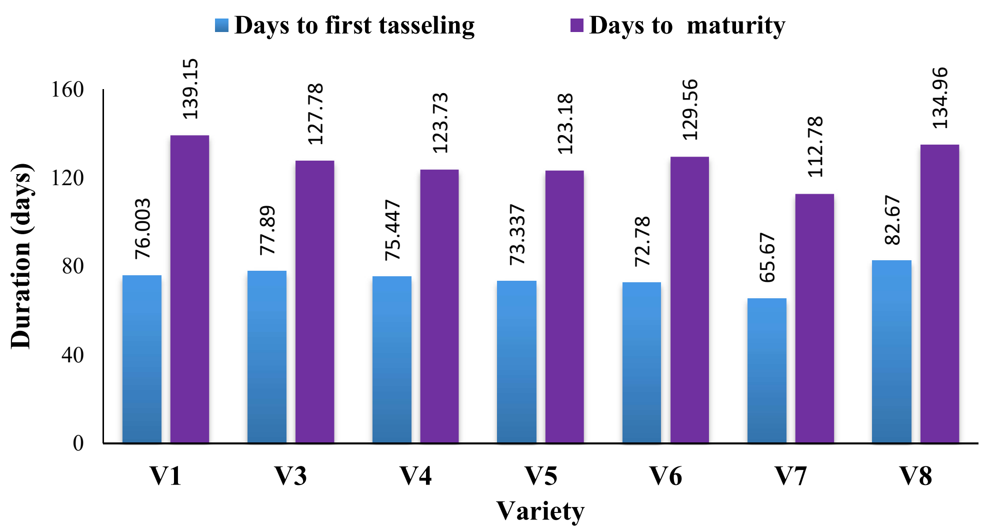
4.6.2.2 Days to maturity

The varieties had significant difference on days to maturity. The longest days to maturity were found in V_1 (139.15 days) and the shortest was in V_7 (112.78 days). The V_1 (139.15) had the longest days to maturity but which had no significant difference among the maturity date of V_8 (134.96 days) (Figure 4.6.2). The V_1 (139.15) showed the longest days to maturity followed by V_3 (127.78 days), V_4 (123.73 days), V_5 (123.18 days), V_6 (129.56 days), V_7 (112.78 days) and V_8 (134.96 days). Significantly V_7 (112.78 days) showed the shortest days to maturity among the varieties.

4.6.3 Yield contributing characters and yield

4.6.3.1 Cob length (cm)

Seven varieties of white maize were tested. Cob length ranged from 14.00 -20.30 cm depending on varieties showing the highest by V_3 (20.30 cm) and the lowest by V_7 (14.00). Although the V_3 had the highest cob length but there was no significant difference with the cob length of V_5 (19.10 cm) (Table 4.6.2). Significantly the second highest cob length was in V_5 (19.10 cm) which was statistically similar to that of V_6 (18.53 cm) and V_8 (18.50 cm) and the lowest cob length was V_7 (12.90).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30.

Figure 4.6.2 Days to first tasseling and days to maturity of white maize at Rangpur Sadar as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ = 3.401, 4.6238 in days to first tasseling and days to first maturity)

Table 4.6.2 Effect of variety on Cob length, Cob breadth and Number of rows cob^{-1} and Number of grains row^{-1} of white maize varieties at Rangpur during Rabi, 2016-2017

Variety	Cob length (cm)	Cob breadth (cm)	Number of rows cob^{-1}	Number of grains row^{-1}
PSC-121 (V_1)	16.38 c	16.43 ab	13.17 a	26.83 cd
Changnuo-1 (V_3)	20.30 a	15.80 abc	12.87 ab	35.13 a
Q-Xiangnuo-1 (V_4)	15.67 c	14.93 c	11.67 c	30.33 bc
Changnuo-6 (V_5)	19.10 ab	15.57 bc	12.67 ab	34.47 ab
Yangnuo-3000 (V_6)	18.53 b	16.13 abc	13.20 a	29.27 c
Yangnuo-7 (V_7)	14.00 d	15.00 bc	12.00 bc	22.67 d
Yangnuo-30 (V_8)	18.50 b	17.07 a	13.53 a	30.47 bc
LSD $_{(0.05)}$	1.643	1.441	0.903	4.405
CV(%)	5.28	5.11	3.99	8.29

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

4.6.3.2 Cob breadth (cm)

Cob breadth was significantly affected by varieties. The highest cob breadth (17.07 cm) was found in V_8 but there was no significant difference between the variety of V_1 (16.43 cm), V_3 (15.80 cm) and V_6 (16.13 cm) (Table 4.6.2). Significantly the minimum cob breadth (14.93 cm) was achieved with V_7.

4.6.3.3 Number of rows cob^{-1}

The varieties had significant difference on number of rowscob^{-1}. The highest number of rows cob^{-1} was found in V_8 (13.33) and the lowest was V_4 (11.67). Significantly V_8 (13.33) had the highest rows cob^{-1} but there was no significant difference observed in number of rows cob^{-1} of V_1 (13.17), V_3 (12.87), V_5 (12.67) and V_6 (13.20) (Table 4.6.2). Significantly the lowest rows cob^{-1} was V_4 (11.67) which was statistically similar to that of V_7 (12.00).

4.6.3.4 Number of grains row^{-1}

The varieties had significant difference on number of grains row^{-1}. The highest number of grains row^{-1} was found in V_3 (35.13) and the lowest was V_7 (22.67) (Table 4.6.2). The V_3 had the highest grains row^{-1} but there was no significant difference 0f number of grains row^{-1} of V_5 (34.47). Significantly the second highest number of grains row^{-1} was V_5 (34.47) which was statistically similar to that of V_4 (30.33) and V_8 (30.47).

4.6.3.5 Number of grains cob^{-1}

Total number of grains cob^{-1} contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. The varieties showed significant difference on number of grains cob^{-1}. The highest number of grains cob^{-1} was found in V_3 (452.72) and the lowest was V_7 (338.00) (Table 4.6.3). V_3 (452.72) showed the highest grains cob^{-1} but there was no significant difference observed with V_5 (436.61).

4.6.3.6 100-grains weight (g)

The 100-grain weight is an important yield contributing character, which plays an important role to showing the potentially of a variety. The varieties influenced the weight of 100-grain in white maize. The highest 100-grain weight was exhibited with V_8 (39.67 g) which had no significant difference with V_1 (39.00 g) and V_3 (38.33g)

(Table 4.6.3). Significantly the lowest 100 grain weigh was found in V_7 (28.66 g) but there was no significant difference than that of the variety V_4 (30.10 g).

Table 4.6.3 Performance of different white maize varieties for number of grains row^{-1} and 100 grain weight of white maize varieties at Rangpur during Rabi, 2016-2017

Varieties	Number of grains cob^{-1}	100 grain weight (g)
PSC-121 (V_1)	353.72 e	39.00 ab
Changnuo-1 (V_3)	452.72 a	38.33 ab
Q-xingnuo-1 (V_4)	359.00 de	30.10 c
Changnuo-6 (V_5)	436.61 ab	36.00 b
Yangnuo- 3000 (V_6)	386.56 cd	38.00 ab
Yangnuo-7 (V_7)	338.00 e	28.66 c
Yangnuo-30 (V_8)	416.60 bc	39.67 a
LSD $_{(0.05)}$	31.619	3.194
CV (%)	4.54	5.03

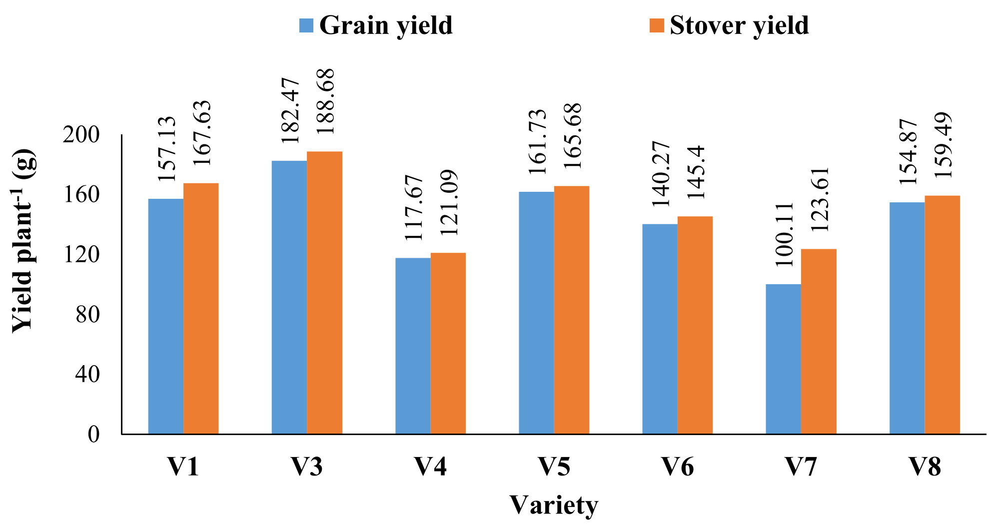
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

4.6.3.7 Grain yield plant^{-1}

The varieties showed significant difference on grain yield plant^{-1}. Significantly the highest grain yield plant^{-1} was found in V_3 (182.47 g) and the lowest was in V_7 (100.11 g) (Figure 4.6.3). The second highest grain yield plant^{-1} was found in V_6 (118.33 g) which was statistically similar to that of V_1 (157.13 g) and V_8 (154.87 g).

4.6.3.8 Stover yield Plant^{-1}

The varieties showed significant difference on stover weight plant^{-1}. Significantly the highest stover yield plant^{-1} was found in V_3 (188.68 g) and the lowest was in V_7 (123.61 g) (Figure 4.6.3). Significantly the second highest stover weight plant^{-1}was observed in V_1 (167.63 g) which was statistically similar to that of V_5 (165.63 g).



V_1 = PSC-121, V_3 =Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30

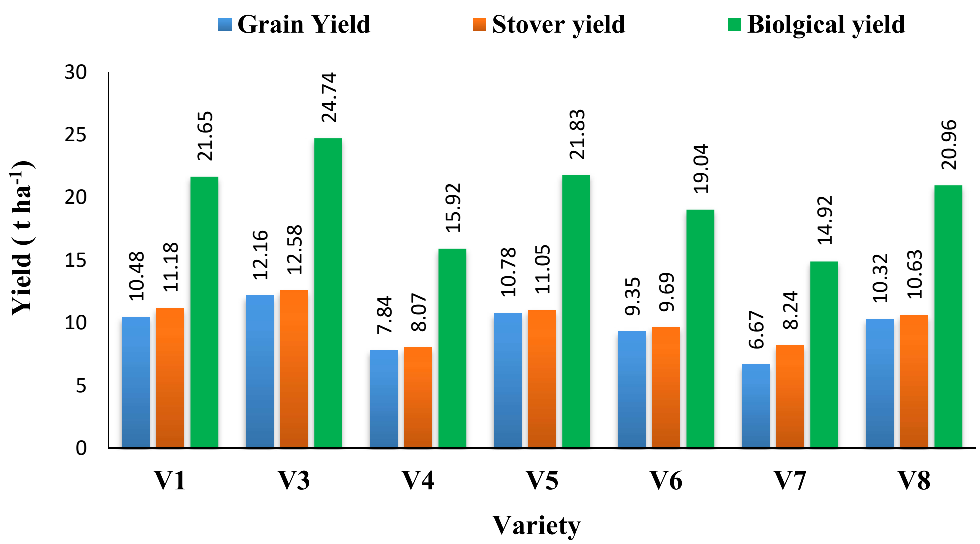
Figure 4.6.3 Stover yield plant^{-1} and grain yield of white maize at Rangpur Sadar as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ = 7.100 and 7.262 to stover yield plant^{-1} and grain yield respectively)

4.6.3.9 Grain yield ha^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. Seven varieties of white maize were tested. Yield ranged from 6.67-12.16 t ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7 (Figure 4.6.4). The V_3 variety showed significantly highest grain yield (12.16 t ha^{-1}) followed by V_1 (10.48 t ha^{-1}), V_4 (7.84 t ha^{-1}), V_5 (10.78 t ha^{-1}), V_6 (9.35 t ha^{-1}) and V_8 (10.32 t ha^{-1}) while V_7 (6.67 t ha^{-1}) showed significantly minimum grain yield.

4.6.3.10 Stover yield ha^{-1}

Stover yield showed difference among the varieties that ranged from (8.24 t ha^{-1}-12.58 t ha^{-1}) depending on varieties showing the highest by V_3 and the lowest by V_7 (Figure 4.6.4). The V_3 showed Significantly highest stover yield among the varieties that followed by V_1 (11.18 t ha^{-1}), V_4 (8.07 t ha^{-1}), V_5 (9.69 t ha^{-1}), V_6 (9.70 t ha^{-1}), V_7 (8.24 t ha^{-1}) and V_8 (10.63 t ha^{-1}). Statistically V_7 (8.24 t ha^{-1}) showed the lowest stover yield.



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30

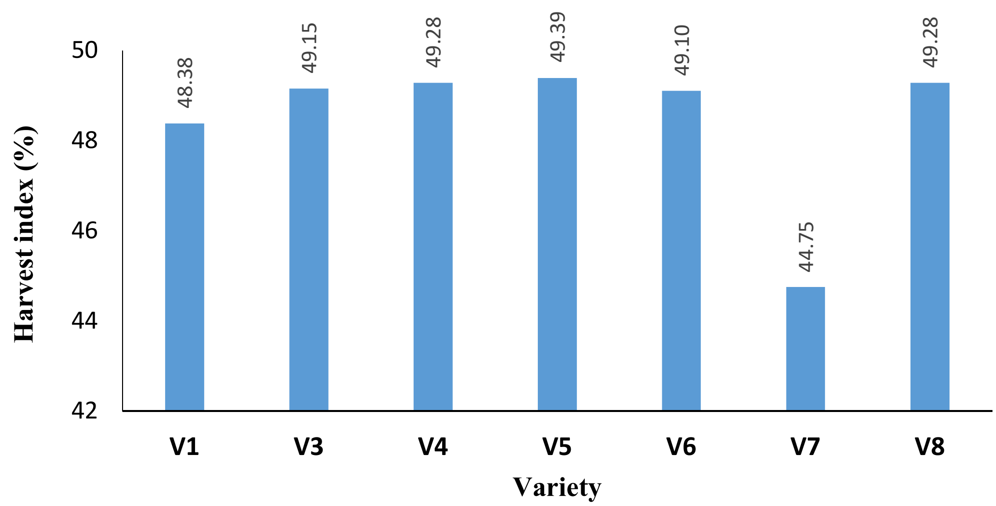
Figure 4.6.4 Stover yield, grain yield and biological yield of white maize at Rangpur Sadar as influenced by different varieties during Rabi, 2016-2017 ($LSD_{0.05}$ = 0.4733, 0.4842 and 0.8661 to Stover yield, grain yield and biological yield respectively)

4.6.3.11 Biological yield ha^{-1}

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. Seven varieties of white maize were tested. Biological yield ranged from (15.92 -24.743) t ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7 (Figure 4.6.4). Significantly V_3 (24.74 t ha^{-1}) showed highest biological yield that followed by V_1 (21.65 t ha^{-1}), V_4 (15.92 t ha^{-1}), V_5 (21.83 t ha^{-1}), V_6 (19.04 t ha^{-1}), V_7 (14.92 t ha^{-1}), V_8 (20.96 t ha^{-1}) (Figure 4.6.6). The second height Biological yield was V_5 (21.83 t ha^{-1}) which was statistically similar among the variety of V_1 (21.65 t ha^{-1}). The V_7 (14.92 t ha^{-1}) showed significantly the lowest biological yield.

4.6.3.12 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among biological and economic yield. Harvest index was varied significantly due to varieties (Figure 4.6.5). The V_5 showed significantly the highest harvest index (49.39 %) and V_5 variety showed the lowest (44.75 %). Although significantly V_5 showed lowest harvest index but there was no significant difference among the variety of V_1 (48.38 %), V_3 (49.15 %), V_4 (49.28 %), V_6 (49.10 %) and V_8 (49.282 %). Significantly the lowest harvest index was V_7 (44.75 %) (Figure 4.6.5).



V_1 = PSC-121, V_3=Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8= Yangnuo-30

Figure 4.6.5 Harvest index of white maize at Rangpur Sadar as influenced by different varieties during Rabi, 2016-2017 (LSD $_{0.05}$ = 1.012)

The varietal difference in producing grain yield was also manifested by Ghimire *et al.* (2016) who set a field experiment in farmer's field in Nepal. Among the two maize varieties Rajkumar (hybrid) and Arun2 (Open Pollinated Variety-OPV) tested, the variety Rajkumar produced the higher average grain yield of 5.13 t ha^{-1} while the variety Arun2 produced the mean grain yield 2.52 t ha^{-1}. Hybrid maize technology has made significantly yield advances and increased productivity in both developed and developing countries (Katuwal, 2012).

Mwakatwila (2019) while developing maize for fresh maize production in the southeastern Nigeria was carried out an experiment in the Center for Agricultural Research, School of Agriculture and Agricultural Technology, Federal University of Technology, Owerri using two local maize collected from southeastern Nigeria and five improved varieties collected from International Institute of Tropical Agriculture (IITA). There were significant differences observed between the entries for the measured traits. Mean Mid – parent heterosis (MPH) ranged from 1.35% for plant height to 90.51% for number of grains cob^{-1} and Better – parent heterosis (BPH) from 2.09% for days to 50% silking to 96.42 for number of grains cob^{-1}.

The grain yield is the function of population density, number of grains $plant^{-1}$ and grain weight. These three components are affected by the growing environment which differes from location to location. Tripathi*et al*. (2016) reported that the tested maize varieties responded differently at two different sites of Parwanipur and Tarahara where the highest grain yield producing sites was Parwanipur in consecutive two years. It also showed that maize growing environment of Rampur was closer to both Parwanipur and Tarahara. A similar kind of result was also reported by Koirala *et al*. (2013). The effect of GEI was high on final harvest of commercial hybrids that's why the same genotype behaves differently on changed location.

Tripathi *et al*. (2016) while examining four distinct groups of genotypes observed genetic variability which was also supported by Francis and Kannenberg (1978) where forty-seven hybrids of twenty seed companies with higher rank value and lower CV percentage were identified as good performing and stable. In the meantime, a large yield variation explained by environments and GEI than genotype indicates that environment and GEI factors were vital than genotype in crop yield. The stable and high yielding genotypes can be suitable for general cultivation to wider regions. In addition to this, those genotypes which are performing better yield on specific location could be suitable for cultivation to a particular region. Superiority measure helps to measure the behavior of genotypes where genotype × environment interactions is significant (Lin and Binns, 1988).

The adaptation of new hybrids maize varieties were also tried elsewhere which in addition to the prevailing environment may also be influenced by the age and education of the farmers and also some other socio economic conditions. Mwakatwila (2019) while doing adaptation trials with the maize hybrids in different locations of Tanzania reported that the hybrid maize was adopted by the persons who had 7 years and more in school and those who had communication and transportation assets were more likely to adopt improved maize varieties and was significant at ($p \leq 0.05$), and respondent's income and savings also significantly influence the adoption of improved maize varieties at p (≤ 0.1). It is therefore concluded that farmers' education, income, savings, zones and access to transportation and communication assets are the major factors influencing extent and adoption of improved maize varieties.

Milander and Jeremy (2015) reported that the most important environmental factors were solar radiation, water and temperature. Management practices such as tillage, irrigation, nutrient supply, and pest management strive to maximize economic yield, but responses to these practices vary across the environments.

4.6.4 Conclusion over the second year's (2016-17) three experiments (Expt. 4-6) regarding the varietal selection

In the second year of 2016-17 Rabi season, seven varieties of white maize were tested in the above mentioned three sites. In the trials, the variety KS-510 was omitted due to its poor performance. Although not documented by data, these varieties had heterogeneity in the field in respect of tasselling, silking and maturity which may cause an extra cost to the farmers for harvesting different times. Results showed that three out of seven white maize varieties, PSC-121 at SAU, while Changnuo-1 both at Dhamria and Rangpur gave significantly the highest grain yields respectively showing 10.30, 8.45 and 12.16 t ha^{-1}.

4.6.5 Conclusion over varietal trials

Considering the two years results across three sites, it may be explained that the variety Changnuo-1 was the only genotype which performed good at all the sites showing grain yield range of 6.65-8.62 t ha^{-1}. The variety PSC-121 performed good at SAU and Dhamrai in the first year, while only at the SAU site in the second year and the range of the grain yield over these two years were 8.26-10.31 t ha^{-1}. Along these two years, the variety Q-Xinagnuo-1 was a good performer in the first year at SAU showing grain yield of 7.17 t ha^{-1} and at Rangpur with the grain yield of 6.139 t ha^{-1} which did not perform good in the second year. Likewise, Changnuo-6 in the first year performed good showing 8.52 t ha^{-1} at SAU, while 9.13 t ha^{-1} at Dhamrai which in the second year did not perform good. KS-510 was found to be the best performer in the first year at Dhamrai showing the grain yield of 8.81 t ha^{-1}. Likewise, the variety Yangnuo-30 performed better in the first year at SAU showing the grain yield of 8.35 t ha^{-1}. Other two varieties performed at nowhere showing the least seed yield ranges by Yangnuo-7 from 3.76 (at Dhamrai in 2016-17) to 6.74 t ha^{-1} (at Rangpur in 2016-17) while by

Yangnuo-3000 from 6.540 t ha^{-1} (at Dhamrai in 2016-17) to 9.481 t ha^{-1} (at SAU in 2016-17).

So, it may be concluded that the variety Changnuo-1 at all the site was the best performer showing the grain yield range of 6.648-12.164 t ha^{-1} while PSC-121 at SAU was the second best performer (8.262-10.305 t ha^{-1}).

In this study, there was a great difference in different traits of the varieties tested. This was obvious as the varieties had variation in their genetic constitutions. Stenger and French (2008) reported that the variety TZEE-Y POP STRC4 was significantly more productive and had higher vigorous in comparison to other tested maize varieties due to its genetic composition which had enabled it to give higher performance. It was also confirmed that improved genetic base also helps any specific variety to thrive well on different locations (Badu-Apraku *et al.*, 2007). This is also in line with IITA (2007) bulletin which reported that any specific variety has ability to resist some or any specific pest that prevail in any specific locality.

Location affected the white maize yield in large extent. It was observed that excluding the first year results, the highest grain yields were obtained from the tested varieties at Rangpur Sadar which may be attributed to the cooler environment of this region. Under the cool situation at the grain filling stage lesser stored starch in the grain is burnt in the process of respiration that lead to more storage of starch (photosynthates) in the grain that in turn to increase yield. The variation of the maize varieties' yield was also manifested by many of the previous workers in the different regions of the world which was mainly attributed to the differences in the genetic make-up of the varieties.

Badu-Apraku *et al.* (2018) conducted a research at different regions of Nigeria on comparative evaluation of growth and yield of seven varieties of maize EV99 QPM, TZEE-Y POP STRC4, 2000 Syn. EE-W QPM C0, 99 TZEE-Y STR, 2000Syn. EE-Y QPM C0, EV2000 QPM, and TZEE-W POP STRC4 and found significant differences in grain yield and growth of the tested varieties. Such differences were attributed to the wide genetic base constitution of the varieties which enabled the most adaptive one. Olakojo and Kogbe (2005) emphasized the need to evaluate maize varieties in various agro-ecological zones for their adaptation, yield potential and disease reactions so as to release suitable varieties for cultivation on farmers' fields. So, it is imperative to understand the relationship among yield testing locations for better adaptation of germ plasm to different production environments (Richard *et al*., 2001). However, Tadesse *et al.* (2014) with regard to location reported that no significant difference was observed for the majority of the traits of the tested maize varieties except plant height and ear height indicating similarity in agro ecologies of the three villages (sites).

4.6.6 Recommendation over the varietal trials

Only eight white maize varieties were tested at three sites. So, more varieties should be tested in different agro-ecological regions of Bangladesh so as to select the most suitable varieties.

4.7 Experiment 7: Yield performance of white maize varieties under varying soil moisture regimes

The objective of this trial was to evaluate the performance of six hybrid white maize varieties under different soil moisture regimes on in growth, phenology and yield performance. The trial was made in Rabi 2016-17 at SAU farm under a temporary shed with polythene roof top so that rain (if any) can be prevented to maintain and implement the treatment regimes. The variety KS-510 (V_2) and Q-Xiangnuo-1 (V_4) were omitted. KS-510 did not perform well at SAU and Rangpur while Q-Xiangnuo-1 was the lowest among the good performers as was found in the previous year's (2015-16) trial. In this trial six different white maize varieties were included such as V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V_7 = Yangnuo-7, V_8=Yangnuo-30.

4.7.1 Growth parameters

4.7.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. Various treatments such variety, moisture stress and their combination were used to observe their effects on plant height of white maize.

It was revealed from the results that plant height was significantly influenced by moisture stress with six examined white maize hybrid varieties. Among the stress, S_2 (no watering from 100 DAS to harvest) showed significantly the tallest plant (204.17 cm) and S_1 showed the shortest (189.04 cm) plants. But there was no significant difference observed among the stress of S_2 (204.17 cm) and Sc (202.00 cm) (Table 4.7.1).

Among the Variety, V_1 had the tallest plants (214.58 cm) while V_7 showed the shortest (172.67 cm) plants. Although V_1 showed significantly highest plant height but there was no significant difference found among the variety of V_5 (197.08 cm), V_6 (214.33 cm) and V_8 (197.17 cm) (Table 4.7.1).

For their various combination among the above stated treatments, V_1S_2 had significantly the tallest plants (230.00 cm), which was statistically similar to V_1S_1 (202.50 cm), V_1S_C (211.25 cm), V_3S_2 (201.25cm), V_3S_C (203.75cm), V_5S_1 (188.00cm), V_5S_2 (200.75cm), V_5S_C (202.50cm), V_6S_1 (207.50 cm), V_6S_2 (219.25 cm) and V_6S_C (216.25 cm). The V_7S_1 showed significantly the shortest (167.50 cm) plants (Table 4.7.2). These results were 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 varieties.

Table 4.7.1 Performance of different varieties and moisture stress on growth attributes of white maize

Treatment	Plant height (cm)	No. of leaves plant^{-1}	LAI
S_1 (no watering from 80 DAS to harvest)	189.04 b	12.38 b	3.449 b
S_2 (no watering from 100 DAS to harvest)	204.17 a	13.33 a	4.126 a
S_C (control, with irrigation at everyday)	202.00 a	13.67 a	4.347 a
$LSD_{(0.05)}$	11.503	3.087	2.886
CV (%)	8.32	8.47	19.69
V_1	214.58 a	13.67 ab	5.12 a
V_3	194.58 b	13.75 ab	3.91 b
V_5	197.08 ab	13.25 b	4.27 ab
V_6	214.33 ab	14.67 a	3.84 6c
V_7	172.67 c	10.58 c	2.91 c
V_8	197.17 ab	12.83 b	3.79 bc
LSD $_{(0.05)}$	19.949	1.345	0.946
CV (%)	8.32	8.47	19.69

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V7= Yangnuo-7, V_8= Yangnuo-30, LAI= Leaf Area Index

4.7.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties, moisture stress and their combinations (Table 4.7.1 and Table 4.7.2). Significantly the highest number of leaves plant^{-1} (13.67) was shown with the moisture stress S_C treatment which was statistically similar to S_2 (13.33) and S_1 variety showed the lowest performance (12.38) (Table 4.7.1). Among the varieties, V_6 had significantly highest number of leaves plant^{-1} (14.67) which was not significantly differed with the variety of V_1 (13.67) and V_3 (13.75). The V_7 showed the lowest number of leaves plant^{-1} (10.58). The combination of V_6S_C (15.00) showed significantly the highest number of leaves plant^{-1} (Table 4.7.2). Among the treatments V_7S_1 showed significantly lowest number of leaves plant^{-1}(10.250) which was statistically similar to V_7S_2 (10.50) and V_7S_C (11.00).

Table 4.7.2 Interaction effect of different varieties with moisture stress on different growth attributes of white maize

Interaction	Plant height(cm)	No. of leaves plant^{-1}	LAI
V_1S_1	202.50 a-d	13.75 a-d	4.19 abc
V_1S_2	230.00 a	13.50 a-d	5.51 a
V_1S_C	211.25 abc	13.75 a-d	5.71 a
V_3S_1	178.75 bcd	12.50 a-f	3.88 abc
V_3S_2	201.25 a-d	14.25 abc	3.77 ac
V_3S_C	203.75 a-d	14.50 ab	4.07 ac
V_5S_1	188.00 a-d	11.75 b-f	3.91 abc
V_5S_2	200.75 a-d	13.50 a-d	4.13 abc
V_5S_C	202.50 a-d	14.50 ab	4.75 ab
V_6S_1	207.50 a-d	14.50 ab	3.31 bc
V_6S_2	219.25 ab	14.50 ab	4.21 abc
V_6S_C	216.25 ab	15.00 a	4.02 abc
V_7S_1	167.50 d	10.25 f	2.40 c
V_7S_2	178.00 bcd	10.50 ef	3.08 bc
V_7S_C	172.50 cd	11.00 d-f	3.27 bc
V_8S_1	190.00 a-d	11.50 c-f	3.02 bc
V_8S_2	195.75 a-d	13.75 a-d	4.06 abc
V_8S_C	205.75 a-d	13.25 a-e	4.27 abc
LSD $_{(0.05)}$	42.826	2.886	2.031
CV (%)	8.32	8.47	19.69

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V7= Yangnuo-7, V_8= Yangnuo-30

S_1 = no watering from 80 DAS to harvest, S_2 = no watering from 100 DAS to harvest, S_C = control with irrigation at every day; LAI= Leaf Area Index

4.7.1.3 Leaf Area Index (LAI)

Leaf Area Index was significantly influenced by varieties moisture stress and their combinations. Significantly the maximum leaf area index (4.35) was shown by the stress treatment S_C which was statistically similar to S_2 (4.13) and significantly S_1 treatment was the lowest performer (3.45) (Table 4.7.2). Among the varieties, V_1 showed significantly highest leaf area index (5.14) which was not significantly differed with V_5 (4.37). The V_7 showed significantly the lowest leaf Area Index (2.91). The combination of V_1S_C (5.71) showed significantly the highest Leaf Area Index. Among the treatments V_7S_1 showed significantly lowest leaf area index (2.40) (Table 4.7.2).

4.7.2 Yield contributing characters and yield

4.7.2.1 Cob length (cm)

Water stress, white maize hybrids and their interactive effect had significant effects on cob length. The highest cob length (16.64 cm) was significantly achieved with S_C that followed by S_1 (15.27 cm) and S_2 variety (15.52 cm) while the lowest cob length was achieved with S_1 water stress (15.27 cm) (Table 4.7.3). Variety had significant effect on Cob length. Among the varieties V_3 resulted the tallest cobs (17.04 cm) and V_7 showed significantly the shortest cobs (14.88 cm). Although V_7 resulted in the significantly shortest cob length but there was no significant difference observed with the variety of V_1 (15.04 cm) (Table 4.7.3). Among the interaction treatments of variety and water stress, it was observed that V_3S_C treatment showed significantly the highest cob length (18.00 cm), which was statistically similar to V_5S_C (17.25 cm) and V_6S_C (17.00 cm) (Table 4.7.4). Among the other treatments, V_7S_1 showed significantly the lowest cob length (13.63 cm).

4.7.2.2 Number of grains row^{-1}

Number of grains row^{-1} was significantly influenced by varieties, water stress and their combinations. The highest number of grains row^{-1} (24.54) was significantly reported from the treatments having S_C which was statistically similar to S_2 whereas S_1 was the lowest performer (16.54) (Table 4.7.3). However, different variety showed the significant effects on number of grains row^{-1}. Among the various treatments, V_3 showed the highest number of grains row^{-1} (27.50) and the lowest (18.75) was shown from V_1 (Table 4.7.3). Although V_1 (18.75) showed significantly lowest number of grains row^{-1} but there was no significant difference observed among the variety of V_6 (19.08) and V_8 (19.75). The V_5 (23.75) was the second height performer.

Moreover, the combination of V_3S_C showed significantly the highest number of grains row^{-1} (30.25) than the other combinations, which were statistically similar to V_1S_2 (27.25), V_3S_2 (28.00), V_5S_C (28.75) and V_7S_2 (25.00) (Table 4.7.4). The V_1S_1 showed significantly the lowest number of grains row^{-1} (9.50) which was not significantly differed with the variety of V_6S_1 (14.25) and V_8S_1 (14.00).

Table 4.7.3 Performance of different varieties and moisture stress on yield attributes of white maize

Treatments	Cob length (cm)	No. of grains row^{-1}	No. of grains cob^{-1}
S_1 (no watering from 80 DAS to harvest)	15.27 b	16.54 b	255.04 c
S_2 (no watering from 100 DAS to harvest)	15.52 b	24.50 a	330.67 b
S_C (control, with irrigation at everyday)	16.54 a	24.54 a	362.21 a
$LSD_{(0.05)}$	0.577	1.557	9.984
CV (%)	6.31	10.22	5.45
V_1	15.04 cd	18.75 d	270.00 d
V_3	17.04 a	27.50 a	407.33 a
V_5	16.17 b	23.75 b	349.92 b
V_6	15.79 bc	19.08 d	299.33 c
V_7	14.88 d	22.33 bc	312.67 c
V_8	15.75 bc	19.75 cd	256.58 d
$LSD_{(0.05)}$	0.8156	2.7002	14.120
CV (%)	6.31	10.22	5.45

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V7= Yangnuo-7, V_8= Yangnuo-30

Table 4.7.4 Interaction effect of different varieties and moisture stress on yield attributes of white maize

Treatment	Cob length (cm)	No. of grains row^{-1}	No. of grains cob^{-1}
V_1S_1	15.00 def	9.50 h	170.00 j
V_1S_2	15.13 de	27.25 abd	355.50 c
V_1S_C	15.00 def	19.50 efg	284.50 f
V_3S_1	17.00 abc	24.25 bce	358.00c
V_3S_2	16.12 bcd	28.00 abc	334.00 cde
V_3S_C	18.00 a	30.25 a	530.00 a
V_5S_1	16.25 bcd	19.50 efg	273.50 fgh
V_5S_2	15.00 def	23.00 bcef	347.50 cd
V_5S_C	17.25 ab	28.75 ab	428.75 b
V_6S_1	14.25 ef	14.25 gh	253.50 h
V_6S_2	16.12 bcd	21.50 def	321.00 e
V_6S_C	17.00 abc	21.50 def	323.50 de
V_7S_1	13.62 f	17.75 fg	255.00 gh
V_7S_2	15.00 def	25.00 a-e	355.50 c
V_7S_C	16.00 bcd	24.25 b-e	327.50 de
V_8S_1	15.50 de	14.00 gh	220.25 i
V_8S_2	15.75 cd	22.25 c-f	270.55 fg
V_8S_C	16.00 bcd	23.00 b-f	279.00 fg
LSD $_{(0.05)}$	1.413	5.797	24.457
CV (%)	6.31	10.22	5.45

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V7= Yangnuo-7, V_8= Yangnuo-30,

S_1 = no watering from 80 DAS to harvest, S_2 = no watering from 100 DAS to harvest, S_C = control with irrigation at every day

4.7.2.3 Number of grains cob^{-1}

Total number of grains cob^{-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, water stress and their combination. The highest number of grains cob^{-1} (362.21) was reported from the treatments having T_C

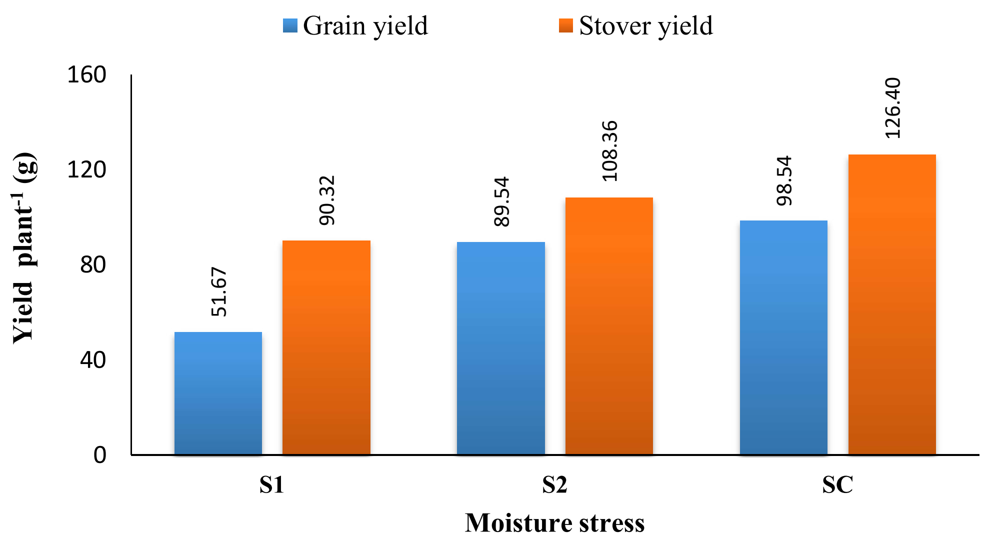
followed by T_2 (330.67) and T_1 (255.04) was the lowest performer among others (255.04) (Table 4.7.3). However, in white maize plant variety showed the significant effects on number of grains cob^{-1}. Among the various treatments, V_3showed the highest number of grains cob^{-1}(407.33), and V_8 was the lowest (256.58) grain producer. The combination of V_3S_C showed the highest number of grains cob^{-1} (530.00) and among the treatments V_1S_1 showed the very minimum number of grains cob^{-1} (170.00) (Table 4.7.4).

Eck (1986) indicated that when kernel numbers have been reduced by water stress in the vegetative growth stages kernel weight may increase in order to compensate for the lower kernel number. This increase might be attributed to the shortening of the ear and elimination of some of the smaller kernels.

4.7.2.4 Grain yield plant^{-1}

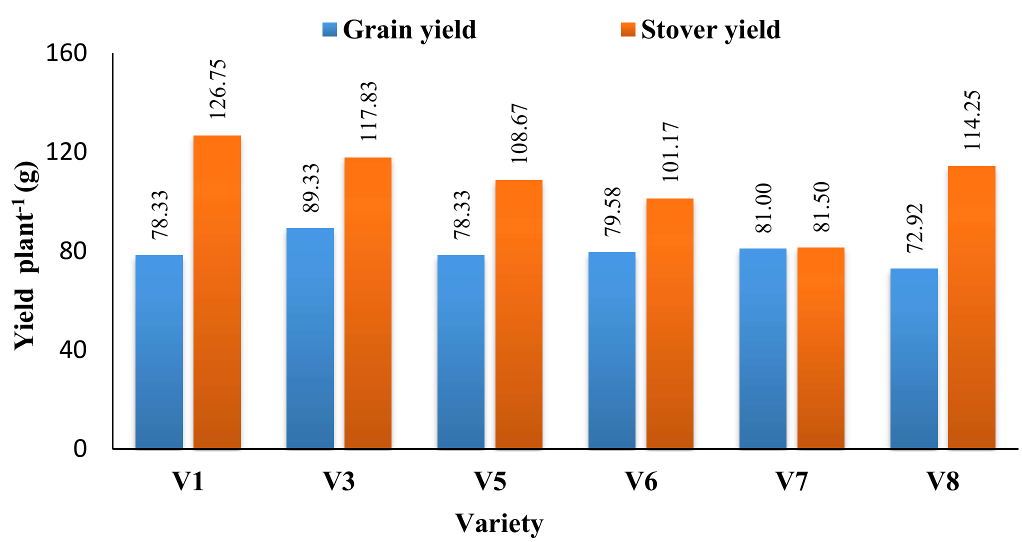
The varieties, water stress and their combinations remarkably influenced the grain yield $plant^{-1}$ of white maize. The highest grain yield $plant^{-1}$ (98.54 g) was achieved with the treatment S_C and the minimum grain yield $plant^{-1}$ (51.67 g) was recorded from the treatment S_1 (Figure 4.7.1). For plant variety treatments, the maximum grain yield $plant^{-1}$ (89.333 g) was obtained from the treatment V_3 and the minimum from V_8 (72.92 g) (Figure 4.7.2).

For their combinations, highest grain yield $plant^{-1}$ (108.50 g) was recorded from treatment V_5S_C (Table 4.7.5). From others treatments combination the lowest grain yield $plant^{-1}$ was significantly observed from V_6S_1 (35.75 g) and it was statistically similar to V_8S_1 (40.50 g).



S_1 = no watering from 80 DAS to harvest, S_2 = no watering from 100 DAS to harvest, S_C = control with irrigation at every day

Figure 4.7.1 Effect of moisture stress on grain yield and stover yield of white maize during Rabi, 2017-2018 ($LSD_{0.05}$ =3.0870, 2.6234 in Grain yield and stover yield respectively)



V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V7= Yangnuo-7, V_8= Yangnuo-30

Figure 4.7.2 Effect of varieties on grain yield and stover yield of white maize during Rabi, 2017-2018 ($LSD_{0.05}$ =3.0870, 2.6234 in Grain yield and stover yield respectively)

Table 4.7.5 Interaction effect of different varieties and moisture stress on yield attributes of white maize

Treatment	Grain yield plant^{-1}(g)	Stover yield plant^{-1}(g)
V_1S_1	60.25 gh	105.08 efg
V_1S_2	86.00 de	132.08 bc
V_1S_C	88.75 de	143.08 a
V_3S_1	65.50 g	104.92 efg
V_3S_2	99.25 bc	113.67 e
V_3S_C	103.25 ab	134.92 ab
V_5S_1	51.50 i	90.25 hi
V_5S_2	75.00 f	109.25 ef
V_5S_C	108.50 a	126.50 bc
V_6S_1	35.75 j	79.25 j
V_6S_2	98.00 bc	100.00 fgh
V_6S_C	105.00 ab	24.25 cd
V_7S_1	56.50 hi	66.58 k
V_7S_2	93.50 cd	80.58 ij
V_7S_C	93.00 cde	97.33 gh
V_8S_1	40.50 j	95.83 gh
V_8S_2	85.50 e	114.58 de
V_8S_C	92.75 cde	132.33 bc
LSD $_{(0.05)}$	7.562	9.776
CV (%)	6.67	3.47

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V7= Yangnuo-7, V_8= Yangnuo-30

S_1 = no watering from 80 DAS to harvest, S_2 = no watering from 100 DAS to harvest, S_C = control with irrigation at every day

4.7.2.5 Stover yield plant^{-1}

The varieties, water stress and their combinations remarkably influenced the stover yield of white maize. The highest stover yield plant^{-1} (126.40 g) was significantly achieved with the treatment Sc and the minimum stover weight plant^{-1} (90.32 g) was found from the treatment S_1 (Figure 4.7.1). Likewise, S_2 (108.36 g) showed intermediate stover yield. For variety, the highest stover yield plant^{-1} (126.75 g) was observed from the treatment V_1 and the lowest per plant stover yield from V_7 (81.50 g) (Figure 4.7.2). For their combinations, the highest stover yield plant^{-1} (143.08 g) was recorded from treatment V_1S_C which was statistically similar to V_3S_C (134.92 g). From others treatments, the lowest stover yield plant^{-1} was found from V_7S_1 (66.58 g) (Table 4.7.5).

4.7.2.6 Grain yield ha^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. The varieties, water stress and their combinations significantly influenced the grain yield of white maize (Table 4.7.6 and Table 4.7.7). The highest grain yield (6.57 t ha^{-1}) was observed with the treatment S_C and the lowest grain yield (3.44 t ha^{-1}) was achieved with the treatment S_1. Likewise, S_2 (5.969 t ha^{-1}) was intermediate grain producer (Table 4.7.6).

For variety the highest grain yield (5.96 t ha^{-1}) was achieved with the treatment V_3 and the lowest grain yielder (4.86 t ha^{-1}) was V_8 that was not significantly different with the variety of V_1 (5.22 t ha^{-1}) and V_5 (5.22 t ha^{-1}) (Table 4.7.6).

In regards to the interaction effect, the highest grain yield (7.23 t ha^{-1}) was counted from treatment V_5S_C which was not significantly differed with the combination of V_3S_2 (6.62 t ha^{-1}), V_3S_C (6.88 t ha^{-1}), V_6S_2 (6.53 t ha^{-1}) and V_6S_C (7. 00 t ha^{-1}) (Table 4.7.7). From others treatments combinations, the minimum grain yield was observed for V_6S_1 (2.38 t ha^{-1}), which was statistically similar to V_8S_1 (2.70 t ha^{-1})

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 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 were in agreement with the findings of Konuskan (2000), Gozubenli et al. (2001) and Farnham (2001).

Table 4.7.6 Performance of varieties and moisture stress conditions on grain yield, stover yield, biological yield and harvest index of white maize

Treatment	Grain yield (tha^{-1})	Stover yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
S_1 (no watering from 80 DAS to harvest)	3.44 c	6.02 c	9.47 c	36.28 b
S_2 (no watering from 100 DAS to harvest)	5.97 b	7.22 b	13.20 b	44.66 a
S_C (control, with irrigation at everyday)	6.57 a	8.43 a	14.99 a	43.94 a
$LSD_{(0.05)}$	0.248	0.175	0.132	1.347
CV (%)	6.67	3.47	3.65	4.64
V_1	5.22 bc	8.45 a	13.67 a	38.02 c
V_3	5.96 a	7.86 b	13.81 a	42.79 b
V_5	5.22 bc	7.24 c	12.47 b	41.06 b
V_6	5.31b	6.74 d	12.05 c	42.00 b
V_7	5.40 b	5.43 e	10.83 d	48.05 a
V_8	4.86 c	7.62 b	12.48 b	37.84 c
$LSD_{(0.05)}$	0.429	0.303	0.187	2.337
CV (%)	6.67	3.47	3.65	4.64

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30

Table 4.7.7 Interaction effect of varieties with moisture stress on grain yield, stover yield, biological yield and harvest index of white maize

Treatment	Grain yield (tha^{-1})	Stover yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
V_1S_1	4.02 fg	7.01efg	11.02 g	36.41 f
V_1S_2	5.73 cd	8.81 bc	14.54 cd	39.37 def
V_1S_C	5.92 cd	9.54 a	15.46 ab	38.29 ef
V_3S_1	4.37 ef	6.99 efg	11.37 g	38.41 def
V_3S_2	6.62 abc	7.58 e	14.20 d	46.62 ab
V_3S_C	6.88 ab	8.99 ab	15.88 a	43.33 bcd
V_5S_1	3.43 gh	6.02 hi	9.45 h	36.34 f
V_5S_2	5.00 de	7.28 ef	12.28 f	40.64 def
V_5S_C	7.23 a	8.43 bc	15.67 a	46.16 abc
V_6S_1	2.38 i	5.28 j	7.67 i	30.99 g
V_6S_2	6.53 abc	6.67 fgh	13.20 e	49.20 a
V_6S_C	7.00 ab	8.28 cd	15.28 ab	45.80 abc
V_7S_1	3.77 fg	4.44 k	8.21 i	45.85 abc
V_7S_2	6.23 bc	5.37 ij	11.61 g	49.47 a
V_7S_C	6.20 bc	6.49 gh	12.69 ef	48.81 a
V_8S_1	2.70 hi	6.39 gh	9.09 h	29.66 g
V_8S_2	5.70 cd	7.64 de	13.34 e	42.65 b-e
V_8S_C	6.18 bc	8.82 bc	15.01 bc	41.21 c-f
$LSD_{(0.05)}$	0.922	0.651	0.324	5.0148
CV (%)	6.67	3.47	3.65	4.64

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

V_1= PSC-121, V_3= Changnuo-1, V_5= Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7, V_8= Yangnuo-30

S_1= no watering from 80 DAS to harvest, S_2 = no watering from 100 DAS to harvest, S_C = control with irrigation at every day

4.7.2.7 Stover yield ha^{-1}

Stover yield was significantly affected by varieties, water stress and their interaction. The highest stover yield (8.49 t ha^{-1}) was significantly observed in S_C and the lowest by S_1 (6.02 t ha^{-1}) which were also statistically dissimilar to each other (Table 4.7.6).

In respect of variety, V_1 showed significantly the highest stover yield (8.45 t ha^{-1}), while V_7 was the lowest stover yielder (5.43 t ha^{-1}). However, for the combination of variety and water stress it was observed that, the highest stover yield (9.54 t ha^{-1}) was significantly shown by (Table 4.7.7). V_1S_C which was statistically similar to V_3T_C (8.99) and the lowest was revealed with V_7S_1 treatment (4.44 t ha^{-1}).

4.7.2.8 Biological yield ha^{-1}

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, water stress and their combination. Among the water stress S_C significantly showed the highest biological yield (14.99 t ha^{-1}) (Table 4.7.5). The S_1 resulted in the significantly the lowest biological yields (9.45 t ha^{-1}). Likewise, T_2 (13.194 t ha^{-1}) was intermediate biological yield producer.

Between varietal treatments, V_3 showed significantly the highest biological yield (13.81 t ha^{-1}) which was not significantly differed with the variety of V_1 (13.67 t ha^{-1}) and V_7 was the lowest biological yield (10.83 t ha^{-1}) producer (Table 4.7.5). However, for the combination of varieties and water stress, it was observed that the highest biological yield (15.87 t ha^{-1}) and (15.67 t ha^{-1}) were produced respectively by V_3S_C and V_5S_C which although showed no significant difference with the combination of V_1S_C (15.46 t ha^{-1}), V_6S_C (15.28 t ha^{-1}) and the lowest was revealed with V_6S_1 treatment (7.667 t ha^{-1}) which was statistically similar to V_7S_1 (8.206 t ha^{-1}) (Table 4.7.6).

4.7.2.9 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among economic yield and biological yield. Harvest index was varied significantly due to moisture stress where, S_2 showed the highest harvest index (44.66 %) while S_1 gave the lowest (36.28 %) harvest index (Table 4.7.5). Variety affect significantly on harvest index and V_7 showed the highest harvest index (48.05 %), and V_8 was the lowest harvest index (37.84 %) which had no significant difference with of V_1 (38.02 %)(Table 4.7.6).For the combinations of variety and water stress , it was observed that V_7S_2 treatment showed the highest harvest index (49.46 %), which was statistically similar to V_7S_C,

V_7S_1,V_6S_C ,V_6S_2, V_5S_C and V_3S_2 (48.84 %, 45.85 %, 45.80 % ,49.20 % ,46.19 % and 46.62 % respectively) (Table 4.7.7).The lowest harvest index was revealed with V_8S_1 treatment (29.66 %), which was statistically similar to V_6S_1 (30.99 %).

Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of I_0 = control, I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0) and observed that the variety Pacific 984) produced the highest (8.60 t ha^{-1}) and I_2 (BHM-7) produced the lowest (7.31 t ha^{-1}) grain yield at IW CPE^{-1} ration of 0.6. The results also showed that the highest water use efficiencies for grain (7.64 kg $ha^{-1}cm^{-1}$) and biomass (14.98 kg $ha^{-1}cm^{-1}$) production under. The lowest water use efficiencies for grain (2.67 kg $ha^{-1}cm^{-1}$) and biomass (4.93 kg $ha^{-1}cm^{-1}$) reductions were obtained under I_4. Niazuddin *et al*., (2002) and Hossain *et al*. (2011) also reported the highest WUE for grain production (4.90 kg $ha^{-1}cm^{-1}$) was obtained one variety and the lowest (4.41 kg $ha^{-1}cm^{-1}$) from another variety. Similar situation was also noticed for biomass production, the highest (9.39 kg $ha^{-1}cm^{-1}$) and lowest (8.60 kg $ha^{-1}cm^{-1}$).

The interaction effect of variety and irrigation regimes had also been noticed to be significant in the works elsewhere. Shariot-Ullah *et al*. (2013) investigated the response of three hybrid maize (V_1=BHM-5, V_2=BHM-7, V_3=Pacific-984) under varying irrigation regime (in the form of IW/CPE ratios of, I_0 = control, I_1=0.4, I_2=0.6, I_3=0.8 and I_4=1.0) and reported that the highest WUE for grain production (8.86 kg $ha^{-1}cm^{-1}$) was under I_0V_1 and the lowest (2.35 kg $ha^{-1}cm^{-1}$) was under I_4V_3. The highest (16.04 kg $ha^{-1}cm^{-1}$) and lowest (4.63 kg $ha^{-1}cm^{-1}$) water use efficiencies for biomass productions were also obtained under $I_0V_1$and I_4V_3, respectively.

Irrigation that is water supply increases the nutrient supply which in turn affect the production of grain in maize have been reported by Pollmer *et al*. (1979). Maize plants differ in their ability to absorb nutrients and this is an inherited characteristic (Jones and Crookston, 1973); The varieties also differ in nutrient absorbtion and so screening crop varieties in this relation is necessary (Mortvedt, 1976;). Moser *et al*. (2006) reported low 1000-kernel weights due to pre-anthesis drought stress and a reduced kernel number stress immediately after pollination resulted in the reduction of kernel number as well (Claasen and Shaw, 1970; Harder *et al*., 1982). Stress occurring after 2 or 3 weeks after pollination no longer affects the number of kernels $plant^{-1}$ but rather reduces kernel weight (Eck, 1986).

Drought considered as the most important factor that limiting maize crop productivity when maize was exposed to drought conditions around flowering (Bänziger *et al*., 2002). Edmeades *et al*. (1999) reported 34–40% of the inter-annual variability of the yields of maize and it has a great impact when it occurs around flowering (Banziger *et al*., 2002; Bruce *et al*., 2002; Banziger *et al.,* 2006).

4.8 Experiment 8. Effect of antitranspirant application at tasseling stage on the growth and yield of white maize

The objectives of this trial was to evaluate the performance of two hybrid white maize varieties under different concentration of antitranspirant Kaolin on different growth parameters, yield contributing characters and yield. In the first year (2015-16) and in second year (2016-2017) the variety PSC-121 performed better at SAU and Dhamrai, while the variety Changnuo-1performed better at all the sites. So, the anitiranspirant was tested in these two varieties during rabi 2017-18 at SAU. The antitranspirant was used at tasseling stage in this experiment.

4.8.1 Growth parameters

4.8.1.1 Plant height (cm)

Plant height is an important component which helps in the determination of growth attained during the growing period. Various treatments such variety, antitranspirant and their combination were used to observe their effects on plant height of white maize.

It was revealed from the results that plant height was significantly influenced by white maize hybrid varieties. Among the variety, V_1 showed significantly the tallest plant (231.48 cm) and V_3 the shorter (214.15 cm) plants (Table 4.8.1). Among the antitranspirant, C_1 had the tallest plants (229.37 cm) while C_0 showed the shortest (216.99 cm) plants. Although C_0 showed significantly shortest plant height but there was no significant difference observed among the concentration of C_3 (222.83 cm) and C_2 (222.08 cm) (Table 4.8.1). For their various combination among the above stated treatments, V_1C_3 showed significantly the tallest plants (240.80 cm), which was statistically similar to V_1C_1 (238.40cm) (Table 4.8.2). The V_3C_3 showed significantly the shortest (204.87 cm) plants which was not significantly differed with the combination of V_3C_0 (213.25).

4.8.1.2 Number of leaves plant^{-1}

Total number of leaves plant^{-1} was significantly influenced by varieties, concentration of antitranspirant and their combinations. The highest number of leaves plant^{-1} (13.39) was produced the variety V_1 which was statistically similar to V_3 (12.85) (Table 4.8.1). Among the concentration of antitranspirant, C_0 should significantly the highest number of leaves plant^{-1} (13.38) which was not significantly differed with the concentration of C_1 (13.33) and C_3 (13.23). The C_2 resulted in significantly the lowest number of leaves plant^{-1} (12.53). The highest number of leaves plant^{1} was produced by V_3C_0 (13.57) and lowest by V_1C_2 (11.80) (Table 4.8.2).

Table 4.8.1 Performance of white maize varieties and antitranspirant (Kaolin) concentrations on vegetative and reproductive growth attributes

Treatments	Plant height (cm)	Number of leaves plant^{-1}
Effect of variety		
V_1	231.48 a	12.85 a
V_3	214.15 b	13.39 a
LSD $_{(0.05)}$	2.3444	0.2759
CV (%)	2.58	5.15
Effect of antitranspirant (Kaolin)		
C_0	216.99 b	13.38 a
C_1	229.37 a	13.33 ab
C_2	222.08 b	12.53 b
C_3	222.83 ab	13.23 ab
LSD $_{(0.05)}$	3.315	0.390
CV (%)	2.58	5.15

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

Table 4.8.2 Interaction effect of white maize varieties and antitranspirant (Kaolin) concentrations on vegetative and reproductive growth attributes

Treatment	Plant height (cm)	Number of leaves plant^{-1}
V_1C_0	220.73 bc	13.20 a
V_1C_1	238.40 a	13.20 a
V_1C_2	226.00 b	11.80 b
V_1C_3	240.80 a	13.20 a
V_3C_0	213.25 cd	13.57 a
V_3C_1	220.33 bc	13.47 a
V_3C_2	218.17 bc	13.25 a
V_3C_3	204.87 d	13.27 a
LSD $_{(0.05)}$	4.689	0.552
CV (%)	2.58	5.15

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

4.8.2 Yield contributing characters and yield

4.8.2.1 Cob length (cm)

Variety, concentration of antitranspirant (Kaolin) of white maize hybrids and their interactive effect had significant effects on cob length. The highest cob length (14.96 cm) was achieved with V_3 variety followed byV_1 (13.22 cm) (Table 4.8.3). Antitranspirant had significant effect on cob length. Among the treatments, C_3 should significantly the tallest cobs (14.57 cm) which was not significantly differed with the variety of C_2 (14.21). The C_0 showed significantly the shortest cobs (13.68 cm) which was statistically differed from C_2 (14.21) (Table 4.8.3).

Among the interactions of variety and antitranspirant, it was observed that the V_3C_2 treatment showed significantly the highest cob length (15.48 cm), which was statistically similar to V_3C_3 (15.00 cm) and V_3C_0 (14.95 cm) (Table 4.8.4). Among the other treatments, V_1C_1 showed significantly the lowest cob length (13.40 cm) which was statistically similar to V_1C_2 (12.933 cm).

Table 4.8.3 Performance of white maize varieties and antitranspirant (Kaolin) concentrations on vegetative and reproductive growth attributes

Treatments	Cob length (cm)	Cob breadth (cm)
Effect of variety		
V_1	13.22 b	15.38 a
V_3	14.96 a	14.75 b
LSD $_{(0.05)}$	0.165	0.244
CV (%)	2.86	3.96
Effect of antitranspirant (Kaolin)		
C_0	13.68 c	14.79 a
C_1	13.90 bc	15.26 a
C_2	14.21 ab	14.79 a
C_3	14.57 a	15.42 a
LSD $_{(0.05)}$	0.233	0.345
CV (%)	2.86	3.96

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

4.8.2.2 Cob breadth (cm)

Variety, concentration of antitranspirant of white maize hybrids and their interactions showed significant effects on cob breath. The highest cob breath (15.38 cm) was achieved with V_1 variety while V_3 variety (14.75 cm) showed the lowest cob length (Table 4.8.3). Antitranspirant had no significant effect on cob breath. Among the treatments, C_3 showed numerically the maximum cob breadth (15.417 cm) that followed by C_0 (14.79 cm), C_1 (15.26 cm) and C_2 (14.79 cm) (Table 4.8.3).

Among the interaction of variety and antitranspirant, it was observed that V_1C_1 treatment showed significantly the highest cob length (15.73 cm), which was statistically similar to V_1C_3 (15.70 cm) (Table 4.8.4). Among the other treatments, V_3C_0 showed the lowest cob length (14.38 cm) which was statistically similar to V_3C_2 (14.68 cm).

Table 4.8.4 Interaction effect of white maize varieties and antitranspirant concentrations on vegetative and reproductive growth attributes

Treatment	Cob length (cm)	Cob breadth (cm)
V_1C_0	12.40 e	15.20 ab
V_1C_1	13.40 d	15.73 a
V_1C_2	12.93 de	14.90 ab
V_1C_3	14.13 c	15.70 a
V_3C_0	14.95 ab	14.38 b
V_3C_1	14.40 bc	14.80 ab
V_3C_2	15.48 a	14.68 ab
V_3C_3	15.00 ab	15.13 ab
LSD $_{(0.05)}$	0.329	0.487
CV (%)	2.86	3.96

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

4.8.2.3 Number of rows cob^{-1}

Variety, concentration of antitranspirant of white maize hybrids and their interaction showed significant effects on number of rows cob^{-1}. The highest number of rows cob^{-1} (12.70) was achieved with V_1 variety followed by V_3(12.02) (Table 4.8.5). Antitranspirant had significant effect on number of rows cob^{-1}. Among the treatments, C_2 variety had the highest number of rows cob^{-1}. (13.40) which was not significantly differed with C_1 (12.27) and C_3 (12.47) (Table 4.8.5).

Among the interaction of variety and antitranspirant, it was observed that V_1C_3treatment showed significantly the highest cob length (13.53), which was statistically similar to V_1C_1 (13.13), V_1C_2 (13.40), V_3C_2 (13.40) and V_3C_0 (11.87) (Table 4.8.6). Among the other treatments, V_1C_0 showed the lowest number of rows cob^{-1} (10.73) which was statistically similar to V_3C_0 (11.87), V_3C_1 (11.40) and V_3C_3 (11.40).

Table 4.8.5 Performance of white maize varieties and antitranspirant (Kaolin) concentrations on vegetative and reproductive growth attributes

Treatments	Number of rows cob^{-1}	Number of Grains row^{-1}
Effect of variety		
V_1	12.70 a	25.88 a
V_3	12.02 a	26.22 a
LSD $_{(0.05)}$	0.396	0.676
CV (%)	7.84	6.35
Effect of antitranspirant (Kaolin)		
C_0	11.30 b	19.50 d
C_1	12.27 ab	24.80 c
C_2	13.40 a	27.30 b
C_3	12.47 ab	32.70 a
LSD $_{(0.05)}$	0.559	0.956
CV (%)	7.84	6.35

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

Table 4.8.6 Interaction effect of white maize varieties and antitranspirant (Kaolin) concentrations on vegetative and reproductive growth attributes

Treatment	Number of rows cob^{-1}	Number of grains row^{-1}
V_1C_0	10.73 b	19.60 d
V_1C_1	13.13 a	23.00 c
V_1C_2	13.40 a	28.73 b
V_1C_3	13.53 a	32.20 a
V_3C_0	11.87 ab	19.40 d
V_3C_1	11.40 b	26.60 b
V_3C_2	13.40 a	25.87 bc
V_3C_3	11.40 b	33.20 a
LSD $_{(0.05)}$	0.791	1.352
CV (%)	7.84	6.35

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

4.8.2.4 Number of grains row^{-1}

Variety, concentration of antitranspirant of white maize hybrids and their interactions showed significant effects on number of grains row^{-1}. The highest number of grains row^{-1} (26.27) was achieved with V_3 while V_1 variety (25.88) gave the lowest number of grains row^{-1} was achieved (Table 4.8.5). Antitranspirant had significant effect on number of grains row^{-1}. Among the treatments, C_3 showed the highest number of grains row^{-1} (32.70) and lowest by C_O (19.50) (Table 4.8.5).

Among the interaction of variety and antitranspirant, it was observed that V_3C_3 treatment showed significantly the highest number of grains row^{-1} (33.20), which was statistically similar to V_1C_3 (32.20) (Table 4.8.6). Among the other treatments, V_3C_0 showed the lowest number of seeds row^{-1} (19.40) which was statistically similar to V_1C_0 (19.60).

4.8.2.5 Number of grains cob^{-1}

Total number of grains cob^{-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, antitranspirant and their combination. The highest number of grains cob^{-1} (333.34) was reported from the treatments having V_1 and V_3 (314.84) was the lower performer (Table 4.8.7). However, antitranspirant showed significant effects on number of grains cob^{-1}. Among the various treatments, C_3 showed highest number of grains cob^{-1}(407.32) and C_0 was the lowest (220.73) grain producer (Table 4.8.7).

Moreover, their combination revealed that V_1C_3 showed significantly the highest number of grains cob^{-1}(435.68) which was statistically similar to V_1C_2 (385.21) (Table 4.8.8). Among the treatments V_1C_0 (210.37) showed the very lowest number of grains cob^{-1} which was statistically similar to V_3C_0 (231.09).

4.8.2.6 100 grain weight (g)

The 100 grain weight contributes to the economic yield as well as represent the productive efficiency of any cereal crop or crop variety. The 100 grain weight was significantly influenced by varieties, antitranspirant and their combination. The highest 100 grain weight (32.33 g) was reported from the treatments having V_1 followed by V_3 (31.08 g) (Table 4.8.7). However, in antitranspirant showed the significant effects on 100 grain weight. Among the various treatments, C_3 showed significantly highest 100 grain weight (34.00 g) which was statistically similar to C_1 (32.33 g) and C_2 (33.17 g). The C_0 was the lowest (27.33 g) grain producer (Table 4.8.7). Moreover, their combination revealed that V_1C_3 showed significantly the highest 100 grain weight (34.67 g). Among the treatments V_3C_0 (26.67 g) (Table 4.8.8) showed the very lowest 100 grain weight which was statistically similar to V_1C_0 (28.00 g).

Table 4.8.7 Performance of white maize varieties and antitranspirant (Kaolin) concentrations on different yield attributes

Treatment	Number of grains cob^{-1}	100 grain weight (g)
Effect of variety		
V_1	333.34 a	32.33 a
V_3	314.84 a	31.08 a
LSD (0.05)	13.106	1.056
CV (%)	9.91	8.16
Effect of antitranspirant (Kaolin)		
C_0	220.73 d	27.33 b
C_1	303.30 c	32.33 a
C_2	365.00 b	33.17 a
C_3	407.32 a	34.00 a
LSD (0.05)	18.535	1.4940
CV (%)	9.91	8.16

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

Table 4.8.8 Interaction effect of white maize varieties and antitranspirant (Kaolin) concentrations on different yield attributes

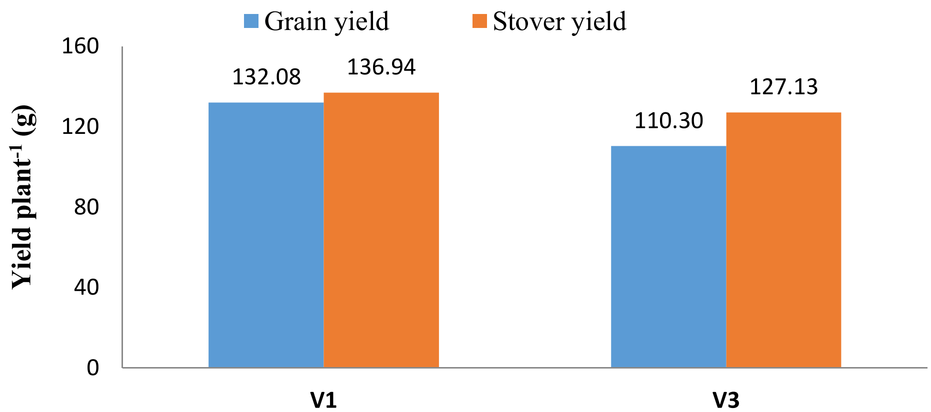
Treatment	Number of grains cob^{-1}	100 grain weight (g)
V_1C_0	210.37 d	28.00 bc
V_1C_1	302.08 c	32.67 a
V_1C_2	385.21 ab	34.00 a
V_1C_3	435.68 a	34.67 a
V_3C_0	231.09 d	26.67 c
V_3C_1	304.52 c	32.00 ab
V_3C_2	344.79 bc	32.33 ab
V_3C_3	378.96 b	33.33 a
LSD $_{(0.05)}$	26.212	2.113
CV (%)	9.91	8.16

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

4.8.2.7 Grain yield Plant^{-1}

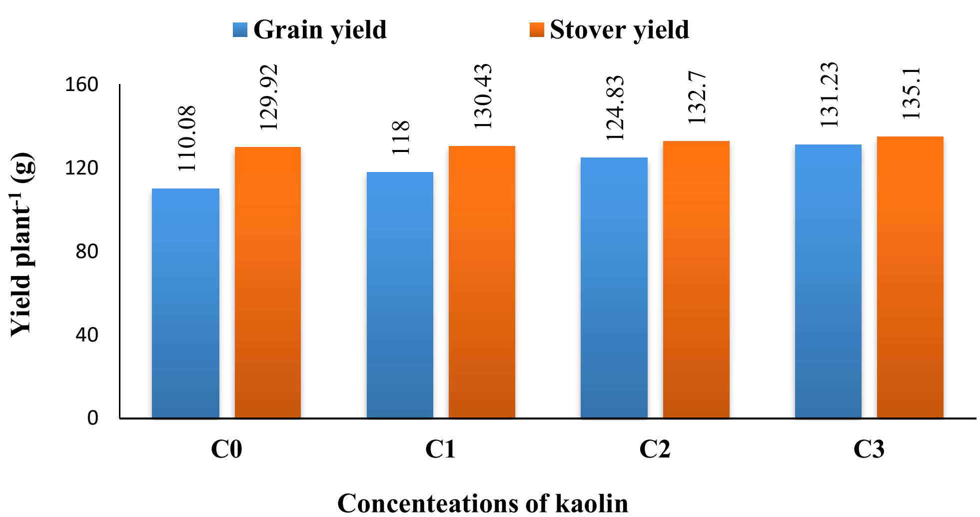
Grain yield plant^{-1} contributes to the economic yield as well as represents the productive efficiency of any cereal crop or crop variety. Grain yield plant^{-1} was significantly influenced by varieties, antitranspirant and their combination. The highest grain yield plant^{-1} (132.08 g) was reported from the treatments having V_1 followed by V_3 (110.30 g) (Figure 4.8.1). However, antitranspirant showed the significant effects on grain yield plant^{-1}. Among the various treatments, C_3 showed significantly highest grain yield plant^{-1} (131.23 g). C_0 was the lowest (110.30 g) grain producer (Figure 4.8.2).



Varieties: V_1= PSC-121 and V_3=Changnuo-1

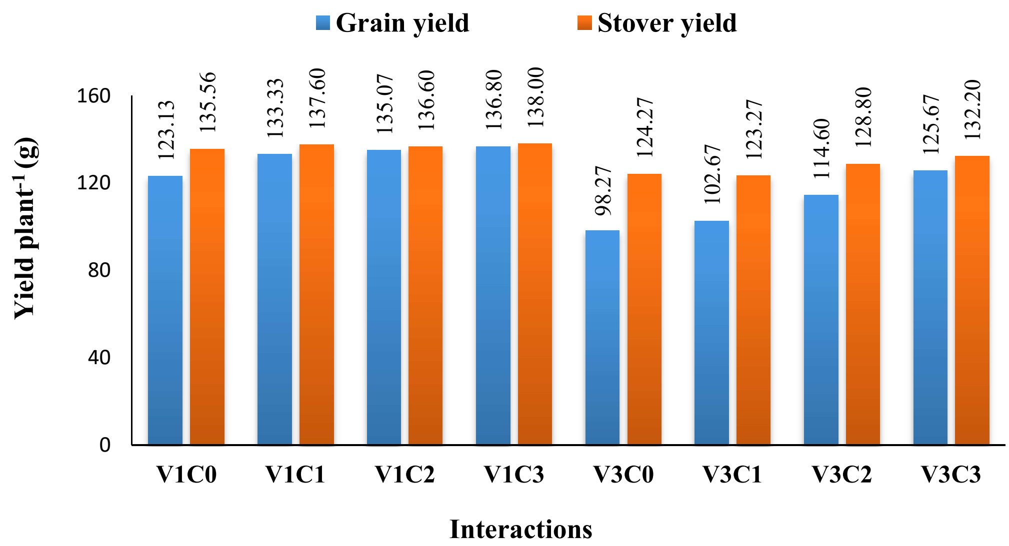
Figure 4.8.1 Effect of variety on grain yield and stover yield of white maize. During Rabi, 2017-2018 ($LSD_{0.05}$ = 1.032, 1.166 in grain yield and stover yield respectively)

Again, their combination effect revealed that V_1C_3 showed significantly the highest grain yield plant^{-1} (136.80 g) which was statistically identical to V_1C_1 (133.33 g) and V_1C_2 (135.07 g) (Figure 4.8.3). Among the treatments V_3C_0 (98.27 g) showed the very lowest grain yield Plant^{-1} which was statistically similar to V_3C_1 (102.67 g).



Concentrations of Kaolin: C_O = 0%, C_1= 2%, C2= 4% and C_3= 6%

Figure 4.8.2 Effect of concentrations of kaolin on grain yield and stover yield of white maize. During Rabi, 2017-2018 ($LSD_{0.05}$ =1.4594, 1.6490 in Grain yield and Stover yield respectively)



Varieties: V_1= PSC-121, V_3=Changnuo-1; Concentrations of Kaolin: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

Figure 4.8.3 Interaction effects of variety and concentrations of kaolin on grain yield and Stover yield of white maize. During Rabi, 2017-2018 (LSD $_{0.05}$ = 2.064, 2.332 in Grain yield and stover yield respectively)

4.8.2.8 Stover yield plant^{-1}

Stover yield plant^{-1} was significantly influenced by varieties, antitranspirant and their combination. The highest stover yield plant^{-1} (136.94 g) was reported from the treatments having V_1 followed by V_3 (127.13 g) (Figure 4.8.1). However, in antitranspirant showed the significant effects on stover yield plant^{-1}. Among the various treatments, C_3 showed significantly the highest stover yield plant^{-1} (135.10 g) which was statistically similar to C_2 (132.70 g). The C_0 was the lowest (129.92 g) stover yield plant^{-1} producer (Figure 4.8.2).

Moreover, their combination revealed that significantly V_1C_3 showed the highest stover yield Plant^{-1} (138.00 g) which was statistically identical to V_1C_0 (135.27 g), V_1C_1 (137.60 g) and V_1C_2 (136.60 g) (Figure 4.8.3). Among the treatments V_3C_1 (123.27 g) showed the very minimum stover yield plant^{-1} which was statistically similar to V_3C_0 (124.27 g).

4.8.2.9 Grain yield ha^{-1}

Grain yield or economic yield is an important characteristic and ultimate objective for which most of crops are grown. The varieties, antitranspirant and their combinations significantly influenced the grain yield of white maize. The highest grain yield (8.81 t ha^{-1}) was observed with the treatment V_1 and the lowest grain yield (7.35 t ha^{-1}) was achieved with the treatment V_3 (Table 4.8.9). For antitranspirant treatments highest grain yield (8.748t ha^{-1}) was achieved with the treatment C_3 and the lowest grain yield (7.38 t ha^{-1}) was C_0.

In respect of the interaction effect, the highest grain yield (9.12 t ha^{-1}) was achieved from the treatment V1C3 that similar to V_1C_2 (9.00 t ha^{-1}) and V1C1 (8.89 t ha^{-1}) (Table 4.8.10). From others treatments combinations, the lowest grain yield was observed for V_3C_0 (6.55 t ha^{-1}), which was statistically similar to V_3C_1 (6.84 t ha^{-1}) (Table 4.8.10). 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.

Table 4.8.9 Performance of white maize varieties and antitranspirant (Kaolin) concentrations on the yield and harvest index

Treatment	Grain yield (tha^{-1})	Stover yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
Effect of variety				
V_1	8.81 a	9.13 a	17.94 a	49.08 a
V_3	7.35 b	8.48 b	15.83 b	46.36 b
LSD $_{(0.05)}$	0.069	0.078	0.104	0.302
CV (%)	2.09	2.16	1.50	1.55
Effect of antitranspirant (Kaolin)				
C_0	7.38 d	8.67 b	16.04 d	45.88 c
C_1	7.87 c	8.70 b	16.56 c	47.33 b
C_2	8.32 b	8.85 ab	17.17 b	48.40 a
C_3	8.75 a	9.01 a	17.76 a	49.26 a
LSD $_{(0.05)}$	0.097	0.1099	0.147	0.427
CV (%)	2.09	2.16	1.50	1.55

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

V_1= PSC-121, V_3= Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

Table 4.8.10 Interaction effect of white maize varieties and antitranspirant (Kaolin) concentrations on the per hectare yield and harvest index

Treatment	Grain yield (tha^{-1})	Stover yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
V_1C_0	8.21 b	9.04 ab	17.25 b	47.60 bc
V_1C_1	8.89 a	9.17 a	18.06 a	49.21 a
V_1C_2	9.01 a	9.11 ab	18.11 a	49.71 a
V_1C_3	9.12 a	9.20 a	18.32 a	49.78 a
V_3C_0	6.55 d	8.28 de	14.84 d	44.16 d
V_3C_1	6.84 d	8.22 e	15.06 d	45.44 d
V_3C_2	7.64 c	8.59 cd	16.23 c	47.08 c
V_3C_3	8.38 b	8.81 bc	17.19 b	48.74 ab
LSD $_{(0.05)}$	0.138	0.156	0.207	0.603
CV (%)	2.09	2.16	1.50	1.55

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

V_1= PSC-121, V_3=Changnuo-1; Kaolin concentrations: C_O = 0%, C_1= 2%, C_2= 4%, C_3= 6%

4.8.2.10 Stover yield ha^{-1}

Stover yield was significantly influenced by varieties, antitranspirantand their combination. The highest stover weight (9.13 t ha^{-1}) was reported from the treatments having V_1 followed by V_3 (8.48 t ha^{-1}) (Table 4.8.9). However, antitranspirant showed the significant effects on stover yield. Among the various treatments, C_3 showed significantly highest stover yield (9.01 t ha^{-1}) which was statistically similar to C_2 (8.85 t ha^{-1}). The C_0 showed the lowest (8.66 t ha^{-1}) stover yield producer.

Moreover, their combination of variety and kaolin revealed that V_1C_3 showed significantly the highest stover yield (9.20 t ha^{-1}) which was statistically identical to V_1C_0 (9.04 t ha^{-1}), V_1C_1 (9.17 t ha^{-1}) and V_1C_2 (9.11 t ha^{-1}) (Table 4.8.10). Among the treatments V_3C_1 (8.217 t ha^{-1}) showed the lowest stover weight which was statistically similar to V_3C_0 (8.28 t ha^{-1}).

4.8.2.11 Biological yield ha^{-1}

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 significantly influenced by varieties, antitranspirant and their combination. The highest biological yield (17.94 t ha^{-1}) was reported from the treatments having V_1 followed by V_3 (15.83 t ha^{-1}) (Table 4.8.9). However, antitranspirant showed the significant effects on biological yield. Among the various treatments, C_3 showed significantly highest biological yield (17.756 t ha^{-1}). The C_0 was the lowest (16.04 t ha^{-1}) biological yield producer (Table 4.8.9).

Moreover, their combination of variety and kaolin revealed that V_1C_3 showed significantly the highest biological yield (18.32 t ha^{-1}) which was statistically identical to V_1C_0 (17.25 t ha^{-1}), V_1C_1 (18.05 t ha^{-1}) and V_1C_2 (18.11 t ha^{-1}) (Table 4.8.10). Among the treatments V_3C_0 (14.84 t ha^{-1}) showed the lowest biological yield which was statistically similar to V_3C_1 (15.062 t ha^{-1}).

4.8.2.12 Harvest Index (%)

Harvest index is the partitioning of dry matter by plant among economic yield and biological yield. Harvest index is a major contributor to total output of any crop and dependent upon crop management, type of variety and various other factors. Harvest index was significantly influenced by varieties, antitranspirant and their combination. The highest harvest index (49.08 %) was reported from the treatments having V_1 followed by V_3 (46.35 %) (Table 4.8.9). However, antitranspirant showed the significant effects on harvest index. Among the various treatments, C_3 resulted highest harvest index (49.26 %)) which was statistically similar to C_2 (48.40 %). The C_0 showed the lowest (45.88 %) harvest index producer (Table 4.8.9).

Moreover, their combination revealed that V_1C_3 showed significantly the highest harvest index (49.78 %) which was statistically similar to V_1C_1 (49.23 %) and V_1C_2 (49.71 %) (Table 4.8.10). Among the treatments V_3C_0 (44.16 %) showed the lowest harvest index which was statistically similar to V_3C_1 (47.077 %).

Antitranspirants can act as either physical or physiological barriers to water loss which may be a cause of the yield reduction through reduced photosynthesis as the CO_2 intake is interrupted by the applied antitranspirant. But under drought stress condition reduction in transpiration is helpful to preserve moisture in the plant tissue and so the reduced plant growth is not always disadvantageous (Khalil, 2006). Kaolin is a non-toxic aluminosilicate (Al4Si4O10 $(OH)_8$ clay mineral and when sprayed it decreased leaf temperature by increasing leaf reflectance and reduced transpiration rate more than photosynthesis in plants (Ibrahim and Selim, 2010).

Khalil *et al.* (2012) conducted an investigation under three soil moisture levels (85, 55, and 25% depletion of the available soil water), and four antitranspirant treatments (control, 6% kaolin, 6% MgCO3, and 6% kaolin + MgCO3) and reported that highest values in different plant characters were observed in plants watered with the highest soil moisture level (25% depletion of the available soil water) and which received 3% kaolin + 3% MgCO3. Metwally *et al*. (2002) reported that the application of antitranspirants significantly increased plant height, number of branches, and number of leaves/ plant as well as FW and DW of roselle (Hibiscus sabdariffa) plants. Khalil (2006) reported that all antitranspirants (film-forming, stomata and reflecting) significantly increased all growth parameters of sesame (Sesamumindicum) plants compared with the control treatment. Bafeel and Moftah (2008) suggested that a foliar spray with kaolin could lead to a reduction in the transpiration rate, which in turn maintained a higher water content in the plant tissues, thus directly affecting plant growth. Similar option was also reported by Cantore *et al*. (2009) and Ibrahim and Selim (2010).

4.8.3 Correlation study between antitransparent and yield contributing traits in white maize

Correlation studies provided information on the nature and extent of association between two pairs of metric characters. In the antitransparent experiment we found that application of Kaolin at varying concentrations had a significant effect on number of grains row^{-1} and other yield contributing traits in white maize (Table 4.8.5; Table 4.8.7; Figure 4.8.1). Therefore, to determine the extent and nature of relationship between the application of Kaolin and yield attributes, the correlation study was performed between antitransparent spray and yield contributing traits in white maize.

The correlation analysis showed that the number of grains row^{-1} was highly and positively correlated with application of Kaolin spray. The correlation coefficient (r) was 0.99 between number of grains row^{-1} and varying Kaolin concentrations (Table 4.8.5). The result indicated that with the increase of Kaolin concentrations the number of grains row^{-1} increased linearly and the relationship between them was very strong and positive. Brillante *et al*., (2016), El-Kholy *et al*., (2005a) also found strong correlation between application of antitrasperants and yield attributes.

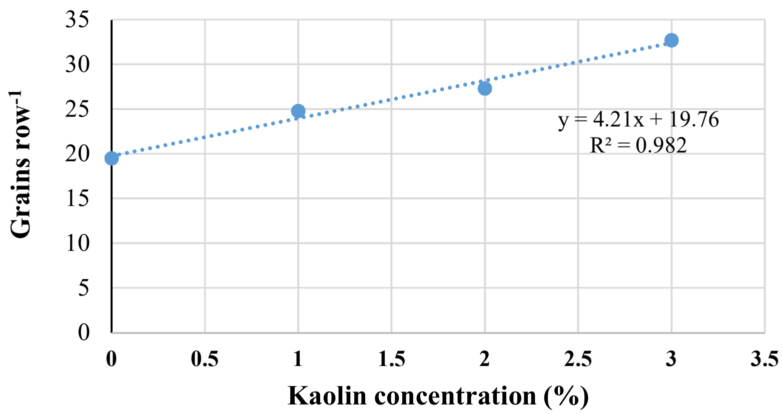


Figure 4.8.4 Relationship between grains row^{-1} and Kaolin concentration

Among the yield contributing traits the number of grains row^{-1} in cob is considered as a prime yield contributing traits in white maize because the increasing or decreasing trends of number of grains row^{-1} in cob mainly determines the other yield contributing traits e.g. number of grains cob^{-1}, grain yield and yield parameters. Therefore, to determine the extent and nature of relationship between number of grains row^{-1} in cob and other yield contributing traits e.g. number of grains per cob, grain yield and yield, the correlation analysis was performed.

In the present study we found that the number of grains row^{-1} had positive and strong correlation with number of grains cob^{-1}, grain yield and yield. The correlation coefficients (r) between number of grains row^{-1} and number of grains cob^{-1} was 0.98, indicating a very strong and positive linear relationship between the number of grains row^{-1} with number of grains cob^{-1} (Table 4.8.5 and Table 4.8.7). Again, the correlation analysis revealed that 100 grain yield and yield plant^{-1} had also positive and strong correlation with number of grains row^{-1}. The correlation coefficients (r) between number of grains row^{-1} and 100 grain yield was 0.91, while the correlation coefficients (r) between number of grains row^{-1} and yield plant^{-1} was 0.99 indicating a very strong and positive linear relationship between number of grains row^{-1} and 100 grain weight and between number of grains row^{-1} and yield plant^{-1} (Table 4.8.5 and Figure 4.8.1). The similar types of correlation studies waere reported by Pandey *et al.* (2017) and Mohammadi *et al.* (2003) in maize. Pandey *et al.* (2017) reported that number of grains row^{-1} (0.66) were positively and significantly associated with grain yield plant^{-1}.

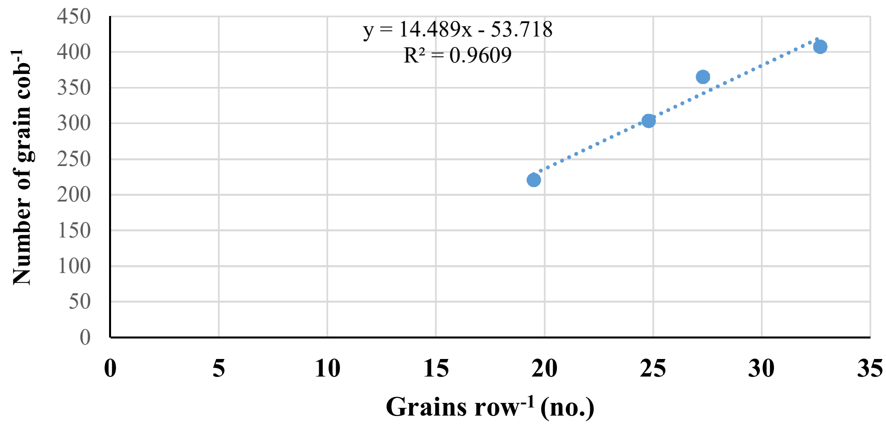


Figure 4.8.5 Relationship between number of grain cob^{-1} and Grains row^{-1}

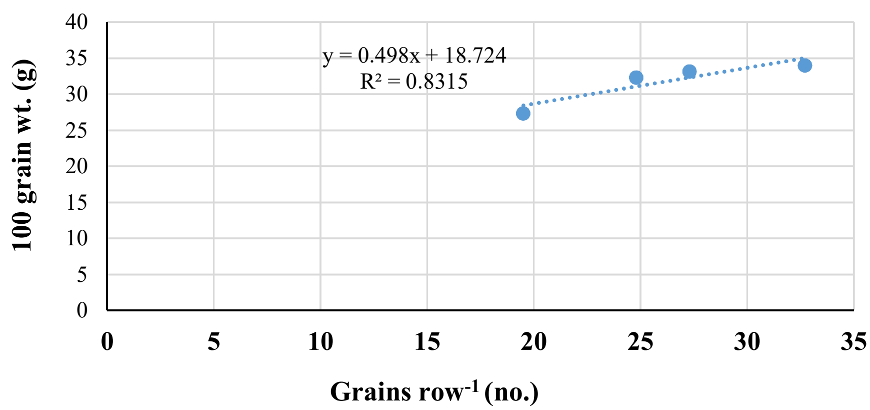


Figure 4.8.6 Relationship between 100 grain weight and Grains row^{-1}

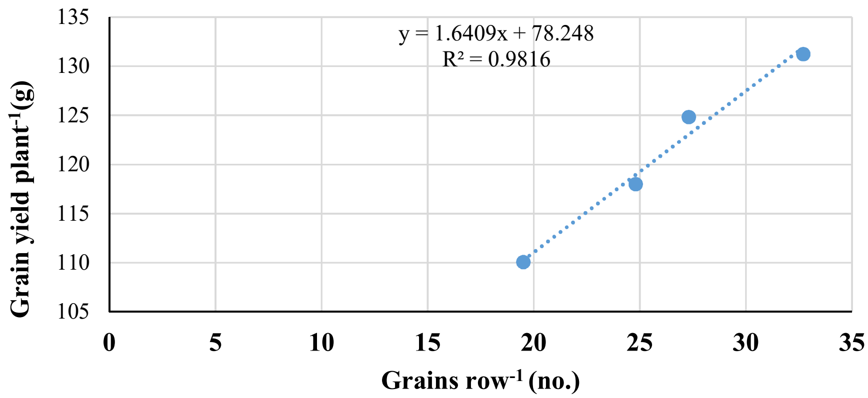


Figure 4.8.7 Relationship between grain yield plant^{-1} and grains row^{-1}

Antitranspirants reduced the transpiration rate and mitigate plant water stress by increasing the leaf resistance and diffusion water vapor (Desoky, *et al*. 2013). Kaolin increases the reflection of incident radiation and, as a related effect, it lowers temperatures and thus limits transpiration rate (Brillante *et al*. 2016.). Spraying plants with antitranspirants improving plant yield components under moderate water stress environments (Desoky *et al*. 2013). In the present investigation Kaolin applied was 1% at varying concentration (0%, 1%, 2%, and 3%) at tasseling stage and did not apply the irrigation to white maize field after tasseling stage which induced a moderate water stress environment at grain filling stage of the white maize plant. In the present investigation it was found that application of Kaolin increased the grain yield by 16 % (6% Kaolin) in comparing to the control (0% Kaolin) condition. The increase of grain yield after Kaolin application might help in the grain filling stage by conserving the water through limiting the transpiration rate in the grain filling. The positive and strong correlation coefficient (0.99) was observed between number of grains row^{-1} and varying Kaolin concentrations (Figure 4.8.5) support this notion.

Again, a strong correlation was found between number of grains row^{-1} and number of grains cob^{-1}, between number of grains row^{-1} and 100 grain and between number of grains row^{-1} and yield plant^{-1} (Figures 4.8.5, 4.8.6 and 4.8.7). The result indicted that the increase trends of number of grains row^{-1} due to Kaolin application increased yield contributing characters e.g. number of grains cob^{-1}, 100 grain weight and thus increased the yield. Thus the antitransparent Kaolin spray helped in mitigating the water stress conditions and thus helped in increasing the grain yield performance in white maize.

CHAPTER V

SUMMARY AND CONCLUSION

The study was carried out to identify suitable white maize variety(ies) for the production in Bangladesh, to select drought tolerant varieties at the reproductive stage and to review the drought management through limited irrigation and antitranspirant technology. Six varietal trials were carried out involving eight white maize varieties in two consecutive Rabi seasons of 2015-16 and 2016-17 at three different sites. One pot experiment was carried out in a polythene shed to examine the drought tolerance of six white maize varieties under varying irrigation regimes in 2017-18. Another experiment was conducted in field to evaluate the yield improvement of two white maize varieties to reduce transpiration loss through spraying an antitranspirant Kaolin at tasseling stage on foliage during the Rabi season of 2017-18.

In the first three experiments (Expt. 1-3) of 2015-16 Rabi seasons, eight varieties of white maize were tested at three sites such as Sher-e-Bangla Agricultural University (SAU), Dhamrai and Rangpur Sadar during Rabi 2015-16. The varieties were V_1 = PSC-121, V_2 = KS-510, V_3 = Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30. In the second year of 2016-17 Rabi season (Expt. 4-6), seven varieties of white maize (V_1 = PSC-121, V_3 = Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 = Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30) were tested in the above mentioned three sites. In the drought imposing trial (Expt. 7 in 2017-18) six variety of white maize such as V_1 = PSC-121, V_3 = Changnuo-1, V_5 = Changnuo-6, V_6 = Yungnuo-3000, V_7 = Yungnuo-7 and V_8 = Yungnuo-30 were grown at different irrigation regimes (T_1 =no watering from 80 DAS to harvest), T_2 =(no watering from 100 DAS to harvest) and T_C = control with irrigation at every day). In the antitranspirant trial (Expt. 8, 2017-18) through the application of Kaolin, two varieties (V_1- PSC-121, V_2=Changnuo-1) were tested under four concentrations of Kaolin (C_O = 0%, C_1=2%, C_2=4%, C_3=6%).

Experiment 1. Yield and yield attributes of different white maize varieties at SAU during Rabi 2015-2016

At 90 days, V_1 showed the highest plant height but there was no significant difference between the variety of V_2 (247.33 cm), V_3 (233.67 cm), V_5 (233.83 cm), V_6 (221.67 cm), V_7 (175.17 cm) and V_8 (232.33 cm). The lowest highest was in V_7 (175.17 cm) which was statistically similar to V_4 (184.50 cm). During harvesting, it was observed that the longest plant height showed in V_2 (263.13 cm) and the lowest was in V_7 (184.17 cm). The V_2 (263.13 cm) showed the highest plant height that was not significantly differed with the plant height of V_1 (261.33 cm).

During harvesting, significantly the maximum number of leaves plant^{-1} (19.08) was produced by the variety V_3 which was statistically similar to V_1 (18.00) and V_7 variety was the lowest performer (12.16). Although the lowest leaves plant^{-1} was in V_7 (12.16) but there was no significant difference observed among the varieties of V_8 (13.00) and V_5 (12.75). Likewise, V_2produced medium number of leaves plant^{-1} (15.083) but there was no significant difference between V_4 (13.75) and V_6 (14.16). The highest leaf area index was showed in V_1 (3.63) and the lowest in V_6 (1.84). The V_1 (3.63) should the highest leaf area index but there was no significant difference with the leaf area index of V_2 (3.45), V_3 (3.01) and V_8 (3.22). The lowest leaf area index was found in V_6 (1.84) which was not significantly differed with V_7 (2.44) and V_5 (1.90).

Among the treatments, V_8variety took significantly maximum days to tasseling (73.000 days) followed by V_2 (70.33 days), V_3 (70.00 days), V_1 (68.67 days), V_6 (68.67 days), V_4 (67.33 days) and V_5 (63.33 days) while V_7 (59.34 days) took significantly minimum days to tasseling (62.17 days). The highest maturity date was found in V_2 (143.67 days) and the lowest in V_7 (108.00 days). The V_2 (143.67) showed the highest days to maturity followed by V_1 (132.67 days), V_8 (127.67 days), V_6 (120.00days), V_3 (118.33 days), V_5 (115.67 days), V_4 (115.33 days).

The cob length was ranged from 12.63-15.80 cm depending on varieties showing the highest by V_5 and the lowest by V_7. Although the V_5had the highest cob length but there was no significant difference with the cob length of V_6 (15.40 cm), V_1 (15.10

cm), V_3 (15.10 cm), V_8 (14.95 cm) and V_4 (14.750 cm). The lowest cob length was found in V_7. Maximum cob breadth (16.97 cm) was found in V_4 but there was no significant difference observed among the varieties of V_5 (16.55 cm), V_8 (16.47 cm), V_3 (16.39 cm), V_6 (16.19 cm) and V_1 (16.03 cm). The minimum (12.35 cm) cob length was achieved with V_7. The Number of rows cob^{-1} was significantly influenced by varieties. Among the varieties, the maximum number of rows cob^{-1} was found in V_3 (14.53) which was statistically similar to V_4 and V_5 (13.80 and 13.77) whereas V_7 (12.00) found the lowest performance (12.25).

The highest number of grains $row^{-1}$was found in V_3 (31.60) and the lowest was in V_7 (22.90). The V_3 showed the highest number of grains row^{-1}but there was no significant difference observed between V_5 (31.53), V_2 (28.60) and V_8 (28.57). The second highest number of grain $row^{-1}$was in V_4 (27.27) that statistically similar to V_1 (26.73) and V_6 (26.33). The highest number of grains cob^{-1} was found in V_3 (413.00) and the lowest was in V_4 (323.00). The V_3 had the highest grain cob^{-1} but there was no significant difference observed between number of grains cob^{-1} of V_8 (412.69). The highest 100-grain weight was obtained with V_4 (36.00 g). The second highest 100-grain weigh was found in V_5 (34.00 g) which was statistically similar to V_3 (32.66). The lowest 100 grain weigh was found in V_6 (26.66 g) but there was no significant difference with V_2 (28.00).

The highest stover weight $plant^{-1}$ was found in V_1 (135.43 g) and the lowest in V_7 (83.83 g). The V_1 showed the highest stover yield $plant^{-1}$ that not significantly differed with V_2 (133.67 g). The second highest stover yield $plant^{-1}$ produced by V_8 (123.07 g) which was statistically similar to V_3 (128.73 g). Yield ranged from 6.16-8.62 t ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7. Likewise, stover yield was in the range of 6.26 t ha^{-1} - 9.03 t ha^{-1}depending on varieties showing the highest by V_1 and the lowest by V_7. The biological yield ranged from 12.37 t ha^{-1} - 17.27 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7. The harvest index was varied significantly due to varieties where V_5 showed the highest harvest index (49.58 %), which was statistically similar to V_3 (49.43 %), V_6 (49.57 %), V_7 (48.53 %) and V_8 (49.43 %).

Analysis of nutritional components of the varieties showed that V_1 (PSC-121) contained maximum fiber (2.92%), while V_3(Changnuo-1) contained maximum carbohydrate (75.13%) and apparent amylose content (AAC) (24.41 %). The highest amount of Glycemic Index (GI) was obtained in V_7 (Yangnuo-7) (71.24 %), while the other varieties showed glycemic index a bit over 60% (61-64%).Carbohydrates with a low GI value (55 or less) are more slowly digested, absorbed and metabolized and cause a lower and slower rise in blood glucose and, therefore usually, insulin levels. The variety V_1 (PSC-121) had the lowest GI (61%) indicating that this variety would be considered as low GI white maize variety.

Experiment 2. Yield and yield attributes of different white maize varieties at Dhamrai during Rabi, 2015-2016

During harvest, V_1showed the height plant height that was 252.89 cm. The lowest plant height was with V_7 (192.53 cm). Likewise, V_2 (235.79 cm) had medium plant height but there was no significant difference between V_4 (235.06 cm). The varieties showed significant difference for leaf area index where the highest leaf area index showed in V_8 (3.00) which was not significantly differed with the variety of V_2 (2.74) and V_1 (2.60). The lowest leaf area index was in V_6 (1.50) which was not significantly differed with V_5 (1.63), V_4 (1.74) and V_3 (1.02).

Among the treatments, V_8 variety took significantly maximum days to tasseling (75.45 days) followed by V_2 (66.57 days), V_3 (66.57 days), V_1 (65 days), V_6 (63.67 days) V_4 (66.56 days) and V_5 (62.56 days) while V_7 (53.6 days) took significantly minimum days to tasseling (62.1670 days). The latest maturity was found in V_2 (138.70 days) while the earliest was with V_7 (103.00 days). The V_2 (138.70 days) showed the highest days to maturity followed by V_1 (126.98 days), V_8 (122.65 days), V_6 (115.00days), V_3 (114.89 days), V_5 (111.07 days) and V_4 (110.73 days).

Although the V_3 showed the highest cob length but there was no significant difference observed with the cob length of V_2 (18.63 cm), V_5 (18.03 cm), V_8 (17.50 cm), V_4 (17.33 cm) and V_6 (17.53 cm). The highest cob breadth (17.07 cm) was found in V_8 but there was no significant difference founds between the varieties of V_1 (16.43 cm), V_6 (16.13 cm), V_2 (15.83 cm) and V_3 (15.80 cm). Among the varieties, the highest number of rows cob^{-1} was found in V_3 (14.53) which was statistically similar to V_4

(13.80) and V_5 (13.77), whereas V_7 (12.00) performed the poorest (12.25). The highest number of grain row^{-1} was found in V_5 (31.60) and the lowest was in V_7 (22.90). The highest number of grainscob^{-1}was found in V_2 (475.47) and the least was with V_7 (332.00).

The heaviest grain was found with V_5 (32.00 g) but there was no significant difference observed between V_3 (31.33 g), V_4 (30.67 g) and V_8 (30.67 g). Yield ranged from 90.67 g plant^{-1} to 136.93g plant^{-1} depending on varieties showing the highest with V_5 and the lowest with V_7. The heaviest stover was found in V_1 (180.30 g) and the lowest with V_7 (93.06 g). The V_1 (155.30 g) showed significantly the highest stover yield plant^{-1}having significantly higher values over the varieties of V_2 (148.03 g), V_5 (134.28 g), V_6 (121.63 g), V_3 (127.26 g), V_4 (102.23 g), V_8 (124.87 g) and V_7 (93.06 g). Significantly lightest stover was found in V_7 (93.06 g). Yield ranged from 6.05 t ha^{-1}- 9.13 t ha^{-1}depending on varieties showing the highest by V_5 and the lowest by V_7. The V_5showed the highest yield which was significantly highest among the varieties of V_2 (8.81 t ha^{-1}), V_1 (8.59 t ha^{-1}), V_3 (8.24 t ha^{-1}), V_6 (8.24 t ha^{-1}), V_8 (7.85 t ha^{-1}) V_4 (6.79 t ha^{-1}) and V_2 (6.05 t ha^{-1}). Significantly the lowest was in V_7 (6.05 t ha^{-1}).

Stover yield ranged from 6.20t ha^{-1}- 10.35 t ha^{-1}depending on varieties showing the highest by V_1 and the lowest by V_7. The V_1 (9.25 t ha^{-1}) showed significantly highest stover yield among the varieties of V_2(9.87 t ha^{-1}), V_5 (8.95 t ha^{-1}), V_6 (8.087 t ha^{-1}), V_3 (8.484 t ha^{-1}), V_4 (6.815 t ha^{-1}) and V_8 (8.325 t ha^{-1}). Significantly the lowest stover yield was found in V_7 (6.20 t ha^{-1}). Biological yield ranged from 12.25 t ha^{-1}- 18.94 t ha^{-1}depending on varieties showing the highest by V_1 and the lowest by V_7. The V_1 (17.83 t ha^{-1}) was significantly highest yielder but significantly differed with V_2 (18.68 t ha^{-1}). Significantly the highest harvest index was found in V_6 (49.80 %) and the lowest was in V_1 (45.34 %). The V_6 showed the highest harvest index but there was no significant difference observed among the harvest index of V_3 (49.28 %), V_4 (48.88 %), V_5 (49.15 %) and V_7 (49.35 %). The second highest harvest index was found in V_8 (48.52 %) which had no significant difference between V_3 (49.28 %), V_4 (48.88 %), V_5 (49.15 %) and V_7 (49.34 %). Significantly the lowest harvest index was V_1 (45.34 %).

Experiment 3. Yield and yield attributes of different white maize varieties at Rangpur during Rabi, 2015 -2016

Significantly maximum plant height (224.22 cm) was found in V_6 but there was no significant difference observed with of V_5 (222.22 cm). Significantly the maximum number of leaves plant^{-1} (13.89) was produced by the variety V_1 which was statistically similar to V_2 (13.56), V_3 (13), V_4 (12.78), V_8 (12.78) and V_6 (12.67). The V_7 variety showed significantly the lowest number of leaves (10.33). Among the treatments, V_2 variety took significantly longest days to tasseling (58 days) but there was no significant difference between the varieties of V_7 (57.67 days), V_3 (57 days) and V_5 (56.67 days). Significantly the lowest number of days to tasseling was found in V_6 (54.33 days) which was not significantly different with V_1 (54.67 days), V_4 (55.33 days) and V_8 (56 days). The V_2 variety took significantly longest time to be matured (101.67 days) which was statistically similar to V_6 (100.33 days). Significantly the shortest days to maturity was found in V_7 (86 days).

Although V_6 showed the highest cob length but there was no significant difference with those of V_3 (18.60 cm), V_4 (18.00 cm) and V_8 (17.67 cm). The lowest cob length was found in V_7 (16.00). Widest cob breadth (17.07 cm) was found in V_8 but there was no significant difference between the variety of V_1 (16.43 cm), V_6 (16.13 cm), V2 (15.83 cm) and V_3 (15.80 cm). The narrowest cob (14.933 cm) was found in $V_{4.}$ Among the varieties, the maximum number of rows cob^{-1} was found in V_5 (14.07) which however, was statistically similar to those of V_1 (13.17), V2 (12.54), V_3 (13.00), V_4 (12.80), V_6 (12.80) and V_7 (13.77). The treatment V_8 (11.60) showed the lowest number of rows cob^{-1}. The highest number of grain row^{-1} was found with V_3 (32.000) while the lowest with V_1 (25.300). The V_3 showed statistically similar highest grains row^{-1} (32.00). Significantly the lowest grains row^{-1} was observed in V_1 (25.30). The maximum number of grains cob^{-1} (418.87) was reported from the treatment V_3 which was then followed by V_1 (336.52), V_2 (334.33), V_4 (337.55), V_5 (393.69), V_6 (380.43) and V_7 (370.71) and V_8 was the lowest performer among others (326.21). Statistically V_1 (336.52), V_2 (334.33), V_4 (337.55) was the similar performer.

The varieties showed significant difference in 100-grain weight. The heaviest grain was observed in V_4 (28.67 g) which was not significantly higher than that of V_5 (27.33 g). The second highest 100- grain weigh was obtained with V_5 (27.33 g) which was statistically higher than those of V_1 (26.00 g), V_3 (26.00 g), V_7 (26.00 g) and V_8 (26.00 g). The lightest 100 grain weigh was found with V_2 (22.00 g). Yield ranged from 65.15g – 98.56 g depending on varieties showing the highest by V_3 and the lowest by V_2. The V_3 showed significantly highest grain yield plant^{-1}among the varieties ofV_1 (68.15 g), V_4 (86.42 g), V_5 (80.29 g), V_6 (77.78 g), V_7 (75.02 g) and V_8 (75.85 g). Significantly the lowest grain yield was found in V_2 (64.15 g plant^{-1}). The highest stover yield plant^{-1} was found in V_1(156.80 g) and the lowest was V_7 (74.94 g). The V_1had significantly highest stover yield plant^{-1}(156.80 g) over other varieties such as, V_2 (144.13 g plant^{-1}), V_3 (106.03 g plant^{-1}), V_4 (100.50 g plant^{-1}), V_5 (129.08 g plant^{-1}), V_6 (100.93 g plant^{-1}) and V_8 (108.40 g plant^{-1}) while, significantly lowest was found in V_7 (74.94 g plant^{-1}).

Yield ranged from 4.54 - 6.35 t ha^{-1} depending on varieties showing the highest with V_3 and the lowest by V_1. The V_3showed the highest yield which was significantly superior among the varieties such as V_2 (4.66 t ha^{-1}), V4 (6.14 t ha^{-1}), V_5 (5.40 t ha^{-1}), V_6 (5.43 t ha^{-1}), V_7 (5.00 t ha^{-1}) and V_8 (5.06 t ha^{-1}). While, significantly the lowest yield was in V_1 (4.54 t ha^{-1}). The V_1 (10.45 t ha^{-1}) showed significantly highest stover yield among the variety of V_2 (9.61 t ha^{-1}), V_3 (7.07 t ha^{-1}), V_4 (6.70 t ha^{-1}), V_5 (8.61 t ha^{-1}), V_6 (6.73 t ha^{-1}) and V_8 (7.23 t ha^{-1}). Significantly the lowest yield was found in V_7 (5.00 t ha^{-1}). Biological yield ranged from 9.99 – 15.17 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7. The V_1 (15.169 t ha^{-1}) showed significantly highest biological yield among the varieties of V_2 (13.49t ha^{-1}), V_3 (13.64 t ha^{-1}), V_4 (12.47 t ha^{-1}), V_5 (13.96 t ha^{-1}), V_6 (11.91 t ha^{-1}) and V_8 (12.29 t ha^{-1}). The second highest biological yield was with V_5 (13.99 t ha^{-1}) which was not significantly differed with those of V_3 (13.64 t ha^{-1}). The V_7 (10.00 t ha^{-1}) showed significantly the lowest yield. Significantly the highest harvest index was found in V_7 (49.93 %) and the lowest was in V_1 (31.09 %). The second highest harvest index was found in V_3 (48.18 %).

Experiment 4. Yield and yield attributes of different white maize varieties at SAU during Rabi, 2016-2017

During harvesting, significantly the longest plants (209.00 cm) were produced by the variety V_1 which however, was similar to that of the variety V_8 (202.40 cm). The maximum number of leaves plant^{-1} (7.33) was produced by the variety V_8. The variety V_1 and V_4 (6.67) showed significantly lower values in number of leaf. During harvesting, leaf area index showed significant effect among the eight varieties. Where V_6 (3.68) showed the height leaf area index which was not significantly differed with the varieties of V_1 (3.26), V_3 (3.31), V_4 (3.296), V_5 (3.54) and V_8 (3.59). Lowest leaf area index was V_7 (2.62).

Among the treatments, V_8 variety took significantly maximum days to tasseling (76.00 days) followed by V_1 (70.03 days), V_3 (71.89 days), V_4 (69.45 days), V_5 (67.34 days), V_6 (66.78 days) and V_7 (61.34 days) while V_7 (61.34 days) took significantly minimum days to tasseling. The varieties had significant difference on days to maturity. The highest was found in V_1 (132.15 days) and the lowest was in V_7 (110.45 days). The V_1(132.15 days) showed the highest days to maturity but not significantly differed with the maturity date of V_8 (128.96 days).

Cob length ranged from 15.00-18.07 cm depending on varieties showing the highest by V_6 and the lowest by V_7. Maximum cob breadth (16.97 cm) was found in V_4 but there was no significant difference observed between the variety of V_1 (16.03 cm), V_5 (16.55 cm), V_6 (16.02 cm) and V_8 (16.41 cm). The minimum cob breadth (12.35 cm) was achieved with V_7. Number of rows cob^{-1} was not significantly influenced by varieties. Among the varieties, the maximum number of rows cob^{-1} was found in V_4 (13.40) and V_8 (12.73) was the lowest performer. The highest number of grains row was found in V_1 (32.53) and the lowest was in V_7 (23.47). The V_1 showed the highest grains row^{-1}but there was no significant difference between number of grains row^{-1} of V_5 (30.87) and V_6 (32.00). The V_1 showed the highest grains cob^{-1} but there was no significant difference with the number of grain per cob of V_5 (419.35).

Significantly the highest 100-grain weight observed with V_4 (42.67 g) which was not significantly different with the varieties of V_3 (40.33 g) and V_1 (40.00 g). The highest grain yield plant^{-1} was found in V_1 (154.57 g) and the lowest was V_7 (101.45 g). The highest number of Stover yield plant^{-1} was found in V_1 (157.77 g) and the lowest was in V_7 (104.83 g). Yield ranged from 6.77-10.31 t ha^{-1} depending on varieties showing the highest by V_1 and the lowest by V_7. The V_1 variety took significantly maximum grain yield (10.31 t ha^{-1}) followed by V_3 (9.89 t ha^{-1}), V_4 (9.95 t ha^{-1}), V_5 (9.97 t ha^{-1}), V_6 (9.48 t ha^{-1}) and V_8 (9.63 t ha^{-1}) while V_7 (6.76 t ha^{-1}) took significantly minimum grain yield. The V_1 showed significantly the highest stover yield among the variety of V_3 (10.21 t ha^{-1}), V_4 (10.32 t ha^{-1}), V_5 (10.10 t ha^{-1}), V_6 (9.65 t ha^{-1}), V_7 (6.99 t ha^{-1}) and V_8 (10.19 t ha^{-1}). Statistically V_7 (6.99 t ha^{-1}) showed the lowest stover yield. The V_1 (20.82 t ha^{-1}) showed highest Biological yield. The second highest biological yield was 20.27 t ha^{-1}which was statistically similar with the variety of V_3 (20.09). The V_5 showed significantly the highest harvest index (49.674 %) and V_8 variety was the lowest (48.612 %) performer.

Experiment 5. Yield and yield attributes of different white maize varieties at Dhamrai during Rabi, 2016-2017

During harvesting, significantly the maximum plant height (214.67 cm) was observed in the variety V_3 which was not significantly differed with the variety of V_5 (213.33) and V_6 (211.33). The maximum number of leaves plant^{-1} (15.08) was produced by the variety V_1 which was statistically similar to that of V_8 (14). The V_7 variety was the lowest performer (10.33). During the V_1 (2.99) showed highest leaf area index which was not significantly differed with the varieties of V_3 (2.50) and V_4 (2.66). The lowest leaf area index was in V_6 (1.74) which was not significantly differed with the varieties of V_5 (2.33), V_7 (2.08) and V_8 (1.91).

Among the treatments, V_8 variety took significantly maximum days to tasseling (80.00 days) followed by V_1 (74.03 days), V_3 (75.89 days), V_4 (73.45 days), V_5 (71.34 days), V_6 (70.78 days) and V_7 (63.67 days) while V_7 (63.67 days) took significantly minimum days to tasseling. The V_1 (132.15) showed the highest days to maturity followed by V_3 (125.78 days), V_4 (121.73 days), V_5 (121.18 days), V_6 (127.56 days), V_7 (110.78 days) and V_8 (132.96 days). The V_7 (110.78 days) showed significantly lowest days to maturity among the varieties.

Cob length ranged from 12.90 -18.93 cm depending on varieties showing the highest by V_3 and the lowest by V_1. The maximum cob breadth (17.07 cm) was found in V_8

but it was not significantly differed with the variety of V_1 (16.43 cm). The highest number of rows cob^{-1} was found in V_3 (13.40) and the lowest was in V_7 (10.00). The V_3 (13.400) showed significantly the highest row cob^{-1}but there was no significant difference observed with V_1 (11.67). The V_3 showed the highest grains row^{-1}but there was no significant difference observed with V_6 (32.53).

The highest number of grains cob^{-1} was found in V_3 (470.01) and the lowest was in V_7 (204.21). The V_3 showed highest grains cob^{-1} but there was no significant difference among the number of grain cob^{-1} of V_1 (407.67) and V_6 (426.19). The highest 100-grains yield was found in V_6 (31.67 g) which was not significantly differed with the varieties of V_1 (30.00 g), V_3 (31.33g), V_4 (27.85 g), V_5 (30.33 g) and V_8 (28.78 g). Significantly the lowest 100 grain yield was found to that of V_7 (26.67 g).

The highest stover yield plant^{-1} was found in V_5 (146.72 g) and the lowest in V_7 (74.36 g). Yield ranged from 3.76-8.44 t ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7. The V_3 variety showed significantly maximum grain yield (8.44 t ha^{-1}) followed by V_1 (7.74 t ha^{-1}), V_4 (5.76 t ha^{-1}), V_5 (6.54 t ha^{-1}), V_6 (7.89 t ha^{-1}) and V_8 (6.06 t ha^{-1}) while V_7 (3.76 t ha^{-1}) showed significantly minimum grain yield. The V_5 showed significantly highest stover yield among the variety of V_1 (9.09 t ha^{-1}), V_3 (8.70 t ha^{-1}), V_4 (6.09 t ha^{-1}), V_6 (8.11 t ha^{-1}), V_7 (4.96 t ha^{-1}) and V_8 (7.04 t ha^{-1}). Statistically V_7 (4.96 t ha^{-1}) showed lowest stover yield. Biological yield ranged from 8.713 -17.135 t ha^{-1} depending on varieties showing the highest by V_3 and the lowest by V_7. Harvest index ranged from 40.03 % - 49.28 % depending on varieties showing the highest by V_3 and the lowest by V_5.

Experiment 6. Yield and yield attributes of different white maize varieties at Rangpur during Rabi, 2016-2017

The V_1 (263.33 cm) was the highest performer among the variety of V_3(235.06 cm), V_4 (219.60 cm), V_5 (219.17 cm), V_6 (228.23 cm), V_7 (186.17 cm) and V_8 (249.27 cm). During harvest, significantly the maximum number of leaves plant^{-1} (12.73) was produced by the variety V_6 which was statistically similar to those of V_1 (12.53), V_3 (12.60), V_4 (12.33), V_5 (12.00), V_7 (10.07) and V_8 (12.40). The V_7 variety was the lowest performer (10.07). The V_8 (3.07) showed the height leaf area index lowest leaf area index was V_6 (1.68). The lowest leaf area index was in V_6 (1.68) which was not significantly differed among the varieties of V_3 (1.99), V_4 (1.99), V_5 (1.79) and V_6 (1.68).

Among the treatments, V_4 variety took significantly maximum days to tasseling (78.34 days) followed by V_1 (76.67 days), V_3 (70.45 days), V_5 (73.67 days), V_6 (75.67 days) , V_7 (65.67 days) and V_8 (76.03 days). The V_4 showed maximum days to tasseling but there was no significant difference observed among the variety of V_1 (76.67 days), V_5 (73.67 days), V_6 (75.67 days) and V_8 (76.03) while V_7 (65.67 days) took significantly minimum days to tasseling. The longest days to maturity were found in V_1 (132.15 days) and the lowest was in V_7 (110.45 days). The V_1 (137.15) showed the highest days to maturity but which was not significantly differed with the maturity date of V_8 (132.96 days). V_1 (132.15 days) showed the longest days to maturity followed by V_3 (125.78 days), V_4 (121.73 days), V_5 (121.18 days), V_6 (127.56 days), V_7 (110.78 days) and V_8 (132.96 days). The V_7 (110.78 days) showed significantly shortest days to maturity among the varieties.

Although the V_3 showed the highest cob length but there was no significant difference found with the cob length of V_5 (19.10 cm). The second highest cob length was in V_5 (19.10 cm) which was statistically similar to that of V_6 (18.53 cm) and V_8 (18.50 cm) and the lowest cob length was in V_7(12.90). Maximum cob breadth (17.07 cm) was found in V_8 but there was no significant difference between the variety of V_1 (16.43 cm), V_3 (15.80 cm) and V_6 (16.13 cm). The minimum (14.93 cm) cob breadth was significantly achieved with V_7.

The V_8 (13.33) showed the highest rows cob^{-1} but there was no significant difference observed V_1 (13.17), V_3 (12.87), V_5 (12.67) and V_6 (13.20). The fewest rows cob^{-1} was V_4 (11.67) which was statistically similar to that of V_7 (12.00). The V_3 should highest grains row^{-1} but there was no significant difference found between number of grain per row of V_5 (34.47). The second highest number of grains row^{-1} was in V_5 (34.47) which was statistically similar to that of V_4 (30.33) and V_8 (30.47).

The highest number of grains cob^{-1} was found in V_3 (452.72) and the fewest in V_7 (338). The V_3 (452.72) should the highest grains cob^{-1} but there was no significant difference with the number of grains cob^{-1} of V_5 (436.61). The highest 100-grain weight was exhibited by V_8 (39.67 g) which was not significantly differed with the varieties of V_1 (39.00 g) and V_3 (38.33 g). The lightest 100 grain weigh was found in V_7 (28.66 g) but there was no significant difference with V_4 (30.10 g). The highest grain yield plant^{-1} was found in V_3 (182.47 g) and the lowest was in V_7 (100.11 g). The second highest grain yield plant^{-1} was in V_6 (118.33 g) that statistically similar to that of V_1 (157.13 g), V_5 (161.73 g) and V_8 (154.87 g). The heaviest stover plant^{-1} was found in V_3 (188.68 g) and the lowest was V_7 (123.61 g). Significantly the second highest stover yield plant^{-1} was observed in V_1 (167.63 g) which was statistically similar to that of V_5 (165.63 g).

Yield ranged from 6.67-12.16 t ha^{-1}depending on varieties showing the highest by V_3 and the lowest by V_7. The V_3 variety gave significantly highest grain yield (12.16 t ha^{-1}) followed by V_1 (10.48 t ha^{-1}), V_4 (7.84 t ha^{-1}), V_5 (10.78 t ha^{-1}), V_6 (9.35 t ha^{-1}) and V_8 (10.32 t ha^{-1}) while V_7 (6.67 t ha^{-1}) gave significantly minimum grain yield. The V_3 showed highest stover yield among the varieties of V_1 (11.18t ha^{-1}), V_4 (8.07t ha^{-1}), V_5 (9.69t ha^{-1}), V_6 (9.69 t ha^{-1}), V_7 (8.24 t ha^{-1}) and V_8 (10.63 t ha^{-1}). The V_7 (8.24 t ha^{-1}) showed lowest stover yield. The V_3 (24.743 tonha^{-1}) showed highest Biological yield among the variety of V_1 (21.65 t ha^{-1}), V_4 (15.92 t ha^{-1}), V_5 (21.83 t ha^{-1}), V_6 (19.04 t ha^{-1}), V_7 (14.92 t ha^{-1}), V_8 (20.96 t ha^{-1}). The second highest biological yield was found in V_5 (21.83 t ha^{-1}) which was statistically similar with V_1 (21.65 t ha^{-1}). The V_7 (14.92 t ha^{-1}) should significantly the lowest biological yield.

The V_5 showed the highest harvest index (49.39 %) and V_7 variety was the lowest (44.75 %). Although V_5 showed significantly highest harvest index, there was no significant difference among the variety of V_1 (48.38 %), V_3 (49.15 %), V_4 (49.28 %), V_6 (49.10 %) and V_8 (49.28 %).

Experiment 7. Yield performance of white maize varieties under varying soil moisture regimes (2017-2018)

The interaction of V_1S_2 showed significantly the tallest plants (230.00 cm), which was statistically similar to V_1S_1 (202.50cm), V_1S_C (211.25cm), V_3S_2 (201.25cm), V_3S_C (203.75cm), V_5S_1 (188.00cm), V_5S_2 (200.75cm), V_5S_C (202.50cm), V_6S_1 (207.50 cm), V_6S_2 (219.25 cm) and V_6S_C (216.25 cm). The V_7S_1 showed significantly the shortest (167.50 cm) plants. The combination of V_6S_C (15.00) showed significantly the highest number of leaves plant^{-1}. Among the treatments, V_7S_1 showed significantly lowest number of leaves plant^{-1} (10.25) which was statistically similar to V_7S_2 (10.50) and V_7S_C (11.00). The combination of V_1S_C (5.71) showed the highest leaf area index. V_7S_1showed the lowest (2.396).

Among the interaction treatments of variety and water stress, it was observed that V_3S_Ctreatment showed the highest cob length (18.00 cm), which was statistically similar to V_5S_C (17.25 cm) and V_6S_C (17.00 cm). Among the other treatments, V_7S_2 showed significantly the lowest cob length (13.63 cm). The combination ofV_3S_Cshowed significantly the highest number of grains row^{-1}(30.25) than the other combinations, that was statistically similar to V_1S_2(27.25), V_3S_2 (28.00), V_5S_C (28.75) and V_7S_2(25.00). The V_1S_1showed significantly the minimum number of grains row^{-1} (9.50). The combination ofV_3S_Cshowed the highest number of grains cob^{-1} (530.00) and V_1S_1 showed the lowest number of grains cob^{-1} (170.00).

For their combinations, maximum grain yield plant^{-1} (108.50 g) was recorded from treatment $V_5S_c$and the minimum grain yield plant^{-1} was observed from V_6S_1 (35.75 g) and it was statistically similar to V_8S_1 (40.50 g). The maximum stover yield plant^{-1}(143.08 g) was recorded from treatment V_1S_C which was statistically similar to V_3S_C (134.92 g) and the minimum stover yield plant^{-1}was found from V_7S_1(66.58 g).

In regards to the interaction effect, maximum grain yield (7.23 t ha^{-1}) was found from treatment V_5S_C which was not significantly differed with V_3S_2 (6.62 t ha^{-1}), V_3S_C (6.88 t ha^{-1}), V_6S_2 (6.53 t ha^{-1}) and V_6S_C (7.00t ha^{-1}). The maximum stover yield (9.54 t ha^{-1}) was shown by V_1S_C which was statistically similler to V_3S_C (8.99 t ha^{-1}) and the minimum was revealed fromV_5S_1 (4.44 t ha^{-1}). The maximum biological yield (15.87 t ha^{-1}) and (15.67 t ha^{-1}) were produced respectively by V_3S_C and V_5S_C which although was not significantly differed with V_1S_C (15.46 t ha^{-1}), V_6S_C (15.28t ha^{-1}) and the minimum was found inV_6S_1 (7.67 t ha^{-1}) which was statistically similar to V_7S_1 (8.21 t ha^{-1}). The V_7S_2 combination showed the highest harvest index (49.47 %), which was statistically similar to V_7S_C, V_7S_1, V_6S_C, V_6S_2, V_5S_C and V_3S_2 (48.84 %, 45.85 %, 45.80 % ,49.20 % ,46.19 % and 46.62 % respectively). The minimum harvest index was given by with V_8S_1 combination (29.66 %).

Experiment 8. Effect of antitranspirant application on the growth and yield of white maize at tasseling stage

The interaction treatments were seen to have significant effect were V_1C_3 showed the tallest plants (240.80 cm), which was similar to V_1C_1(238.40 cm). The V_3C_3 showed significantly the shortest (204.87 cm) plants but there was no significant difference with the variety of V_3C_0 (213.25 cm). The highest number of leaves plant^1 was produced by V_3C_0 (13.57) and lowest by V_1C_2 (11.80).

The V_3C_2 combination showed significantly the highest cob length (15.48 cm), which was similar to V_3C_3 (15.00 cm) and V_3C_0 (14.95 cm). Among the other treatments, V_1C_1 showed significantly the lowest cob length (13.40 cm) which was statistically similar to V_1C_2 (12.93). The V_1C_1 showed significantly the highest cob length (15.73 cm), which was statistically similar to V_1C_3 (15.70 cm). Among the other treatments, V_1C_0 showed the lowest cob length (14.38 cm) which was statistically similar toV_1C_2 (12.93). The V_1C_3 showed significantly the highest rows cob^{-1} (13.53), which was statistically similar to V_1C_1 (13.13), V_1C_2 (13.40), V_3C_2 (13.40) and V_3C_0 (11.87). Among the other treatments, V_1C_0 showed the lowest number of rows cob^{-1} (10.73).

The V_3C_3treatment showed significantly the highest number of seeds row^{-1} (33.20), which was statistically similar to V_1C_3 (32.20). Among the other treatments, V_3C_0 showed the lowest number of seeds row^{-1} (19.40) which was statistically similar to V_1C_0 (19.60). The V_3C_3 combination showed significantly the highest number of seeds row^{-1} (33.20), which was statistically similar to V_1C_3 (32.20). Among the other treatments, V_3C_0 showed the lowest number of seeds row^{-1} (19.40) which was statistically similar to V_1C_0 (19.60).

The V_1C_3 showed significantly the highest grain yield plant^{-1} (136.80 g) which was statistically similar to V_1C_1 (133.33 g) and V_1C_2 (135.07 g). Among the interactions V_3C_0 (98.27 g) showed the lowest grain yield plant^{-1} which was statistically similar to V_3C_1 (102.67 g). The V_1C_3 showed significantly the highest stover yield plant^{-1} (138 .00 g) which was statistically similar to V_1C_0 (135.27 g), V_1C_1 (137.60 g) and V_1C_2(136.60 g). Among the treatments V_3C_1 (123.27 g) showed the lowest stover yield Plant^{-1} which was statistically similar to V_3C_0 (124.27 g).

The highest grain yield (9.12 t ha^{-1}) was found from treatment V_1C_3 which was not significantly differed with V_1C_1 (8.89t ha^{-1}) and V_1C_2 (9.00t ha^{-1}). From others treatments combinations, the minimum grain yield was observed for V_3C_0 (6.55 t ha^{-1}), which was statistically similar to V_3C_1 (6.84 t ha^{-1}). The V_1C_3 showed significantly the highest stover yield (9.20t ha^{-1}) which was statistically similar to V_1C_0 (9.04t ha^{-1}), V_1C_1 (9.17t ha^{-1}) and V_1C_2 (9.11t ha^{-1}). Among the treatments, the V_3C_1 (8.22t ha^{-1}) showed the minimum stover weight which was statistically similar to V_3C_0 (8.28t ha^{-1}). The V_1C_3 showed significantly the highest biological yield (18.320 t ha^{-1}) which was statistically similar to V_1C_0 (17.25t ha^{-1}), V_1C_1 (18.05t ha^{-1}) and V_1C_2 (18.11t ha^{-1}). Among the treatments V_3C_0 (14.84t ha^{-1}) showed the minimum biological yield which was statistically similar to V_3C_1 (15.06t ha^{-1}). The V_1C_3 showed the highest harvest index (49.783 t ha^{-1}) which was statistically similar to V_1C_1 (49.23t ha^{-1}) and V_1C_2 (49.71t ha^{-1}). Among the treatments V_3C_0 (44.16t ha^{-1}) showed the minimum harvest index which was statistically similar to V_3C_1 (47.08t ha^{-1}).

In antitransparent experiment, application of Kaolin increased the grain yield by 16 % (6% Kaolin) in comparing to the control (0% Kaolin) condition. The increase of grain yield after Kaolin application might help in the grain filling stage by conserving the water through limiting the transpiration rate in the grain filling stage. The positive and strong correlation coefficient (r) 0.99 was observed between number of seeds row^{-1} and varying Kaolin concentrations support this notion. Again, a strong correlations observed between number of grains row^{-1} and number of grains cob^{-1}, between number of seeds row^{-1} and 100 grain weight and between number of seeds row^{-1} and yield $plant^{-1}$. The result indicted that the increased trends of number of grains row^{-1} due to Kaolin application increased yield contributing characters e.g. number of grains cob^{-1}, 100 grain weight and thus increased the yield. Thus the antitransparent Kaolin spray helped in mitigating the water stress conditions and thus helped in increasing the grain yield performance in white maize.

Conclusion

The study was carried out to identify suitable white maize variety(ies) for the production in Bangladesh and to select drought tolerance of the varieties at the reproductive stage and to review the drought management through limited irrigation and antitranspirant technology. Six varietal trials were carried out involving eight white maize varieties in first year and seven varieties in 2nd year in two consecutive Rabi seasons of 2015-16 and 2016-17 at three different sites. One pot experiment was carried out in a polythene shed to examine the drought tolerance of six white maize varieties under varying irrigation regimes in 2017-18. Another experiment was conducted in field to evaluate the yield improvement of two best performers white maize varieties to reduce transpiration loss through spraying an antitranspirant Kaolin at tasseling stage on foliage during the Rabi season of 2017-18.

In the first three experiments of 2015-16 Rabi seasons (Expt. 1-3), eight varieties of white maize were tested at three sites such as Sherr-e-Bangla Agricultural University (SAU), Dhamrai and Rangpur Sadar during rabi 2015-16. The varieties were V_1 = PSC-121, V_2=KS-510, V_3 =Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6= Yangnuo-3000, V_7= Yangnuo-7 and V_8= Yangnuo-30. Results showed that out of eight varieties at SAU, five varieties were at par showing statistically similar seed yields (t ha^{-1}) although there were marked differences among them, such as PSC-121(8.26), Q-Xiangnuo-1 (7.17), Changnuo-1 ((8.62), Changnuo-6 (8.52) and Yangnuo-30 (8.35). That is except Q-Xiangnuo-1, all of the five good performing varieties had grain yields over 8 t ha^{-1}. At Dhamrai, four out of eight varieties showed significantly higher grain yields over others showing yields over 8 t ha^{-1}such as PSC-121 (8.59), KS-510 (8.81), Changnuo-1 (8.24) and Changnuo-6(9.13). But at Rangpur only two out of eight varieties yielded significantly higher grain yields such as Changnuo-1 (6.65) and Q-Xingnuo-1 (6.14). Over all, it was observed that the variety Changnuo-1 proved to be the good performer at all the sites. Others except the KS-510 not performed well at least two sites. The variety KS-510 did good performance only at Dhamrai.

In the second year of 2016-17 Rabi season (Expt. 4-6), seven varieties of white maize (V_1 = PSC-121, V_3 =Changnuo-1, V_4 = Q- Xiangnuo-1, V_5 = Changnuo-6, V_6 =

Yangnuo-3000, V_7 = Yangnuo-7, V_8 = Yangnuo-30) were tested in the above mentioned three sites. In the trials, the variety KS-510 was omitted due to its poor performance in two sites. Although not documented by data, this variety showed heterogeneity in the field in respect of tasselling, silking and maturity which might cause an extra cost to the farmers for harvesting at different times. Results showed that three out of seven white maize varieties, PSC-121 at SAU, while Changnuo-1 both at Dhamria and Rangpur gave significantly the highest grain yields respectively showing 10.31, 8.45 and 12.16t ha^{-1}.

Considering the two years results across three sites, it may be explained that the variety Changnuo-1 was the only genotype which performed good at all the sites showing grain yield range of 6.65-8.62t ha^{-1}. The variety PSC-121 performed good at SAU and Dhamrai in the first year, while only at the SAU site in the second year and the range of the grain yield over these two years were 8.26-10.31t ha^{-1}. Along these two years, the variety Q-Xinagnuo-1 was a good performer in the first year at SAU showing grain yield of 7.17 and at Rangpur with the grain yield of 6.14 which did not perform good in the second year. Likewise, in the first year and Changnuo-6 in the first year performed good showing 8.52t ha^{-1}at SAU, while 9.13t ha^{-1}at Dhamrai which in the second year did not perform good. KS-510 was found to be the best performer in the first year at Dhamrai showing the grain yield of 8.81t ha^{-1}. Likewise, the variety Yangnuo-30 performed well in the first year at SAU showing the grain yield of 8.35t ha^{-1}. Other two varieties not performed well at nowhere showing the least seed yield ranges by Yangnuo-7 from 3.76 (at Dhamrai in 2016-17) to 6.74t ha^{-1} (at Rangpur in 2016-17) while by Yangnuo-3000 from 6.54 (at Dhamrai in 2016-17) to 9.48t ha^{-1}(at SAU in 2016-17).

So, it may be concluded that the variety Changnuo-1 at all the site was the best performer showing the grain yield range of 6.65-12.17t ha^{-1} while PSC-121 at SAU was the second best performer (8.26-10.31t ha^{-1}).

In the drought imposing trial (Expt. 7 in 2017-18) six varieties of white maize such as V_1 = PSC-121, V_3 = Changnuo-1, V_5 = Changnuo-6, V_6 = Yungnuo-3000, V_7 = Yungnuo-7 and V_8 = Yungnuo-30 were grown at different irrigation regimes (S_1 = no watering from 80 DAS to harvest), S_2 = (no watering from 100 DAS to harvest) and

S_C = control with irrigation at every day). The grain yield reduced drastically to almost half (3.44 t ha^{-1}) when watering was stopped 80 days after sowing in comparison to that of the control (6.57 t ha^{-1}) when watering was not stopped. But the seed yield of the treatment S_2 (5.97 t ha^{-1}) in which watering was stopped at 100 days after sowing, that is it reduced almost 9% when compared with that of the control (6.57 t ha^{-1}). Out of six varieties, the variety Changnuo-1 produced significantly the highest seed yield (5.96t ha^{-1}). But in respect to the interaction treatments, the variety Changnuo-1 and Yangnuo-3000 had significantly the higher seed yield both at stopping watering at 100 DAS compared to other combined treatments. The Changnuo-1 showed 6.89 t ha^{-1} yield at control while 6.62 t ha^{-1} at S_2 showing only about 4% reductions in grain yields compared with that of control. The variety Yangnuo-3000 yielded 6.53 t ha^{-1} with S_2 and 7.00 t ha^{-1} with control showing about 7% yield reductions due to stopping water from 100 DAS.

So, it may be concluded that stopping irrigation from 80 DAS reduced grain yield but the reduction was minimum when applied at 100 DAS, Among the varieties, the Changnuo-1 and Yangnuo-3000 were found to be more drought tolerant.

In the antitranspirant trial (Expt. 8) through the application of Kaolin, two varieties (V_1- PSC-121, V_3=Changnuo-1) were tested under four concentrations of Kaolin (C_O = 0%, C_1=2%, C_2=4%, C_3=6%).Results showed that the variety PSC-121 out yielded the Changnuo-1 (8.81 and 7.35 t ha^{-1}respectively). The C_3 yielded significantly the highest of 8.75 t ha^{-1}which was 7.38 t $ha^{-1}$from control showing an improvement in yield of about 16%. The interaction treatments of PSC-121 did not show significant variation in seed yields at all the concentrations although showed the highest with C_3 (9.12 t ha^{-1}) which was 8.89t ha^{-1} with C_1 showing 8.20 t $ha^{-1}$with control. That is C_3 yielded significantly the highest of 8.75 t ha^{-1}which was 7.38 t $ha^{-1}$from control showing an improvement in yield of about 16%. But, the yields from 2-6% Kaolin concentration treatments were not significantly different. So, it may be concluded that the PSC-121 can be cultivated under applying antitranspirant Kaolin 2% at the tasseling stage.

So, it was concluded that spraying 2% Kaolin at tasseling stage might be sprayed to recover the drought stress at tasseling stage through reducing the foliage transpiration loss of the maize plant.

Main findings

1. From expt. 1-6, it may be concluded that the variety Changnuo-1 at all the site was the best performer showing the grain yield range of 6.65-12.16t ha^{-1}while PSC-121 at SAU was the second best performer (8.26-10.31t ha^{-1}).

2. From Expt. 7, it may be concluded that anirrigation may be reduced from 100 days after sowing and among the varieties, the Changnuo-1 and Yangnuo-3000 were found to be more drought tolerant.

3. From Expt. 8, it was concluded that spraying 2% Kaolin at tasseling stage on foliage improved grain yield by 8%.

Recommendation

1. The adoption of a certain variety in addition to the environment, depends of farmers' preferences and the profitability becomes visible when such farmer's preference coincide with the researchers' selection. In general, farmers' preference is greatly affected by some of the plant parameters such as earliness, drought tolerance, grain yield, vigor, husk cover, cob size, grain color and grain size. So, to decide about the varietal choice, participatory research should come more preference.

2. Only seven varieties were included in the soil moisture regime test for only one year. So, for the confirmation such trial should be repeated involving more white maize varieties.

3. Only two varieties were tested under only one antitranspirant 'Kaolin' sprayed at tasseling stage. So, more varieties should be included in the future studies using more antitranspirant at different growth stages.

CHAPTER VI

REFERENCES

Abdulatif, A. (2002). Effects of plant population density and N fertilizer rate on maize (*Zea mays* L.) intercropped in the alleys of chat (Catha edulisForskk) culture at Tinike, Eastern Hararghe, M.Sc. Thesis, Haramaya University, Ethiopia. p. 145.

Abdullah, A.E., Mahmoud, F.M. and Naim, A.M.E. (2015). Evaluation of some maize (*Zea mays* L.) varieties in different environments of the Nuba mountain of Sudan. *Australian J. Basic and Appl. Sci.* **4**(12): 6605-6610.

Abendroth, L. J., Elmore, R.W., Boyer, M. J. and Marlay, S. K. (2011). Corn growth and development. PMR 1009. Iowa State University Extension, Ames, Iowa. https:// store.extension.iastate.edu/product/Corn-Growth-and-Development

Abera, T., Debele, T. and Wegary. D. (2017). Effects of Varieties and Nitrogen Fertilizer on Yield and Yield Components of Maize on Farmers Field in Mid Altitude Areas of Western Ethiopia. *Intl. J. Agron.* Volume 2017, Article ID 4253917, 13 pages.

Agrama, H. A. S. (1996). Sequential path analysis of grain yield and its components in maize. *Plant Breed*. **115**: 343-346.

Ahmad S.Q., Khan, S., Ghaffar M. and Ahmad, F. (2011). Genetic diversity analysis for yield and other parameters in maize (*Zea mays* L.) genotypes. *Asian J. Sci.* **3**(5): 385-388.

Ahmad, N. (2000). Fertilizer Scenario in Pakistan Policies and Development. In: Proceedings of the conference Agriculture and Fertilizer Use. Planning and Development Division Governmentof Pakistan 1999 NFDC Islamabad Pakistan.

Ahmad, R., Mahmood, A., Ikraam, M. and Hassan, B. (2002). Irrigation methods and maize productivity. *Intl. J. Agric. Biol.* **4**: 540-543.

Ajmal, S. U., Sohail, K., Saleem, M. and Haq, M. I. (2000). Association analysis for grain yield and yield components in maize. *Pak. J. Biol. Sci*. **6**: 12-17.

Ali, M., Jonsen, C. R., Mogensen, V. O., Andersen, M. N. and Henson, I. E. (1999). Root signaling and osmotic adjustment during intermittent soil during sustain grain yield of field grown wheat. *Field Crops Res.* **62**: 35-52.

Ali, S., Khan, N.U., Gul, R., Naz, I., Goher, R., Ali, N., Khan, S.A., Hussain, I., Saeed, M. and Saeed, M. (2018). Genetic analysis for earliness and yield traits in maize. *Pak. J. Bot*., **50**(4): 1395-1405.

Ali, Z. (1994). Comparative economic returns of different maize genotypes. M.Sc Thesis Deptt. Agron Univ Agri Faisalabad. *Pak J. Soc Sci.* **6**(2): 118-120.

Ali, Z., Haqqani, A. M., Saleem, A. and Bakhsh, A. (2006). Growth and yield components of maize cultivars in Khushab District. *Pak. J. Agric. Res*. **19**(4): 55-58.

Alom, M. S., Paul, N. K. and Quayyum, M. A. (2009). Performances of different hybrid maize (*Zea mays* L.) varieties under intercropping systems with groundnut (*Arachis hypogaea* L.). *Bangladesh J. Agril. Res*. **34**(4): 585-595.

Andrade, F. H., Vega, C. R. C., Uhart, S. A., Cirilo, A. G., Cantarero, M. and Valentinuz, O. R. (1999). Kernel number determination in maize. *Crop Sci. J*. **39**: 453459.

AOAC. (1995). Association of Official Analytical Chemists. Washington, DC.

Arunachalam, V. (1981). Genetic distances in plant breeding. *Indian J. Genet*., **41**: 226-236.

Ashraf, M. (2010). Inducing drought tolerance in plants: recent advances. *Biotechnol. Adv*. **28** (1): 169–183.

Azam, S., Ali, M. Amin., S. Bibi. and Arif. M. (2007). Effect of plant population on maize hybrids. *J. Agron. Bio.Sci***.** **2**: 13-16.

Badu-Apraku, B., Fakorede, M. A. B., and Lum, A. F. (2007). Evaluation of experimental varieties from recurrent selection for *Striga* resistance in two extra-early maize populations in the savannas of West and Central Africa. *Exp. Agric.*, **43**: 183– 200.

Badu-Apraku, B. Talabi, O. A., Garcia-Oliveira, A. L. and Gedil, M. (2018). IITA scientists develop multiple stress tolerant maize hybrids with high levels of Pro-Vitamin A. *IITA News* 2463, 7th January 2019. (Accessed 13 September 2019).

Bafeel, S. O. and Moftah, A. E. (2008). Physiological response of eggplants grown under different irrigation regimes to antitranspirant treatments. *Saudi J. Bio. Sci*. **15**: 259-267.

Bänziger, M., Edmeades, G. O. and Lafitte, H. R. (2002). Physiological mechanisms contributing to the increased N stress tolerance of tropical maize selected for drought tolerance. *Field Crops Res.* **75**: 223-233.

Bänziger, M., Setimela, P. C., Hodson, D. and Vivek, B.(2006). Breeding for improved abiotic stress tolerance in maize adapted to southern Africa. Agric. Water Management. **80**(1-3): 212-224.

BARC. (2011). Non-Rice Cereals, Sugarcane and Jute. Sub-sectoral study series: vol. 02. Bangladesh Agricultural Research Council, New Airport Road, Farmgate, Dhaka-1215.

BARI (Bangladesh Agricultural Research Institute). (2014). KrishiProjuktiHatboi (Handbook on Agro Technology), Gazipur-1707, Bangladesh, 6th edition. p. 54.

BARI (Bangladesh Agricultural Research Institute). (2018). BARI developed variety 2017-18. Gazipur-1707, https://bari.portal.gov.bd /sites/default/files/ files/ bari.portal. gov.bd/ annual_reports.

BBS (Bangladesh Bureau of Statistics). (2003). Yearbook of Agricultural Statistics of Bangladesh 2015, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2011). Yearbook of Agricultural Statistics of Bangladesh 2015, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS (Bangladesh Bureau of Statistics). (2018). Yearbook of Agricultural Statistics of Bangladesh 2015, Statistics and Informatics Division, Ministry of Planning, Government of the People's Republic of Bangladesh.

BBS. (2019). Statistical Year Book of Bangladesh. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

BBS (2020). Yearbook of Agricultural Statistics-2019. Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh. http://bbs.portal.gov.bd/2020.

Beyene, Y., Mugo, S., Mutinda, C., Tefera, T. and Karaya, H. (2011). Genotype by environment interactions and yield stability of stem borer resistant maize hybrids in Kenya. *African J. Biotech.* **10(**23): 47-52.

Bhuiyan, M. S., Bhuiyan, M. S. R, Tiwari,T. P., Rahaman, M. A., Bhowal, S. K., Uddin, R. and Paul,S. K. (2015). Performance of hybrid maize varieties as influenced by irrigation levels. *Bangladesh Agron. J.* **18**(2): 23-29.

Bonnet, O.T. (1947). Ear and tassel development in maize. Annals of the Missouri Botanical Gardens 35: 4. The 1947 Conference on the Inflorescence of *Zea mays*. p**.** 269 – 287.

Brillante, L., Belfiore, N., Gaiotti, F., Lovat, L., Sansone, L., Poni, S. and Tomasi, D. (2016). Comparing Kaolin and Pinolene to Improve Sustainable Grapevine Production during Drought. *Plos One*. **11**(6): 156-631.

Brolley, M. (2015). Rice security is food security for much of the world. Rice Today. International Rice Research Institute (IRRI), DAPO Box 7777, Metro Manila, Philippines. p. 30-32.

Brown, W. L., Bressani R., Glover, D. V., Hallauer, A. R., Johnson, V. A. and Qualset, C. O. (1988). Malnutrition and protein quality. In: Board on Science and Technology for International Development, National Research Council. Quality-protein maize: Report of an ad hoc panel of the advisory committee on technology innovation. Washington, DC.

Bruce,W. B., Gregory, O., Edmeades, D., Thomas, C. and Barker. J. (2002). Molecular and physiological approaches to maize improvement for drought tolerance. *J. Expt. Bot.* **53**(366): 13-25.

Cantore, V., Pace, B. and Albrizio, R. (2009). Kaolin-based particle film technology affects tomato physiology, yield and quality. *Env. Expt. Bot*. **66**: 279-288.

Carlon, M. R. and Russel, W. A. (1987). Response to plant densities and nitrogen level for four maize cultivars from different areas of breeding. *Crop Sci*. **27**(2): 465-470.

CGIAR. (2002). Maize (*Zea mays* L.) Areas of research. http://www.cgiar.org/research/res_maize.html.

Claasen, M. M. and Shaw, R. H. (1970). Water deficit effects on corn. II. Grain components. *Agron. J.* **62**: 652-655.

Clark, R. B. and Brown, J. C. (1974). Differential mineral uptake by maize inbred. *Com. Soil Sci. Plant Annu.* **5**: 213–227.

Clintock, B. (1959). Genetic and Cytological studies of maize. Carnegies Inst. Washinton. Year book. **58**: 452-456.

Coligado, M. C., and D. M. Brown. (1975). A bio-photo-thermal model to predict tassel initiation time in corn (*Zea mays* L.). *Agric. Meteorol*. **15**: 11-31.

Cooper, P. J. M. and Law, R. (1977). Soil temperature and its association with maize yield variations in the Highlands of Kenya. *J. Agric. Sci. Camb.* **89**: 355–363.

Coulter, J. A., Nafziger, E. D., Janssen, M. R. and Pedersen, P. (2010). Response of Bt and near-isoline corn hybrids to plant density. *Agron. J.* **102**: 103– 111.

Davenport, D. C., Hagan, R. M. and Martin, P. E. (1974). Antitranspirants uses and effects on plant life. *California Agric.* **23**(5): 14-16.

Dawadi, D. R. and Sah, S. K. (2012). Growth and yield of hybrid maize (*Zea mays* L.) in relation to planting density and nitrogen levels during winter season in Nepal. *Tropical Agril. Res.,* **23** (3): 218-227.

Desoky, E. S. M., Tohamy, M. R. A., Eisa, G. S. A. and El-Sarkassy, N. M. (2013). Effect of some antitranspirant substances on growth, yield and flag leaf structure of wheat plant (Triticumaestivum L.) grown under water stress conditions. *Zagazig J. Agric*. Res., **40**(2): 215-230.

Devi, I.S. and Muhammad, S. (2001). Character association and path coefficient analysis of grain yield components in double crosses of maize. *Crops Res. J.* **21**: 255-259.

Dhungana, P., Eskridge, K.M., Baenziger, P.S., Campbell, B.T., Gill, K.S. and Dweikat. I. (2007). Analysis of genotype-by-environment interaction in wheat using structural equation model and chromosome substitution lines. *Crop Sci.* **47**: 477-484.

Doebley, J. (2004). The genetics of maize evolution. Annual Reviews of Genetics. **38**: 37-59.

Dofing, S. M., and Knight. C. W. (1994). Yield component compensation in uniculm barley lines. *Agron. J.* **86**: 273-276.

Dowswell, C. R., Paliwa, R. L. and Cantrell, R. P. (1996). Maize in 3rd World. West Views Press. *Inc. Colorado*, USA.

Duncan, W. G. (1969). Cultural manipulation for higher yields. In: JD Eastin Physiological aspects of crop yield. ASA and CSSA Madison WI. p. 327- 342.

Duplessis, J. (2003). Maize Production. Department of Agriculture. Pretoria 0001, South Africa.

Dwyer, L., Tollenaar, M., and Stewardt, D. W. (1991). Change in plant density dependence of leaf photosynthesis of maize (*Zea mays* L.) hybrids. *Canadian J. Plant Sci*. **71**(1): 1-11.

Ebuka, O. E. (2018). Developing maize (*Zea mays* l.) for fresh maize production in southeastern nigeria. Thesis, Master of Science (m.sc.) degree in crop science and technology (crop breeding and genetics). Reg. no: 20144911278. The Postgraduate School, Federal University of Technology, Owerri. Nigeria.

Echarte, L., Andrade, F. H., Vega, C. R. C. and Tollenaar, M. (2004) Kernel number determination in Argentinean maize hybrids released between 1965 and 1993. *Crop Sci*. **44**: 1654-1661.

Eck, H.V. (1986). Effects of water deficits on yield, yield components, and water use efficiency of irrigated corn. *Agron. J.* **78**: 1035-1040.

Edmeades, G. O., Bolanos, J., Chapman, S. C., Lafitte, H. R. and Bänziger, M. (1999). Selection improves drought tolerance in tropical maize populations: I. Gains in biomass, grain yield, and harvest index. *Crop Sc.* **39**: 1306-1315.

El-Kholy, M. A., Gaballah, M. S., El-Ashry, S. and Oraby, A. (2005b). Combating drought using yield stabilizing agents in barley. *J. Agric. Bio. Sci*. **7**: 369-375.

El-Kholy, M. A., Ouda, S. A. H., Gaballah, M. S. and Hozayn, M. (2005). Predicting the interaction between the effect of anti-transpirant and climate on productivity of wheat plant growth under water stress. *J. Agron*. **4**(1): 75-82.

Eubanks, M. W. (2001). The Origin of Maize: Evidence for *Tripsacum* Ancestry. *Plant Breed. Rev.* **20**: 15–61.

Eyasu, E., Dereje, S., Dawit, D. and Eyasu. E. (2018). Yield Response of Maize (*Zea mays* L.) Varieties to Row Spacing Under Irrigation at Geleko, OfaWoreda, Wolaita Zone, Southern Ethiopia. *J. Expt. Agric Intl.* **20**(1): 1-10.

Fageria, N. K., Baligar, V. C. and Clark, R. (2006). Physiology of Growth and Yield Components In Physiology of Crop Production. Food Products Press, an imprint of Haworth Press, Inc., Binghamton, New York. p. 61-94.

Falconer, D.S. (1960). Introduction to quantitative genetics. Oliver & Boid, London. p. 304-305

Fan, T. L., Stewart, B. A., Wang, Y. G., Luo, J. J. and Zhou, G.Y. (2005). Long-term fertilization effects on grain yield, water-use efficiency and soil fertility in the dry land of Loess Plateu in China. *Agric. Ecosys. Env*. **106**: 313-329.

FAO (Food and Agriculture Organization of the United Nations). (1988). Land resources appraisal of bangladesh for agricultural development: Report 3 - Land resources data base - Volume II soil, landform and hydrological data base.

FAO. (1992). Maize in human nutrition. FAO Food and Nutrition series, No. 25. Rome. FAO (2010). http://www.fao.org/inpho/maize.

FAO (Food and Agriculture Organization). (2016). Save and Grow in practice: maize, rice, wheat - A guide to sustainable cereal production. Cereals and us: time to renew an sancient bond. http://www.fao.org/ag/save-and-grow/MRW/en/1/index.html

FAO (Food and Agriculture Organization). (2018a). Oecd-FAO Agricultural OutLOOK 2018-2027 © OECD/FAO 2018. 3. Cereals. p. 109-125.

Farnham D. E. (2001). Row spacing, plant density and hybrid effects on corn grain yield and moisture. *Agron. J.* **93**(5): 1049-1053

Farrag, A. M. and El-Nagar, A. M. (2005) Response of cucumber plants to drip irrigation levels, NPK fertilization rates and salinity distribution in the soil. *In:* 3rd Conference on Recent Technologies in Agriculture, 14-16 November, Cairo University, Egypt. p. 519-534.

Fehr, W. R. (1991). Principles of cultivar development. Macmillan publishing company. A division of Macmillan Inc. New York. **1**: 1-465.

Fergason, V. (2001). High amylose and waxy corns. In: Specialty corns (Hallauer A.R., ed). Boca Raton, CRC Press, USA. p. 63-84.

Francis T. R. and Kannenberg. L. W. (1978). Yield stability studies in short-season maize. i. a descriptive method for grouping genotypes. *Canadian. J. Pl. Sci*. **58**(4): 1029-1034.

François, T.; Thierry Simonneau, T. and Bertrand Muller, B. 2018. The Physiological Basis of Drought Tolerance in Crop Plants: A Scenario-Dependent Probabilistic Approach. *Annu. Rev. Plant Biol*. **69**: 733-759.

Gab-Alla , F. I., Shahin, M. M., Eid, H. M. and EL-Marsafawy, S. M. (1995). Relationship between nitrogen level, yield and its components through some irrigation regimes for maize. Egypt *J. Soil Sci*. **35**: 297-310.

Gaballah, M. S., and Moursy, M. (2004). Reflectants application for increasing wheat plants tolerance against salt stress. *Pakistan J. Bio. Sci.***7**: 956-962.

Gardner, F. P., Pearce, R. B. and Mitchell, R. L. (1985). Physiology of crop plants. Iowa State University Press, Ames.

Gauch, H. G. and Zobel, R.W. (1997). AMMI analysis of yield trials. In: Kang, M.S. and Gauch, H.G. (editions) genotype by environment interaction. CRC Press. Boca Raton, FL.

Ghaderi, A., Shishegar, M., Regai, A. and Ehdaie, B. (1984). Multivariate analysis of genetic diversity for yield and its components in mungbean. *J. Amer. Soc. Hort. Sci.* **104**: 728-731.

Ghimire, S., Sherchan, D. P., Andersen, P., Pokhrel, C., Ghimire, S. and Khanal, D. (2016). Effect of Variety and Practice of Cultivation on Yield of Spring Maize in Terai of Nepal. *Agrotechnol*. **5(**2): 1-6.

Giri, U. and Bandyopadhyay, P. (2016). Performance of Hybrid Maize Varieties towards Different Levels of Irrigation during Rabi Season of West Bengal. *J. Agroecol. Nal. Res. Mng*. **3**(3): 306-308.

Glass, A. D. M. (1989). Plant nutrition- An Introduction to Current Concepts. Jones and Bartlett Publishers, Boston, MA.

Goldsworthy, P. R. (1984). Crop growth & development: the reproductive-phase. In: Goldsworthy Pr, Fisher Nm (eds). Physiology Tropical Field Crop. Wiley & Sons.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedures for Agricultural Research. 2nd Ed. John Willey & Sons, Inc. New York. P.641.

Goodman, M. and Brown, W. L. (1988). Races of corn. pp. 33-79. In: G.F. Sprague, J.W. Dudley (Eds.), Corn and Corn Improvement. 3rd ed., ASA, Madison, WI.

Gordon, W. B., Raney, R. J. and Stone, L. R. (1995). Irrigation management practice for corn production in north central Kansas. *J. Soil Water Cons*. **50**(4): 395-398.

Gouse, M., Pray, C. E., Kirsten, J. and Schimme, D. (2005). A GM subsistence crop in Africa: the case of Bt white maize in South Africa. *Int. J. Biotech.* **7**(1): 84-94.

Gozubenli, H., Ulger, A.C. and Sener, O. (2001). The effect of different nitrogen doses on grain yield and yield-related characters of some maize genotypes grown as second crop. *J. Agric*. Fac. C.U. **16**: 39-48.

Grant, R. F., Jackson, B. S., Kiniry, J. R. and Arkin, G. F. (1989). Water deficit timing effects on yield components in maize. *Agron. J*. **81**: 61-65.

Greveniotis, V., Zotis, S., Sioki, E. and Ipsilandis, C. (2019). Field Population Density Effects on Field Yield and Morphological Characteristics of Maize. *Agric*, **9**(160): 1-11. doi:10.3390/agriculture9070160.

Gyenes-Hegyi, Z., Kizmus, L., Zsubori, L. and Marton, L.C. (2002). Plant height and height of the main ear in maize (Zea mays L.) at different locations and different plant densities. *Acta Agri. Hungarica*. **50**: 75-84.

Hallauer, A. R., Carena, M. J. and Miranda, J. B. (1988). Quantitative genetics in maize breeding. 3rd edition, New York: Springer, p. 66.

Hanway, J. J. (1971). How a corn a plant develops. Iowa State University Cooperative Extension Service Special Report, p. 48.

Harder, D., Carlson, R. E. and Shaw, R. H. (1982). Yield and yield components and nutrient content of corn grain as influenced by post-silking moisture stress. *Agron. J*. **174**: 275-278.

Hashemi, A. M., Herbert, S. J. and Putnam, D. H. (2005). Yield response of corn to crowding stress. *Agron. J*. **97**: 839-846.

Heichel, G. H. and Musgrave, R. B. (1969). Varietal differences in net photosynthesis of *Zea mays* L. *Crop Sci*. **9**: 483–486.

Heisey, P. W., Morris, M. L., Byerlee, D. and Lopez-Pereira, M. A. (1998). Economics of hybrid maize adoption. In Morris, M.A. (ed.). Maize seed industries in developing countries. Boulder, Colorado, Lynne Reinner.

Honghong, H. and Lizhong, X. (2014). Genetic Engineering and Breeding of Drought-Resistant Crops". *Ann. Rev. Plant Bio.* **65**(1): 715–741.

Hoon, J. H., Herselman, M. J. and King, B. R. (2010). The utilisation of white and yellow maize by sheep. http://gadi.agric.za/articles/Hoon_JH/mielga.php.

Hossain, M., Khan, Y. and Baloch, M. S. (2011). Screening of maize varieties for grain yield at Dera Ismail Khan. *J. Anim. Plant Sci*. **21**(3): 626-628.

Huffnagel, H. P. (1961). Agriculture in Ethiopia. FAO (Food and Agriculture Organization of the United Nations. https://www.worldcat.org/title/agriculture-in-ethiopia-compiled-by-hp-huffnagel-consultant-to-fao/oclc/639639913.

Hunter, R. B. (1980). Increased leaf area (source) and yield of maize in short season areas. *Crop Sci.* **20**: 571-574.

Ibrahim, E. A. and Selim, E. M. (2007). Effect of irrigation intervals and nitrogen fertilizer rates on summer squash (Cucurbitapepo L.) growth, yield, nutritional status and water use efficiency. *J. Agric. Sci.,* Mansoura Univ. **32**: 10333-10345.

Ibrahim, E. A. and Selim, E. M. (2010). Effect of irrigation intervalles and antitranspirants (Kaolin) on summer squash (*Cucurbita pepo* L.) growth, yield quality and economics. *J. Soil Sci. Agric. Engin*., Mansoura University. **1**: 883-894.

IITA (International Institute of Tropical Agriculture). (2001). Stopping the scourge, Annual Report 2001 http// www.iita.org/info/ar99/8.htm retrieved June 5, 2014.

IPBO. (2017). Maize in Africa. Fact Series. International Plant Biotechnology Outreach. http://www.fao.org/docrep/w2698e/w2698e02.htm#TopOfPage, retrieved on 01-05-2018. Irrigation systems as related to sustainable land use, Leuven (Belgium). p.14-17.

Izhar, S. and Wallace. D. H. (1967). Studies on the physiological basis for yield differences. III. Genetic variation in photosynthetic efficiency of *Phaseolus vulgaris* L. *Crop Sci*. **7**: 457–460.

Izhar, T., and Chakraborty, M. (2013). Combining ability and heterosis for grain yield and its components in maize inbreds over environments (*Zea mays* L.). *African J. Agril Res.* **8**(25): 3276-3280.

Jacobs, B. C. and Pearson, C. J. (1991). Potential yield of maize, determined by rates of growth and development of ears. *Field Crops Res*. **27**: 281-298.

Jain, A. and Srivaslava, H. S. (1981). Effect of salicyalic acid on nitrate reductase activity in maize seedlings. *Physiol. Plantarum*. **51**: 339-345.

Jaliya, A. M., Falaki, A. M., Mahmud, M. and Sani, Y. A. (2008). Effects of sowing date and NPK fertilizer rate on yield and yield components of quality protein maize (*Zea mays* L.). *ARPN J. Agric. Biol. Sci*. **2**: 23-29.

Jiang, S., Zhang, D. and Wang, L. (2013). A maize calcium-dependent protein kinase gene, ZmCPK4, positively regulated abscisic acid signaling and enhanced drought stress tolerance in transgenic Arabidopsis. *Plant Physiol. Bioch*. **71**: 112–120

Jones, J. R. and Benton, J. (1930). Plant nutrition and soil fertility manual. Second edition, CRC Press, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, 33487-2742.

Jones, R. J. and Crookston, R. K. (1973). Thermal environment during endosperm division and grain filling in maize: effects of kernel growth and development in Vitro. *Crop Sci*. **24**: 133-137.

Jong, Q., Bingwv, W. and Yong, M. A. (2003). Study on Comprehensive evaluation of maize hybrids. *J. Jilin Agril. Univ*. **25**: 139-142.

Kabir, R., Kabir, M., Uddin, M. S. G., Ferdous, N. and Chowdhury, M. R. K.(2015). Elderly Population Growth in Bangladesh: Preparedness in Public and Private Sectors. *IOSR J. Humanities Social Sci*. **21**(8): 58-73.

Kabir, S. H, Das, A. K., Rahman, M. S., Singh, S. K., Morshed, M. and Marma, A. S. (2019). Effect of genotype on proximate composition and biological yield of maize (*Zea mays* L.). *Agric. Env. Sci*. **4**(2): 185-189.

Karim, R. (1992). Studies on Maize in Bangladesh. International Food Policy Research Institute, BFPP, Dhaka, *Sci World J*. **8**.

Kato, Y. T. A. (1976). Cytological studies of maize and teosinte in relation to their origin and evolution. *Massachusetts Agric. Expt. Sta. Bull.* p. 635.

Kato, Y. T. A. (1984). Chromosomes morphology and the origin of maize and its races. *Evol. Bol*. **17**: 219-253.

Katuwal, R. B. (2012). Influence of variety and planting date on cold tolerance and yield for winter maize in Nepal. Chitwan, Rampur: Institute of Agriculture and Animal Science.

Kaul, M. L. M. (1985). Genetic divergence analysis in rice. *Annals Biol.* **16**(1): 41-44.

Khalil, S. E. (2006). Physiological study on sesame plants grown under saline water irrigation condition. PhD thesis, Cairo University. p. 229.

Khalil, S. E. Mohamed, M., Hussein, A. and Jaime, A. (2012). Roles of Antitranspirants in Improving Growth and Water Relations of *Jatropha curcas* L. Grown under Water Stress Conditions. Plant Stress, Global Science Books.

Khalil, S. E., Abd El-Aziz, N. G. and Abou-Leila, B. H. (2010). Effect of water stress and ascorbic acid on some morphological and biochemical composition of *Ocimum basilicum* plant. *J. American Sci.* **6**: 33-44.

Khalil, S. E., Hussein, M. M. and da Silva, J. A. T. (2011). Roles of Antitranspirants in Improving Growth and Water Relations of Jatrophacurcas L. Grown under Water Stress Conditions. Department of Water Relation and Field Irrigation, National Research Centre, Dokki, Cairo, Egypt.

Khan, M. khan, K., Afzal, S. U., Ali, N., Anjum, M.M., Usman, H. and Iqbal, M. (2017). Seed Yield Performance of Different Maize (*Zea mays* l.) Genotypes under Agro Climatic Conditions of Haripur.

Koester, R. P., Sisco, P. H. and Stuber, C. W., (1993). Identification of quantitative trait loci controlling days to flowering and plant height in two near isogenic lines of maize. Online http://www.app.jcipgroup.tw.

Koirala, K. B., Pandey, Y. R. and Ghimire, T. B. (2013). Road-map for development and deployment of heat resilient maize in Nepal. Paper presented at 1st Annual progress review and planning workshop, held at Hotel Yak and Yeti, Kathmandu, Nepal, 2013.

Konuskan O., (2000). Effects of plant density on yield and yield related characters of some maize hybrids grown in hatay conditions as second crop. M.Sc. Thesis, Science Institute. M.K.U. p. 71.

Laekemariam, F. and Gidago, G. (2012). Response of maize (*Zea mays* L.) to integrated fertilizer application in Wolaita, *South Ethiopia. Adv. Life Sci. Technol*. **5**: 21-30.

Lana, M. A.,Vasconcelos, A. C. F., Gornott, C., Schaffert, A., Bonatti, M.,Volk, J., Graef, F., Kersebaum, K.C. and Sieber, S. (2018). Is dry soil planting an adaptation strategy for maize cultivation in semi-arid Tanzania? *Food Security*, **10**: 897–910.

Landoni, M., Lago, C., Cassani, E., Cantaluppi, E., Doria, E. and Nielsen, E. (2015). Study and Characterization of an Ancient European Flint White Maize Rich in Anthocyanins: MilloCorvo from Galicia. *PLoS One*. **10**(5): 126- 521.

Lauer, J. (2006). Corn Development. University of Wisconsin. Online at http://corn.agronomy.wisc.edu/Management/L011.aspx (verified 23 Feb. 2015).

Lee, B. R. (1979). The effect of nitrite on root growth of barley and maize. Agricultural research council. Letcombe Laboratory. Wantage, U.K.

Lee, B. R. (2012). Corn Growth Stages. Grain Crops Extension. University of Kentucky, Kentucky.

Lieberman, M. and Wang, S.Y. (1982). Influence of calcium and magnesium on ethylene production by apple tissue slices. *Plant Physiol*. **69**: 1150-1155.

Lin,C. S. and Binns, M. R. (1988). A superiority measure of cultivar performance for cultivar x location data. *Canadian J. Plant Sci. **68***: 193-198.

Lopes, T., Hatt, S., Xu, Q., Chen, J., Liu, Y., and Francis, F. (2016). Wheat (*Triticumaestivum* L.)-based intercropping systems for biological pest control. *Pest Mng. Sci.* **72**: 2193-2202.

Macharia, C. N., Njeru1, C. M., Ombakho, G. A. and Shiluli, M. S. (2010). Comparative performance of advanced generations of maize hybrids with a local maize variety: Agronomic and financial implications for smallholder farmers. *J. Anim. Plant Sci*. **7**(2): 801- 809.

Magorokosho, C. (2006). Genetic diversity and performance of maize varieties from Zimbabwe, Zambia and Malawi. Texas A & M University.

Mangelsdorf, P. C. (1974). Corn - its origin, evolution and improvement. The Bellknap Press. New York, NY.

Masood, M., Shamsi, I. H., Hussain, N. and Shah, W. A. (2003). Performance of various maize varieties as affected by different NP levels. *Asian JPl Sci.* **2**(7): 535-538.

Matsuoka, Y., Vigouroux, Y., Goodman, M. M., Sanchez, J., Buckler, G. E. and Doebley, J. (2002). A single domestication for maize shown by multi-locus microsatellite genotyping. *Proc. Natl. Acad. Sci.* USA. **99**: 6080-6084.

McCann J. C. (2005). Maize and Grace: Africa's Encounter with a New World Crop, 1500-2000. Harvard University Press, Cambridge, Massachusetts.

McClintock, B. (1978). Significance of chromosome constitutions in tracing the origin and migration of races of maize in the Americas. Chapter 11. p. 159–184.

McClintock, B., Kato, T. A. and Blumenschieu, A. (1981). Chromosomes constitutions of Races of maize. Its significance in the interpretation of relationship between races and varieties in the America. Colego de Postgraduados, Mexico.

Metwally, M. M., Afify, M. M., Wahba, H. E., Makarem, A. M., Mohamed, A., Mohamed, A. E. and Mahfouz, S. (2002). Effect of irrigation and Vapor Guard on growth, yield and chemical composition of roselle plant. *Bull. NRC, Egypt*. **27**: 533-548.

Mian, M. A. K. and Bahl, P. N. (1989). Genetic divergence and hybrid performance in chickpea. *Indian J. Genet*. **49**: 119-124

Milander and Jeremy, J. (2015). Maize Yield and Components as Influenced by Environment and Agronomic Management. Theses, Dissertations, and Student Research in Agronomy and Horticulture Department, University of Nebraska-Lincoln.

Milbourn. K. and Carr, M. K. V. (1977). The influence of temperature on the development and yield of maize in Britain. *Annl. Appl. Bio.* **87**: 261–266.

Mohammadi, S. A., Prasanna, B. M. and Singh, N. N. (2003). Sequential path model for determining inter-relationships among grain yield and related characters in maize. *Crop Sci*. **43**: 1690–1697.

Mohammadi, S. A., Prasanna, B. M. and Singh, N. N. (2003). Sequential path model for determining interrelationships among grain yield and related characters in maize. *Crop Sci*. **43**:1690-1697.

Mondal, M. R. I., Sultan, M. K. Nur, S. Sarkar, M. J. U. Alam, M. S. and Rahman. M. H. H. (2014). KrishiProjuktiHatboi (Handbook on Agro-technology), 6th edition. Bangladesh Agricultural Research Institute, Gazipur 1701, Bangladesh.

Mortvedt, J. J. (1976). Soil chemical constrains in tailoring plants to fit problem soils. 2. Alkaline soils, pp. 141-149. M. J. Wright (ed.). Plant Adaptation to Mineral Stress in Problem Soils. Proc. of a Workshop, the Nat. Agric. Library, Beltsville, Maryland.

Moser, S. B., Feil, B., Jampatong, S. and Stamp, P. (2006). Effects of pre-anthesis drought, nitrogen fertilizer rate, and variety on grain yield, yield components, and harvest index of tropical maize. *Agric. Water Mng*. **81**: 41-58.

Moshood, A.Y., Abdulraheem, M. and Charles, E. F. (2018). Evaluation of four maize varieties for optimum growth and yield under field condition. *Adv. Agri. Tech. Plant Sci*. **1**(1): 1-5.

Moss, G. I. and Downey, L. A. (1971). Influence of drought stress on female gametophyte development in corn (*Zea mays* L.) and subsequent grain yield. *Crop sci*. **11**(3).

Mukherjee, N., Chowdhury, G. A., Khan, M. F. A. and Islam, A. K. M. (2011). Implication of Changing Consumption Pattern on Food Security and Water Resources in Bangladesh. Proceedings of the 3rd International Conference on Water and Flood Management (ICWFM 2011), 8-10 January 2011, Dhaka, Bangladesh, **2**: 731-738.

Mukhtar, T., Arif, M., Hussain, S., Tariq, M. and Mehmood, K. (2011). Effect of Different rates of nitrogen and phosphorus fertilizers on growth and yield of maize. *J. Agric. Res*. **49**(3): 333-339.

Musa, H. A., Mamo, K. Tazeze, G. A. and Andualem, E. (2016). The Impact of improved maize varieties on farm productivity and wellbeing: evidence from the East Hararghe Zone of Ethiopia. *J. Dev. Studies Res.* **4**(1): 9 -21.

Mwakatwila, A. (2019). Extent of adopting improved maize varieties in northern and eastern zones of Tanzania, 2019 Sixth International Conference, September 23-26, 2019, Abuja, Nigeria 295773, African Association of Agricultural Economists (AAAE).

Nakano, A. and Uehara, Y. (1996). The effect of kaolin clay on cuticle transpiration in tomato. *Acta Hort*. **440**: 233-238.

Nasraui, B. (1993). Role of antitranspirant films in protecting plants against fungal disease. *Ann. Inst. Nat. Rec. Agron. Tunisie*. **66**: 125-135.

Nawaz, A. Satter, A., Sher, A., Naeem, A. and Mahmood, K. (2019). Potassium application improves grain yield and alleviates drought susceptibility in diverse maize hybrids. *Plant Physiol.* ***15*****:** 1272–1276.

Nazfiger, E. (2010). Corn. (In) Illinois Agronomy Handbook. Department of Crop Sciences, University of Illinois, Illinois.

NBC. (2017). Namibia expects a bumper harvest of close to 70000 metric tons of white maize, editor, Namibian Broadcasting Corporation.

Nermeen, S. and Emad, S. (2011). Influence of some chemical anti-transpirant agents on vase-life of Monsteradeliciosa leaves. *African J. Agric. Res*. **6**(1): 132-139.

Niazuddin, M., Talukder, M. S. U., Shirazi, S. M., Adham, A. K. M. and Hye, M. A. (2002). Response of maize to irrigation and nitrogenous fertilizer. *Bangladesh J. Agric. Sci*. **29**(2): 283-289.

Nielsen, R. L. (1995). Effects of stress during grain fill in corn. Agronomy department, Purdue University. http://www.agry.purdue.edu/ext/corn/news/articles/p&9525.

Noor, M., Rahman, H. U., Durrishahwar, Iqbal, M., Shah, S. M. A. and Ihteramullah. (2010). Evaluation of maize half-sib families for maturity and grain yield attributes. *Sarhad J. Agric*. **26**: 545-549.

Novacek, M. J., Mason, S. C., Galusha, T. D. and Yaseen, M. (2014). Bt transgenes minimally influence maize grain yields and lodging across plant populations. *Maydica*. **105**: 268-276.

O'keefe, K. and Schipp, A. (2009). Maize: Growth and development. New South Wales (NSW) Primary Industries.

OGTR (Office of the Gene Technology Regulator). (2008). The biology of *Zea mays* L. spp. mays (maize or corn). Department of Health and Ageing, Australian Government.

Olakojo, S. A. and Kogbe, H. (2005). Reaction of some maize Genotypes with infestation with StrigaAsiatica. *Agris*. **9**: 131-139.

Orfanou, A., Pavlou, D. and Porter, W. M. (2019). Maize Yield and Irrigation Applied in Conservation and Conventional Tillage at Various Plant Densities. *Water Mng.* **11**: 1-23.

Ouda, S. A., El-Mesiry, T. and Gaballah, M. S. (2007). Effect of using stabilizing agents on increasing yield and water use efficiency in barley grown under water stress. *Australian J. Basic Appl. Sci*. **1**: 571-577.

Panday, D. (2019). Future of maize: Introduce hybrid varieties. Young Professionals for Agricultural Development. https: //ypard. net/ 2019-12-27/ future-maize-introduce-hybrid-varieties.

Pandey, R. K., Maranville, J. W and. Admou, A. (2000). Deficit irrigation and nitrogen effects on maize in a Sahelian environment I. Grain yield and yield components. *Agric. Water Mng.* **46**: 1-13.

Pandey, Y., Vyas, R. P., Kumar, J., Singh, L., Singh, H. C., Yadav, P. C. and Vishwanath (2017). Heritability, correlation and path coefficient analysis for determining interrelationships among grain yield and related characters in maize (*Zea mays* L.). *Int. J. Pure Appl. Biosci*. **5**: 595–603.

Pannar. (2013). The Pannar Seed Handbook. Greytown, South Africa.

Paudel, M. N. (2009). Evaluation of hybrid and opv maize varieties for grain yield and agronomic attributes under farmer's field conditions at dukuchhap. *Nepal Agric. Res. J*. **9**: 17-20.

Pennazio, S. and Roggero, P. (1984). Effect of ABA and DNP on stomatal resistance in detached tobacco leaves. *Giornale Bot. Italiano*. **118**: 132-140.

Pingali, P. L. and Pandey, S. (2000). Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector. **In:** Prabhu L. Pingali (Ed.). 2000. Meeting World Maize Needs: Technological Opportunities and Priorities for the Public Sector. Pp. 1-3. https://repository.cimmyt.org/ bitstream/ handle/ 10883/771/74558.pdf?sequence=1&isAllowed=y.

Plessis, J. D. (2003). Maize Production. Directorate Agricultural Information Services, Department of Agriculture in cooperation with ARC-Grain Crops Institute, Private Bag X144, Pretoria, 0001 South Africa, Republic of South Africa.

Pollmer, W. G., Eberhard, D., Klein, D. and Dhillon, B. S. (1979). Genetic control of nitogen uptake and translocation in maize. *Crop Sci*. **19**: 82–86.

Prasanna, B. M. (2016). Maize in the Developing World: Trends, Challenges, and Opportunities. Proceeding International Maize Conference. Global Maize Program, CIMMYT (International Maize and Wheat Improvement Center), Nairobi, Kenya; Email: b.m.prasanna@cgiar.org. P. 26-38.

Ransom, J. (2013). Corn;growth and managemrnt; Quickguide; North Dakota State University; Fargo. North Dakota, USA.

Ransom, J. and Endres, G. J. (2014). Corn; Growth and Management: Quick Guide. North Dakota State University, Fargo, North Dakota, USA.

Ranum, P., Peña-Rosas, J. P., Garcia-Casal, M. N. (2014). Global maize production, utilization, and consumption. *Ann. New York Aca. Sci.* **13**: 105- 112.

Reddy, M. T., Babu, K. H. Ganesh, M. Begum, H. Reddy, R. S. K. and Babu, J. D. (2013). Exploitation of hybrid vigour for yield and its components in okra [*Abelmoschus esculentus* (L.) Moench]. *American J. Agric. Sci. Technol*. **1**: 1–17.

Richard, M., Trethowan, C. J., Ginkel, M. and Rajaram, S. (2001). Relationships among bread wheat international yield testing locations in dry areas. *Crop Sci*. **41**: 1461-1469.

Ritchie, S. W., Hanway, J. J and Benson, G. O. (1993). How a corn plant develops? Iowa State University, Special Report. Available at http://www.extension.iastate.edu/hancock/info/corn.html.

Russel, W. A. (1991). Genetic improvement of maize yields. *Adv. Agron*. **46**(1): 245-298.

Russell, K. and Sandall, l. (2005). Corn Breeding: Lessons from the Past- Overview and Objectives. University of Nebraska Lincoln (UNL), USA. https:// passel.unl.edu/

Salam, M. A. Solaiman, A. R. M. Karim, A. J. M. S. and Saleque, M. A. (2013) System productivity, nutrient use efficiency and apparent nutrient balance in rice-based cropping systems. *Archiv. Agron. Soil Sci*. **60**(6): 747-764.

Salami, A.E., Adegoke, S.A.O. and Adegbite, O.A. (2007). Genetic variability among maize cultivars grown in Ekiti-State, Nigeria. *Middle East J Sci Res*. **2**(1): 9-13.

Saleem, A., Javed, H. I. Ali, Z. and Ullah, I. (2003). Response of maize cultivars to different NP levels under irrigated condition in Peshawar valley. *Pak. J. Bio. Sci*. **6**(14): 1229-1231.

Samir, A. Z. M. (1988). Water use efficiency, growth and yield of corn as influenced by antitranspirant materials. MSc Thesis, Ain Shams University, Cairo, Egypt.

Santoso, S. (1981). Performance of maize varieties in three tropical soil families and their response to N and P fertilization; A thesis submitted to the graduate division of the University of Hawaii.

Selim, E., Gönül, C., Ömer, K., Ahmet, C.U., Levent, O. and Smail, C. (2007). Effect of salinity stress on dry matter production and ion accumulation in hybrid maize varieties. *Turk J Agric. Sci*. **9**: 567-456.

Severini, A. D., Borras, L., Westgate, M. E. and Cirilo, A. G. (2011). Kernel number and kernel weight determination in dent and popcorn maize. *Field Crops Res*. **120**(3): 360 -369.

Shaozhong, K. and Minggang, Z. (1993). Crop water production function and optimal allocation of irrigation water use. **In**: Advances in Planning, Design and Management. https://agris.fao.org/agris-search/search.do?recordID=BE9301400.

Shariot-Ullah, M., Mojid, M. A., Tabriz, S. S., Acharjee T. K. and Adham, A. K. M. (2013). Growth and yield of three hybrid maize varieties under different irrigation levels. *J. Agric. Tech*. **9(**7): 1749-1758.

Sharma, D., Sharma, R. C., Dhakal, R., Dhami, N. B., Gurung, D. B., Katuwal, R. B., Koirala, K. B., Prasad, R. C., Sah, S. N., Upadhyay, S. R., Tiwari, T. P. and

Ortiz-Ferrara, G. (2008). Performance stability of maize genotypes across diverse hill environments in Nepal. *Euphytica*. **164**: 689-698.

Shill, N. C. Saleque, M. A. Islam, M. R. and Jahiruddin, M. (2016). Soil fertility status of some of the intensive crop growing areas under major agro-ecological zones of Bangladesh. *Bangladesh J. Agril. Res*. **41**(4): 735-757.

Shrestha, J. and Kunwar C. B. (2014) Evaluation of original and selected maize populations for agronomic traits under mass selection. *Scrutiny Intl. Res. J. Agrl., Plant Biotech. and Bio. Products*. **1**(4): 1-11.

Siddique, M., Hamid, R. B. and Islam, M. A. (1999). Drought stress effect on photosynthetic rate and leaf gas exchange of wheat. *Bota Bullet. AcadSinica*. **40**: 141-149.

Sleper, D. A. and Poehlman, J. M. (2006). Breeding Field Crops. The Blackwell Publishing Inc Ames Lowa, Columbus, USA.

Statista, A. (2020). Bangladesh: Total population from 2014 to 2024. https://www.statista.com/statistics/438167/total-population-of-bangladesh/

Stenger, D. C. and French, R. (2008). Complete nucleotide sequence of a maize chlorotic mottle virus isolate from Nebraska. *Archiv. Virol.* **153**(5): 995-997.

Sun, J., Gao, J., Wang, Z., Hu, S., Zhang, F., Bao, H. and Fan. (2018). Maize Canopy Photosynthetic Efficiency, Plant Growth, and Yield Responses to Tillage Depth. *Agron*. **9**(3): 2-18.

Sutresna, I. W., Aryana, I. G. P. and Gunartha, M. I G. E. (2018). Evaluation of superior maize genotypes on growth environment with improved cultivation technology. *IOSR J. Agric. Veterinary Sci*. **11**(6): 01-04.

Taba, S. (1997). Maize. In: D. Fuccillo, L. Sears and P. Stapleon (eds.). Biodiversity in trust. Cambridge University Press. Cambridge, UK. p. 213 -226.

Tadesse, D., Zenebe, G., Medhin, A. and Ayalew, J. (2014). Participatory on Farm Evaluation of Improved Maize Varieties in Chilga District of North Western Ethiopia. *Intl. J. Agric. Forestry*. **4**(5): 402-407.

Talukder, M. S. U., Shirazi, S. M., Hossain, M. A, Dey, H. and Hye, M.A. (1999). Growth parameters and yield response of maize to water stress and nitrogenous fertilizer. *J. Okinawa Agric*. **34**: 12-14.

Thomison, P. (2011). Specialty corns: waxy, high-amylose, high-oil, and high-lysine corn. Ohio State University Extension. http://ohioline.osu.edu/agf-fact/0112.html

Thomison, P. and Nielson, R. (2002). Impact of delayed planting on heat unit requirements for seed maturation in maize. Pontificia Universidad Católica de Chile. Departamento de CienciasVegetales. SeminarioInternacionalSemillas: comercializaciónproducción y tecnología. *Santiago*. **15**: 140-164.

Tollenaar, M. (1977). Sink-source relationships during reproductive development in maize. A Review. *Maydica*. **22**: 49-75.

Tollenaar, M., Dwyer, L.M. and Stewart, D.W. (1994). Ear and kernel formation in maize hybrids representing three decades of grain yield improvement in Ontario. *Crop Sci*. **32**: 432-438.

Tripathi, M. P., Shrestha, J. and Gurung, D. B. (2016). Performance evaluation of commercial maize hybrids across diverse Terai environments during the winter season in Nepal. *J. Maize Res. Dev*. **2**(1): 1-12

Troyer, A. F. (1999). Background of U.S. hybrid corn. *Crop Sci*. **39**: 601-626.

Tsimba, R., Edmeades, G. O., Millner, J. P. and Kemp, P. D. (2013). The effect of planting date on maize: Phenology, thermal time durations and growth rates in a cool temperate climate. *Field Crops Res*. **150**: 145-155.

Uchida, R. (2000). Essential nutrients for plant growth: Nutrient functions and deficiency symptoms. In: SILVA JA, UCHIDA R. (eds). Plant nutrient management Hawaii's soils, approaches for the tropical and sub-tropical agriculture. College of Tropical Agriculture and Human Resources, University of Hawaii, Mano.

Ullah M. J., Islam, M. M., Fatima, K., Mahmud, M. S. and Islam, R. I. (2018). Yield and yield attributes of two exotic white maize hybrids at different agroclimatic regions of Bangladesh under varying fertilizer doses. *Adv. Agr. Environ. Sci*. **2**(2): 65-71.

Ullah, M. J. (2017). Third Half Yearly Progress Report, Collection, Evaluation and Introduction of White Maize for Human Consumption in Bangladesh. Submitted to KGF. BARC, Farmgate, Dhaka, Bangladesh.

USDA. (2008). US Department of Agriculture and Food Agriculture Service. Corn 2008: Production, supply, demand database. 2008. Available at: http://www.pecad.fas.usda.gov/cropexplorer/.

USDA. (2019). US Department of Agriculture and Food Agriculture Service. Corn 2019: Production, supply, demand database. 2019. Available at: http://www.pecad.fas.usda.gov/cropexplorer/.

Walker, S. (1988). Spatial pattern of leaf growth of sorghum as affected by water stress and implication for canopy development. Ph.D. Thesis, University of California, Davis.

Wallace, H. A. and Brown, W. L. (1988). Corn and its early fathers. Michigan State Univ. Press, East Lansing, MI.

Warburton, M. L., Ribaut, J. M., Franco, J. and Crossa, J. (2005). Genetic characterization of 218 elite CIMMYT maize inbred lines using RFLP markers. *Euphytica.* **142**: 97-106.

Watson, D. J. (1997). Comparative physiological studies on the growth of field crops. I: variation on net assimilation rate and leaf area between species and varieties and within and between years. *Annals Bot*. **41**: 41-76.

Westgate, M. E., Boote, K., Edmeades, G.O., Bolaños, J., Elings, A., Ribaut, J.M. and Banziger, M. (2000). The role and regulation of the anthesis-silking interval in maize. *In* ME Westgate, K Boote, eds, *Physiology and Modeling Kernel Set in Maize*. **29**: 43-73.

Xia, X.C., Reif, J.C., Melchinger, A.E., Frisch, M., Hoisington, D.A., Beck, D., Pixley, K. and Warburton, M. L. (2005). Genetic diversity among CIMMYT maize inbred lines investigated with SSR markers. *Crop Sci.* **45**: 2573-2582.

Yakozawa, M. and Hara, T. (1995). Foliage profiles, size structure and stem diameter of plant height relationships in crowded plant population. *Ann. Bot*. **76**: 271-285.

Yangcheng, H., Hongxin, J., Blanco, M. and Jane. J. (2012). Characterization of normal and waxy corn starch for bioethanol production. *Agric. Food Chem*. **61**: 379-386.

Yasin, S. M., Ghannam, G. A., Sahawneh, J. and Madanat, G. M. (2015). Kaolin. Ministry of Energy and Mineral Resources Mineral Status and Future Opportunity, Jordan.

APPENDICES

Appendix I: Map showing the experimental locations (black * sign)

Appendix II. Mean square values of growth and yield components of white maize as affected by variety at SAU during Rabi 2015-16

Source of variation	df *	Plant height				No. of leaves $plant^{-1}$			
		30 DAS	60 DAS	90 DAS	Time of harvest	30 DAS	60 DAS	90 DAS	Time of harvest
Replication	2	1.754	9.659	380.00	3.70	0.024	1.081	0.106	1.882
Variety	7	63.221	437.913	2478.17	2060.58	0.289	0.595	6.496	19.083
Error	14	0.844	3.364	415.12	5.35	0.108	0.548	0.680	0.698

*df = Degree of freedom

Appendix III. Mean square values of growth and yield components of white maize as affected by variety at SAU during Rabi 2015-16

Source of variation	df	Leaf Area Index				Cob length	Cob breadth	No. of rows cob^{-1}	100 grain weight	No. of grains row^{-1}
		30 DAS	60 DAS	90 DAS	Time of harvest					
Replication	2	1.633	0.012	0.003	0.140	0.158	0.442	0.720	0.202	0.981
Variety	7	6.020	0.321	1.420	1.393	3.724	7.129	2.514	10.138	17.297
Error	14	9.531	0.011	0.001	0.125	0.407	0.397	0.322	5.704	5.243

Appendix IV. Mean square values of growth and yield components of white maize as affected by variety at SAU during Rabi 2015-16

Source of variation	df	No. grains cob^{-1}	Stover yield $plant^{-1}$ (g)	Grain yield $plant^{-1}$ (g)	Stover yield ha^{-1} (t)	Grain yield ha^{-1} (t)	Biological yield ha^{-1} (t)	Harvest index (%)
Replication	2	6.47	5.686	31.644	0.025	0.097	0.168	0.758
Variety	7	3177.32	922.963	573.376	4.102	2.433	10.128	29.169
Error	14	0.39	3.882	5.419	0.017	0.019	0.035	0.384

Appendix V. Mean square values of quality of white maize as affected by variety at SAU during Rabi 2015-16

Source of variation	df	Protein	Moisture	Fat	Fiber	Ash	Carbohydrate	AAC	GI
Replication	2	0.011	0.968	0.036	0.019	0.042	0.074	0.327	0.228
Variety	5	1.267	12.999	0.170	0.191	0.032	8.780	135.41	38.60
Error	10	0.120	0.036	0.125	0.043	0.022	0.153	0.206	0.014

Appendix VI. Mean square values of yield components of white maize as affected by variety at Dhamrai during Rabi 2015-16

Source of variation	df	PH			Number of Leaves plant^{-1}		
		60 DAS	90 DAS	Time of harvesting	60 DAS	90 DAS	Time of harvesting
Replication	2	12.336	7.143	1.75	1.041	0.106	1.83073
Variety	7	446.991	782.897	2945.06	0.352	6.496	2.83891
Error	14	5.196	8.610	1.78	0.602	0.680	1.24740

Appendix VII. Mean square values of yield components of white maize as affected by variety at Dhamrai during Rabi 2015-16

Source of variation	df	Leaf Area Index			Tasseling date	Maturity date	Cob leng-th	Cob bread-th
		60 DAS	90 DAS	Time of harvesting				
Replication	2	0.034	0.063	0.039	0.782	3.586	0.946	0.186
Variety	7	0.176	8.990	1.008	108.077	375.132	4.062	1.519
Error	14	0.010	0.065	0.072	3.804	0.529	0.606	0.581

Appendix VIII. Mean square values of yield components of white maize as affected by variety at Dhamrai during Rabi 2015-16

Source of variation	df	No. of Grains cob^{-1}	Stover yield plant^{-1}	Stover yield ha^{-1}	Grain yield ha^{-1}	Biological yield ha^{-1}	Harvest index
Replication	2	63.9	28.05	0.131	2.645	0.131	0.787
Variety	7	18716.8	1821.78	8.121	3.301	19.828	14.955
Error	14	2.1	36.98	0.159	8.117	0.159	1.032

Appendix IX. Mean square values of yield components of white maize as affected by variety at Rangpur during Rabi 2015-16

Source of variation	df	Plant height	Number of leaves plant^{-1}	Leaf area index	Tasseling date	Maturity date	Cob leng-th	Cob bread-th
Replication	2	2.70	0.615	0.006	0.782	3.586	0.250	0.186
Variety	7	1860.58	8.412	0.925	100.077	370.132	2.448	1.519
Error	14	4.35	1.748	0.037	3.804	0.529	0.789	0.581

Appendix X. Mean square values of yield components of white maize as affected by variety at Rangpur during Rabi 2015-16

Source of variation	df	No. of rows cob^{-1}	No. of grains row^{-1}	No. of grains cob^{-1}	Stover yield $plant^{-1}$	Grain yield $plant^{-1}$
Replication	2	0.161	0.293	6.47	6.10	11.846
Variety	7	1.697	13.761	3377.32	2113.04	429.385
Error	14	0.632	1.226	0.39	4.82	3.693

Appendix XI. Mean square values of yield components of white maize as affected by variety at Rangpur during Rabi 2015-16

Source of variation	df	Stover yield	Grain yield	Biological yield	Harvest index
Replication	2	0.027	0.044	0.086	0.718
Variety	7	9.391	1.826	7.335	180.037
Error	14	0.021	0.014	0.048	0.285

Appendix XII. Mean square values of yield components of white maize as affected by variety at SAU during Rabi 2016-17

Source of variation	df	Plant height			Number of Leaves $plant^{-1}$		
		60 DAS	90 DAS	Time of harvesting	60 DAS	90 DAS	Time of harvesting
Replication	2	8.798	48.842	2.75	0.306	2.305	0.619
Variety	6	366.324	251.555	2745.06	0.199	0.739	2.563
Error	12	12.912	161.922	2.78	0.275	0.611	0.292

Appendix XIII. Mean square values of yield components of white maize as affected by variety at SAU during Rabi 2016-17

Source of variation	df	Leaf Area Index			Tasseling date	Maturity date	Cob leng-th	Cob bread-th
		60 DAS	90 DAS	Time of harvesting				
Replication	2	0.251	0.103	0.009	2.170	0.502	1.654	1.860
Variety	6	0.281	0.349	0.590	60.088	163.960	2.832	7.949
Error	12	0.057	0.346	0.142	3.861	6.310	0.938	0.637

Appendix XIV. Mean square values of yield components of white maize as affected by variety at SAU during Rabi 2016-17

Source of variation	df	Number of rows cob^{-1}	Number of seeds row^{-1}	Grain yield $plant^{-1}$	Grain yield ha^{-1}
Replication	2	0.893	1.754	1.692	0.007
Variety	6	0.208	29.572	976.548	4.340
Error	12	0.217	1.156	3.260	0.014

Appendix XV. Mean square values of yield components of white maize as affected by variety at SAU during Rabi 2016-17

Source of variation	df	Grain yield	Stover yield	Stover yield	Biological yield	Harvest index
Replication	2	0.007	2.24	0.009	0.034	0.002
Variety	6	4.340	1018.62	4.527	17.671	0.391
Error	12	0.014	1.38	0.006	0.013	0.179

Appendix XVI. Mean square values of yield components of white maize as affected by variety at Dhamrai during Rabi 2016-17

Source of variation	df	Plant height	Number of leaves $plant^{-1}$	Leaf area index	Tasseling date	Maturity date	Cob leng-th	Cob bread-th
Replication	2	637.54	2.892	0.549	2.582	0.819	9.023	0.160
Variety	6	5908.34	6.241	0.576	81.462	222.407	10.750	1.773
Error	12	237.98	0.674	0.135	3.237	6.184	1.371	0.656

Appendix XVII. Mean square values of yield components of white maize as affected by variety at Dhamrai during Rabi 2016-17

Source of variation	df	Number of grains cob^{-1}	100 grain wt.	Number of rows cob^{-1}	Number of grains row^{-1}	Grain yield $Plant^{-1}$
Replication	2	10843.9	0.202	4.539	27.766	0.33
Variety	6	24107.8	10.138	4.130	101.114	1737.05
Error	12	2267.1	5.704	1.387	7.465	13.83

Appendix XVIII. Mean square values of yield components of white maize as affected by variety at Dhamrai during Rabi 2016-17

Source of variation	df	Grain yield	Stover yield Plant^{-1}	Stover yield	Biological yield	Harvest index
Replication	2	0.001	33.07	0.146	0.126	1.379
Variety	6	7.720	2020.41	8.979	30.007	36.155
Error	12	0.061	8.35	0.037	0.133	0.716

Appendix IXX. Mean square values of yield components of white maize as affected by variety at Rangpur during Rabi 2016-17

Source of variation	df	Plant height	Number of leaves plant^{-1}	Leaf area index	Tasseling date	Maturity date	Cob leng-th	Cob bread-th
Replication	2	0.25	0.619	0.006	5.016	18.657	0.717	0.160
Variety	6	1822.93	2.563	0.735	57.253	147.278	14.662	1.773
Error	12	1.11	0.292	0.043	8.095	17.197	0.852	0.656

Appendix XX. Mean square values of yield components of white maize as affected by variety at Rangpur during Rabi 2016-17

Source of variation	df	No. of grains cob^{-1}	100 grain wt.	No.of rows cob^{-1}	No. of grains row^{-1}	Grain yield plant^{-1}
Replication	2	145.73	4.098	0.070	2.171	33.78
Variety	6	5891.27	59.928	1.371	55.437	2356.24
Error	12	315.89	3.224	0.257	6.131	15.93

Appendix XXI. Mean square values of yield components of white maize as affected by variety at Rangpur during Rabi 2016-17

Source of variation	df	Grain yield	Stover yield	Stover yield	Biological yield	Harvest index
Replication	2	0.150	36.01	0.160	0.620	0.018
Variety	6	10.472	1814.63	8.065	36.393	8.437
Error	12	0.070	16.67	0.074	0.237	0.323

Appendix XXII. Mean square values of yield components of white maize as affected by variety and water stress at SAU during Rabi 2017-18

Source of variation	df	Plant height	Number of leaves $plant^{-1}$	Leaf Area Index	Number of grains row^{-1}
Replication	3	490.16	1.717	0.799	0.833
Variety (A)	5	2869.91	23.091	6.295	137.856
Moisture stress (B)	2	1605.51	10.791	5.258	509.347
Variety (A) x Moisture stress (B)	10	141.30	1.658	0.376	32.964
Error	51	272.38	1.237	0.612	4.990

Appendix XXIII. Mean square values of yield components of white maize as affected by variety and water stress at SAU during Rabi 2017-18

Source of variation	df	Number of grains cob^{-1}	Number of rows cob^{-1}	Grain yield $Plant^{-1}$	Grain yield ha^{-1}
Replication	3	208.4	1.013	66.2	0.294
Variety (A)	5	37025.6	13.125	345.5	1.535
Moisture stress (B)	2	72794.8	7.166	14851.1	66.005
Variety (A) x Moisture stress (B)	10	10637.0	4.566	391.8	1.741
Error	51	296.8	5.082	28.4	0.126

Appendix XXIV. Mean square values of yield components of white maize as affected by variety and water stress at SAU during Rabi 2017-18

Source of variation	df	Stover yield $plant^{-1}$	Stover yield ha^{-1}	Biological yield ha^{-1}	Harvest index
Replication	3	47.94	0.213	199.6	5.132
Variety (A)	5	2966.22	13.183	3170.1	169.026
Moisture stress (B)	2	7812.04	34.720	43057.7	517.501
Variety (A) x Moisture stress (B)	10	58.84	0.261	530.2	49.839
Error	51	14.17	0.063	46.4	3.735

Appendix XXV. Mean square values of yield components of white maize as affected by variety and concentration of kaolin at SAU during Rabi 2017-18

Source of variation	df	No. of grains row^{-1}	No. of grains cob^{-1}	100 grains wt.	Grain yield $plant^{-1}$	Grain yield ha^{-1}
Replication	2	2.555	1098.7	2.791	0.71	0.003
Variety (A)	1	0.882	2052.8	9.375	2847.08	12.653
Kaolin concentration (B)	3	180.495	39431.4	53.819	468.72	2.083
Variety (A) x Kaolin concentration (B)	3	10.815	1959.1	0.263	101.79	0.452
Error	14	2.742	1030.6	6.696	6.39	0.028

Appendix XXVI. Mean square values of yield components of white maize as affected by variety and concentration of kaolin at SAU during Rabi 2017-18

Source of variation	df	Grain yield	Stover yield $plant^{-1}$	Stover yield	Biological yield ha^{-1}	Harvest index
Replication	2	0.003	0.529	0.002	0.001	0.082
Variety (A)	1	12.653	577.122	2.564	26.612	44.528
Kaolin concentration (B)	3	2.083	33.792	0.150	3.309	12.744
Variety (A) x Kaolin concentration (B)	3	0.452	21.395	0.095	0.948	2.228
Error	14	0.028	8.158	0.036	0.064	0.546

Appendix XXVII

Photographs of experimental activities

Plates 1 and 2. Showing the field views of the varietal trial of different white maize varieties at SAU in Rabi season of 2015-16.

Plate 3. Showing a single plot at two collar leaf stage of the varietal trial at SAU during Rabi 2016-17 season

Plate 4. Showing the plants of Changnuo-1 (V_3) variety of the varietal trial at SAU in Rabi 2015-16 season

Plate 3. Showing plants in Yangnuo-30 (V_8) variety of the varietal trial at SAU in Rabi 2015-16 season

Plate 4. Showing plants in PSC-121 (V_1) variety of the varietal trial at SAU in Rabi 2015-16 season

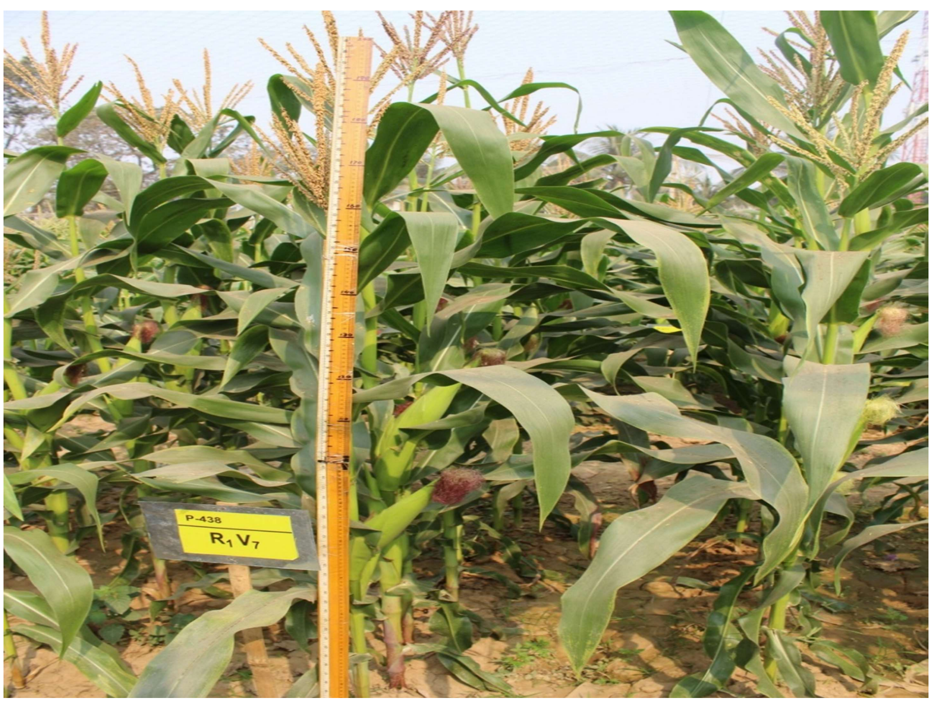


Plate 5. Showing plants in one plot of the varietal trial of Yangn0-7 (V_7) at SAU in Rabi 2016-17 season at silking stage

Plate 6. Showing plants of the varietal trial of Yangnuo-30 (V_8) at SAU in Rabi 2016-17 season at cob filling stage

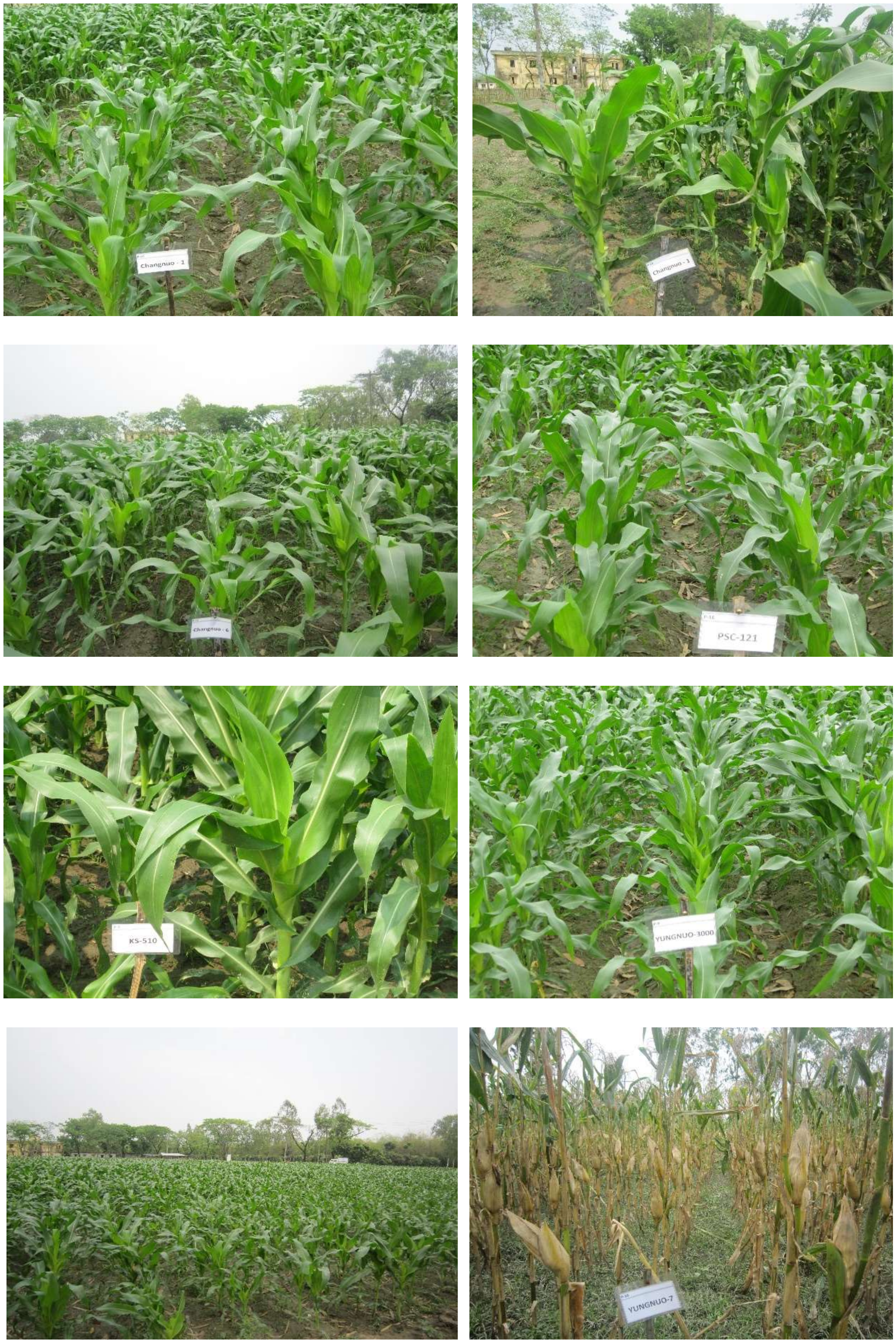
Plate 7. Showing plants of the varietal trial of PSC-121 (V_1) at SAU in Rabi 2016-17 season at maturity stage

Plate 8. Showing matured cobs in one plot of Changnuo-6 (V_5) variety in varietal trial experiment at SAU in Rabi 2016-17 season

Plate 9. Showing matured cobs in one plot of of KS-510 (V_2) in varietal trial at SAU in Rabi 2016-17 season

Plate 10. Showing plant sampling activities of the varietal trial at Dhamrai in Rabi 2016-17 season

Plates 11. Showing harvesting of matuted cobs of different varieties at Dhamrai in Rabi 2016-17



Plates 12. Showing experimental plots at Rangpur during Rabi 2016-17 season

Plate 13. Showing the drought management through differential irrigation regimes during 2017-18 Rabi season

Plate 14. Showing the view of drought management experiment through differential irrigation regimes at tasseling stage during Rabi season of 2017-18.