CHARACTERIZATION OF MAIZE (*Zea mays* L.) LANDRACES OF BANDARBAN IN KHARIF SEASON

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CERTIFICATE

*This is to certify that the thesis entitled, **"CHARACTERIZATION OF MAIZE (Zea mays L.) LANDRACES OF BANDARBAN IN KHARIF SEASON"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, in partial fulfillment for the requirements for the degree of **MASTER OF SCIENCE IN AGRONOMY,** embodies the results of a piece of bona fide research work successfully carried out by **MD. ARAFIN HASAN** bearing Registration No. **18-09179** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated:
Place: Dhaka, Bangladesh

Prof. Dr. Md. Jafar Ullah
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

SOME COMMONLY USED ABBREVIATIONS

Full word	Abbreviation	Full word	Abbreviation
Agricultural	Agril.	Food and Agricultural Organization	FAO
Agriculture	Agric.	Genetics	Genet.
Agro-Ecological Zone	AEZ	Gram	g
Agronomy	Agron.	Harvest Index	HI
Analysis of variance	ANOVA	Hectare	ha
And others	*et al.*	International	*Intl.*
Applied	Appl.	Journal	*J.*
At the rate	@	kilogram	kg
Bangladesh Agricultural Research Institute	BARI	Least significant difference	LSD
Bangladesh Bureau of Statistics	BBS	Meter	m
Biological	Biol.	Millimeter	mm
Biological science	Biosci.	Ministry of Agriculture	MOA
Biology	Bio.	Parts per milion	ppm
		Percent	%
Biotechnology	Biot.	Randomized Complete Block Design	RCBD
Botany	Bot.	Relative humidity	R. H.
Breeding	Breed.	Research	Res.
Centimeter	cm	Science	Sci.
Degree Celsius	ºC	Sher-e-Bangla Agricultural University	SAU
Degrees of freedom	df	Soil Resources and Development Institute	SRDI
Ecology	Ecol.	Squre meter	m^2
Edition	ed.	Ton	t
Etcetera	etc.	Weight	Wt.

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The Author

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ABSTRACT

An experiment was carried out under field conditions to characterize 10 maize landraces during the period from March 2019 to July 2019 in Kharif season at the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. Planting materials of the landraces were collected from different location of Bandarban district. The landraces were characterized in terms of plant growth and yield parameters on morphological traits. High level of significance of variation was found among the landraces. Maximum time (67.67 days) for flowering was taken by V_{10} and minimum time (53.67 days) was taken by V_1. V_8 took highest time (128.67 days) and V_1 took lowest time (105 days) to be matured for harvesting. Tallest plant was found in V_{10} (210.50 cm) and shortest plant was found in V_6 (160 cm). The maximum number of leaves per plant (18) were observed in V_8 and minimum number (13) were observed in V_1. Longest leaf was noted in V_2 (95 cm) and shortest was in V_3 (67.5 cm). V_7 presented the maximum leaf width (7.75 cm) and V_1 presented the minimum (6 cm). Highest stem base circumference was found in V_6 (9.35 cm) whereas, lowest was found in V_1 (5.05 cm). The longest plant root length was in V_{10} (24.5 cm) and shortest was in V_3 (17.5 cm). Root area circumference was maximum in V_9 (25 cm) and minimum in V_7 (14.5 cm). The highest tassel length (47.75 cm) was in V_9 and lowest (30 cm) was in V_1. The maximum cob length (28.4 cm) was recorded from V_1 and V_3 was minimum (18.25 cm). The highest cob circumference (16.70 cm) was in V_4 whereas, the lowest (10 cm) was in V_{10}. Grain color variation was displayed among the landraces as white, off white, red, pink, black, brown, purple, yellow and variegated color. Among the varieties, V_3 had the maximum grain rows cob^{-1} (16.17) whereas, V_6 had the minimum (10.75). V_1 exhibited the maximum number grains row^{-1} (26.70) and V_9 had the minimum (13.50). Highest number of grains per cob was counted at V_1 (335.17) and lowest number was at V_9 (164.31). Maximum stem dry weight per plant was in V_8 (80 g) and minimum was found in V_6 (49.75 g). Highest leaf dry weight per plant was found in V_8 (55 g) and lowest leaf dry weight per plant was in V_6 (24.5 g). The highest total grain weight per plant was attained in V_1 (62.55 g) whereas, the lowest was in V_6 (27 g). V_1 showed the maximum 100 grains weight (23.36 g) and V_6 showed the minimum (14.94 g). Among them, V_6 showed the maximum chaff weight (10.89 g) and V_{10} (4.75 g) the minimum. The highest shell weight (17.13 g) was recorded from V_4 and the lowest shell weight (9.75 g) was from V_9. V_1 showed the highest grain yield (3.10 t ha^{-1}) and V_6 showed the lowest grain yield (1.28 t ha^{-1}). V_8 presented the highest stover yield (6.89 t ha^{-1}) and V_6 the lowest (4.40 t ha^{-1}). Highest biological yield (8.92 t ha^{-1}) was exhibited by V_4 and lowest biological yield (5.68 t ha^{-1}) was exhibited by V_6. Finally, V_1 showed the maximum harvest index (40.72%) and V_5 showed the minimum harvest index (19.28%).

CHAPTER 1

INTRODUCTION

Maize (*Zea mays*, L.) is a cereal crop belongs to the family Poaceae (Gramineae) and the tribe Maydeae (Sikandar *et al*., 2007). It is also referred to as corn or Indian corn in the United States. In the cereal crops family the three most important crops for human food are wheat, rice and maize (Jelena, 2009). On the basis of importance maize ranked third after wheat and rice but it has high productivity potential compared to other Gramineae family members and referred to as a miracle crop (Subramanian and Subbaraman, 2010). It is also called “Queen of cereals”. Maize is a staple food for millions of people in several African countries, Asia and South America (FAO, 2003). It is one of the most widely distributed food plants today (Andrews, 1993).

Although the exact origins of maize are still a point of academic debate, there seems to be general consensus that maize originated in Mexico, South America about ten thousand years ago (Benz, 2001). The name maize is believed to come from the Arawak *mahiz.* Experts have established that modern maize came from teosinte (God’s corn) or *Zea mays ssp. Mexicana* (Beadle, 1939). After Columbus discovered America in 1492 it was carried to Europe later on Africa, Asia and other regions of the world (Burtt-Davy, 1914).

Maize was introduced into Indian sub-continent in the 16th century by the Portuguese, after Vasco da Gama discovered the trade-routes in 1498 (Watt, 1893). Anderson (1945), Stonor and Anderson (1949) proposed the Asiatic origin of maize based on genetic diversity in the maize landraces but recent workers considered their view as inconclusive. Singh (1977) described those races of maize in India could be grouped in to four categories *viz.* primitive, advanced or derived, recent introductions and hybrid races. Primitive variety had hard endosperm, were early maturing, and had variegated bright colored grains. These varieties formed the new local maize populations or landraces. Although maize may have its ancestry outside of Asia, it has been around for so long and has become indigenized as a result of hundreds of years of farmers and natural selection.

In Bangladesh maize was introduced through Christian Missionaries after Portuguese establishment in Chittagong around 1528 (Kumar and Sachan, 1993). From that time the tribal people in the hilly areas of Chittagong (Chittagong hill tracts, CHT) have been growing local landraces in jhum (mixed cropping) system specially in Bandarban (Chakma and Ando, 2008; Ullah *et al*., 2017a; Ullah *et al*., 2017b; Ullah *et al*., 2012). The Chittagong Hill Tracts (CHT) occupied a total of 13,295 square kilometers in south-eastern Bangladesh which are one tenth of the country and Bandarban occupied 4,479 square kilometers. This area has immense potentialities containing huge amount of plant genetic resources of maize. About 69 landraces are found here and conserved at BARI gene bank (Razzaque and Hossain, 2007). Modern variety maize cultivation got attention at late twentieth century in Bangladesh. The interest for conserving its germplasm is enhanced after that because of the narrow genetic base of most of the modern cultivated varieties. The replacement of traditional germplasm is observed in commercial cultivars as well as in breeding programs (Malvar *et al.*, 1996; Ullah *et al*., 2018).

The prolonged and significant loss of genetic variability in most crops seen in recent years has stimulated a growing interest in the preservation of biodiversity especially of endangered species (Myers *et al*., 2000). Erosion of plant genetic resources occurs in the country at intra-specific level of cultivated crops as loss of landraces or traditional cultivars and at the species level. The causes include use of modern varieties and land degradation. In degraded lands, farmers tend to concentrate on production of stress adapted species. Lifestyles have changed varieties to be cropped, due to different preferences in consumption habits and consequently market demand and crop utilization. Use of genetically uniform modern cultivars contributes to replacing and marginalizing the highly diverse local cultivars and landraces in traditional agro-ecosystems though no research has been done to quantify the loss. Other threats include over-exploitation of land and other natural resources. Landraces within species seem to be threatened and they include rice, maize, millets, yams, and local different vegetable species (MoEF, 2016). Study shows that, only 5% of local maize germplasm is used for commercial purposes. But maize landraces are considered to be a valuable resource and because of their high genetic diversity, are most connected to the traditional agricultural practices. Conservation of the landraces and traditional agricultural practices is interconnected (Yadav *et al.*, 2006).

Lack of proper characterization and conservation of local varieties, commercial maize hybrids and their expansion have suppressed the cultivation of landraces in many countries (Shrestha, 2013). But the narrowing of genetic diversity in modern varieties emphasizes the importance of conserving genetic traits and characterizing them for future plant breeding work. Morphological characterization was the first method used by researchers to select superior genotypes (Cadee, 2000). A comparative morphological study of maize shows an important role in the management of crop diversity. Farmers working in traditional and subsistence agricultural communities use morphological traits to guide their use of germplasm in selecting superior traits (Perales *et al.*, 2005; Van Etten, 2006).

Characterization of morphological variability allows breeders to identify accessions with desirable characteristics such as earliness, disease resistance, desirable plant height or improved ear morphology. Characterization of germplasms allow breeders to avoid duplication in sampling populations. Also, in the absence of pedigree records or information on combining ability it would be useful to organize the collection based on morphology. This may allow breeders to identify potential combining ability groups (Falconer, 1960). But detailed study about the maize landraces has seldom been done in this purpose.

The use of local populations could be useful in increasing the genetic variability of maize in different zones and seasons. This justifies the continued characterization of the different landraces and populations germplasm of the country. Based on the above facts the study was conducted to achieve following objectives:

1. To characterize the phenology, growth and yield attributes of local maize landraces.
2. To identify the prospective characters for developing new productive maize varieties.

CHAPTER 2

REVIEW OF LITERATURE

Characterization is the process by which detailed information can be gathered about specific specimen. A significant variation can also be found among the crop cultivars by studying their characters. Former studies revealed that a wide range of variation can be found by evaluating the characteristics of maize landraces. An attempt was made in this section to collect and study relevant information available to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion.

2.1 General description of maize

Maize plant has long stout stem with nodes and internodes and fibrous root system. Leaves are large, narrow and alternately oriented with stem. It is a monoecious plant species, which has separate male and female flowers on the same plant. The male inflorescence (tassel) emerges from the apical meristem of the shoot, while the female inflorescences (ears) initiate from the axillary bud apices. The number of chromosomes in *Zea mays* is 2n =2x = 20. Maize or corn is a plant that belongs to the family of grasses (Poaceae) and tribe Maydeae. It is generally agreed that maize phylogeny was largely determined by the American genera Zea and Tripsacum, however it is accepted that the genus Coix contributed to the phylogenetic development of the species *Zea mays* (Doriana *et al.*, 2012).

2.2 Maize in Bangladesh

Maize cultivation is rising on sharp in last few years in Bangladesh (The Daily Star, Dec 31, 2012). It was introduced as relatively new crop in the cropping patterns of Bangladesh (Hasan *et al*., 2008). It was grown in 4, 87,517 acres area in 2011-2012 (BBS, 2013). Now after several years it is grown on an estimated area of 9, 63, 000 acres and 9,89,582 acres in 2016-2017 and 2017-18 respectively (BBS, 2019). At earlier maize has been considered as a minor crop in Bangladesh. Periodic attempts were however made to promote its cultivation in the past. Last ten years, maize had gained an increasingly importance by the government. There is a huge demand of maize, particularly for poultry feed industry. So, the government and farmers intend to increase the production area of maize. Quality seed supply by the private companies, less pest attack and low production cost make the farmers confident in maize cultivation.

In Bandarban district, maize is the important cereal crops after rice and wheat. Total of 111 acres land was under maize cultivation in 2010-11, but in last two years 388 acres and 396 acres was under cultivation in 2016-17 and 2017-18 tenure respectively in Bandarban hill district in kharif season. Among this production a remarkable amount of maize is local varieties which are mainly cultivated by indigenous people of hill (BBS, 2019).

2.3 Landraces and their importance

Villa *et al.* (2005) stated that, landraces are intrinsically highly genetically diverse and recognized as a distinct entity via common-shared traits. These traits will allow the distinction of one landrace from another or from modern cultivars for the same crop. Landrace names can often give rise to them, but at other times, names may be decided by other variables such as use or origin.

Zeven (1998) found landraces are crop genetic resources that have evolved continuously under natural and farmer selection practices rather than in the collection of gene banks or plant breeding programs. Apart from being identified by its local names, landraces also possess other unique characteristics which distinguish them from improved varieties. Historically, landraces were the progenitors of modern crop varieties. Landraces possess certain unique phenotypic, morphological and phenological characteristics as well as a reputation for adaptation to local climatic conditions and cultural practices, resistance and tolerance to disease and pests. As a result, landraces usually have yield stability and intermediate yield levels under a low input agricultural system.

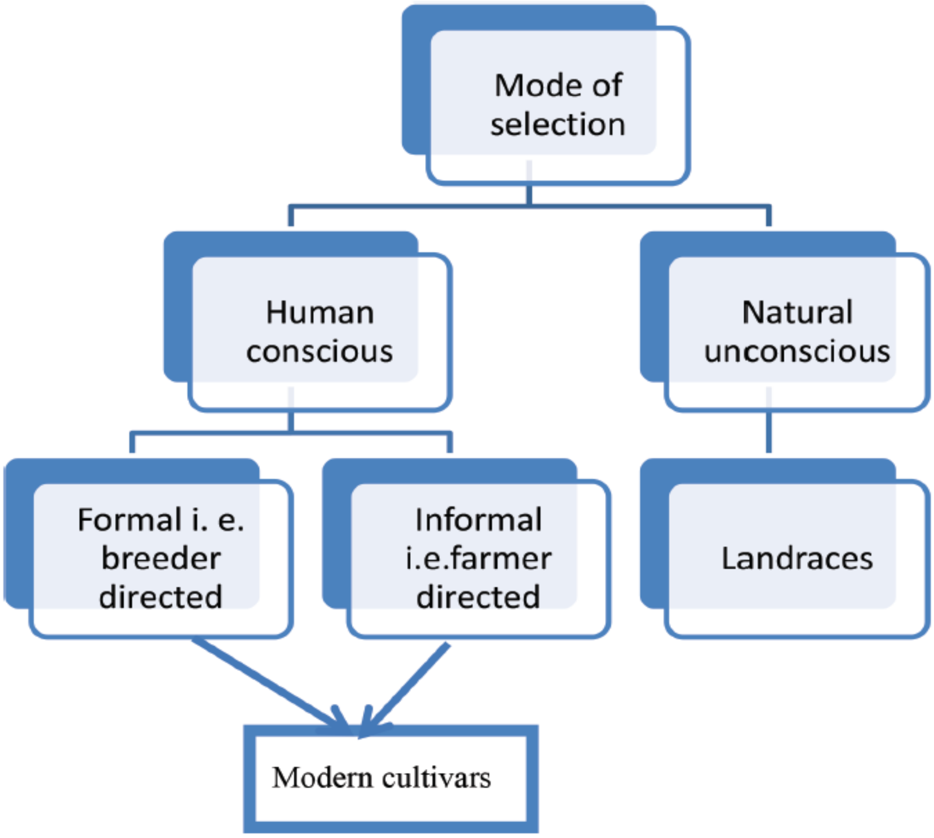

Figure 1. Different opinions about the types of landrace selection (Cleveland *et al.*, 1994).

2.4 Diversity of maize cultivars

Shrestha (2013) experimented on sixty inbred lines done at Rampur, Chitwan, Nepal in 2010/ 2011, indicated a wide range of variability among these inbred lines. Such study of maize accessions was also done in 2013 in Sinola, Mexico. The study showed high genetic diversity of landraces and they can be used as a gene reservoir in breeding programs (Karen *et al*., 2013).

Doriana *et al*. (2012) characterized eighteen maize landraces of the Albanian Gene Bank collection by agro morphological descriptors. Results indicated significant morphological diversity in this study.

Subramanian and Subbaraman (2010) conducted an experiment to analyze the genetic diversity among 38 maize accessions of the germplasm bank of Department of Millets, Coimbatore. Results showed existence of maximum dissimilarity between the accessions which could be further evaluated for their breeding values as parents that have important value in maize crop improvement.

Jelena (2009) evaluated genetic diversity in Eastern Serbia in 2009 using morphological and molecular methods for ten collected maize landraces, showed significant differences on the characteristics measured hence variability was both within and between landraces. It also showed that, during the last two decades cultivation of maize landraces has potentially gone down in that area.

Miguel *et al*. (2008) conducted an experiment at Madeira and Porto Santo Island in Portugal in 1999 to 2000 and found high morphological variability across maize landraces, which were useful for choosing the appropriate material for crop improvement in breeding programs.

2.5 Morphological attributes of maize varieties

2.5.1 Days to flowering and harvesting

Ullah *et al.* (2017b) while conducting an experiment to compare modern varieties of white maize with landraces in Bangladesh observed that the days to flowering and harvesting of the modern white maize varieties varied significantly with landraces. Among the varieties, the Suvra took the highest time (68 days) while the Plough-201 took the lowest time (58 days). The Plough-202 needed 60 days. Harvesting time ranges between Plough-201 and Plough-202 was 85 to 96 days which was significantly lower than that of the maize variety Suvra (106 days).

Malik *et al.* (2011) studied ten maize hybrids with the aim to estimate variation among maize hybrids at Agriculture Research Institute, Tarnab Farm, Peshawar, Pakistan during spring season 2010. The analysis of variance showed highly significant differences among the maize hybrids for days to 50% pollen shedding and days to 50% silking.

Arellano Vazquez (2010) evaluated forty two maize landraces and the hybrids 'H-33', 'H-44' and 'H-137', in experiments established under rainfed conditions in Calimaya and Metepec, both in Toluca Valley, State of Mexico. Among landraces there were differences (P<=0.01) for days to silking and lodging percent. Days to silking ranged from 99 to 106 d after sowing, and lodging from 12 to 24%. These landraces were classified as late season varieties, with moderate to high lodging.

Li Rong Dan *et al.* (2010) conducted an experiment in Changming Town of Daxin County with a view to screening new corn varieties with good quality, high yield, strong resistance to diseases and suitable harvesting time and to find out their suitability for planting. Ten new corn varieties were tested in a field experiment in 2009. The 118–123 days growth duration of varieties Taipingyang 98, Zhengda 629, Hongdan 4, Guidan 30 and Hongdan 3 indicated their suitability for planting in Changming town.

Malik *et al.* (2010) examined 18 hybrids and 13 open pollinated varieties of maize at the National Agricultural Research Centre, Islamabad, Pakistan during kharif 2007. Significant differences were observed for days to 50% tasselling and silking. Days to 50% tasselling ranged from 47.33 (EV-1098) to 64 (NT-6632) while for silking varied from 47.67 (EV-1098) to 63.33 (30-K-95).

Islam and Mian (2004) exhibited the comparative performance of 10 maize hybrids (CTS-991058, CTS-991060, CTS-991062. CTS-993044, CTS- 993046, CTS-9930501, Pacific-1, 1434, 3435 and 6734) during Rabi season of 2000–2001. The analysis of variance for days to 6-leaf stage, days to 12-leaf stage, days to bud initiation and days to tassel emergence revealed significant variation among the hybrids. To complete vegetative growth CTS-991062 required minimum days.

2.5.2 Plant height

Akter (2018) set up an experiment at agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018 with a view to evaluating the influence of weeding regimes on the performance of white maize varieties. The experiment comprised of four weed control treatments *viz.* T_0 = No weeding, T_1= One hand weeding at 60 DAS, T_2= two hand weeding at 40 DAS and 60 DAS and T_3= Weed free after 40 DAS combined with two varieties *viz.* YANGNUO-3000 and PSC-121, designated as V_1 and V_2 respectively. YANGNUO- 3000 showed the inferior performance in terms of plant height than PSC- 121.

Mannan (2018) conducted an experiment to examine the varietal performances of white maize as influenced by different level of herbicides at the agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018. The experiment comprised of six levels of weed control treatments, *viz.*, T_0 = No weeding, T_1 = Carfentrazone + Isoproturon 500g @ 1.5 g/ha (Affinity 50.75% WP), T_2 = Carfentrazone + Isoproturon 500g @ 2.0 g/ha (Affinity 50.75% WP), T_3 = Pendimethalin @ 2.0 l/ha (Panida 50EC), T_4 = Pendimethalin @ 3.0 l/ha (Panida 50EC) and T_5 = One Hand Weeding at 45 DAS with two white maize varieties (PSC-121 and Yangnuo-3000). In the experiment, PSC- 121 showed the superior performance in terms of plant height over YANGNUO- 3000.

Hasan *et al.* (2018) set up an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and 5 plants spacing *viz.*, 75 cm × 20 cm, 75 cm × 25 cm, 75 cm × 30 cm, 75 cm × 35 cm and 75 cm × 40 cm. The shortest plant was recorded from Khoi bhutta. On the other hand, the highest plant height was observed from BARI hybrid maize-7.

Ullah *et al.* (2017b) found that the plant height of the modern white maize varieties varied significantly, giving a wide range of 167 to 222 cm, while conducting an experiment to compare modern white maize varieties with landraces in Bangladesh. The Suvra displayed the highest value among the varieties, while the Plough-201 had the lowest value for plant height. The Plough-202 gave identical result to that of the Plough-201 but a higher value as compared to that of the Plough-201 (172 cm) which was significantly lower than that of the white maize variety Suvra.

Akbar *et al.* (2016) reported that the plant height ranged between 243 and 279 cm across treatments with an average of 263 cm. Generally, with increasing rate of fertilizer application plant height increased and plants of hybrid PSC- 121 were taller than KS-510.

Khan *et al.* (2016) conducted an experiment considering three hybrid maize varieties, e.g., P-3025, P-32T78 and P-3203. From the experiment, they found that, plant height (247.188 cm) was maximum in maize hybrid P-3025, while the minimum plant height (202.00 cm) was recorded in P-32T78 among three hybrid maize varieties.

2.5.3 Dry matter weight plant^{-1}

Islam (2015) carried out an experiment during the period from November 2014 to April 2015 at the experimental field of Sher-e-Bangla Agricultural University, Dhaka to study the growth and yield of white maize varieties under fertilizer doses. The experiment consisted of two factors. Factor A: Fertilizer doses (five levels); F_1 = Recommended dose (100%); F_2 = Below 25% of recommended dose (75%); F_3 = Below 50% of recommended dose (50%); F_4 = above 25% of recommended dose (125%) and F_5 = above 50% of recommended dose (150%) and factor B: Varieties (two levels); they are V_1: KS-510 and V_2: PSC-121. At harvest, KS-510 showed the highest dry matter weight plant^{-1} (289.8 g) and PSC-121 showed the lowest dry matter weight plant^{-1} (288.2 g). Variety did not differ in dry matter production in this study.

Asaduzzaman *et al.* (2014) completed an experiment where four baby corn varieties *viz*. Hybrid baby corn-271, Shuvra, Khoibhutta and BARI sweet corn-1 were planted at five N fertilizer rates *viz.* 0 kg N ha^{-1} (N_0), 80 kg N ha^{-1} (N_1), 120 kg N ha^{-1} (N_2), 160 kg N ha^{-1} (N_3) and 200 kg N ha^{-1} (N_4) to find out the suitable variety and N fertilizer rate for baby corn production. They reported that, Hybrid baby corn-271 produced the highest dry matter plant^{-1} (172.15 g) whereas, the Khoibhutta had the lowest dry matter production plant^{-1} (112.56 g).

Athar *et al.* (2012) arranged a pot experiment in a wire netting green house at Bahauddin Zakariya University, Multan, Pakistan to investigate the beneficial effect of urea on corn cultivars (C-20 and C-79) differing in yield production. Two weeks old plants were subjected to different levels of urea (46% N). Five levels of urea (0, 50, 100, 175 and 225 kg ha^{-1}) with constant (150 kg ha^{-1}), TSP (46% P_2O_5**)** and SOP (50% K_2O) were applied in two steps: half dose at the seedling stage and the remaining half was supplied at vegetative stage (6 weeks) at constant (100 kg ha^{-1}) sulfate of potash (SOP) and triple super phosphate (TSP). They reported that, maximum dry matter accumulation plant^{-1} (100.41 g) was recorded from C-79 and the lowest dry matter accumulation plant^{-1} (60.28 g) was observed from C-20 variety.

Aliu *et al.* (2010) conducted an experiment in order to evaluate some physiological traits and yield of different maize hybrids in growth conditions of Kosovo. The field experiment was arranged in 2006 and 2007 in Kosovo, near Prishtina. Seven commercial maize hybrids belonging to different FAO groups (FAO 300, 400 and 600), originating from two breeding institutions: Maize Dept. of Bc Institute Rugvica - Croatia (Jumbo 48 [H-I], BC418 [H-2], BC408 [H-3], BC288 [H-4], BC394 [H-5]) and from Pioneer Hi-Bred Int. (Austria) (Pregia [H-6] and Colombo [H-7]) were included. For traits biological dry matter (BDM), higher values were obtained in the 2nd year in comparison to the 1st year. The highest values for all traits, was expressed by the H-6 and these values were significantly higher than those of all other hybrids, but not for biological dry matter (BDM).

Santos *et al.* (2010) carried out an experiment to find the dry and fresh matter yield, height of cob insertion, number of cobs per plant, plant height and the cob stem^{-1} leaf^{-1} ratio of six maize varieties recommended for the Brazilian semiarid region (BR 5033 - Asa Branca, BR 5028 - Sao Francisco, BRS 4103, BRS Caatingueiro, BRS Assum Preto and Gurutuba) aiming at silage production. The varieties Gurutuba, BRS 4103 and BR 5028 - Sao Francisco showed the highest dry matter yield (16.0, 16.5 and 15.8 t ha^{-1}, respectively).

2.5.4 Cob length

Akter (2018) recorded the influence of weeding regimes on the performance of white maize varieties at agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018. The study comprised of two varieties *viz.* YANGNUO-3000 and PSC-121, designated as V_1 and V_2 respectively combined with four weed control treatments *viz.* T_0 = No weeding, T_1= One hand weeding at 60 DAS, T_2= two hand weeding at 40 DAS and 60 DAS and T_3= Weed free after 40 DAS. There PSC- 121 showed the superior performance in terms of cob length (18.35 cm) over YANGNUO-3000.

Hasan *et al.* (2018) performed an experiment in order to evaluate the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and 5 plants spacing *viz.*, 75 cm × 20 cm, 75 cm × 25 cm, 75 cm × 30 cm, 75 cm × 35 cm and 75 cm × 40 cm. The longest cob was observed in BARI hybrid maize 7. On the other hand, the shortest cob was observed in Khoi bhutta.

Enujeke (2013) conducted a study to find the effects of variety and spacing on yield indices of Open-pollinated maize. Four open-pollinated varieties (Suwan-1-SR, ACR97, BR9922-DMRSF2 and AMATZBRC2WB) were evaluated under three different plant spacing (75 cm × 15 cm, 75 cm × 25 cm and 75 cm × 35 cm) for yield indices as number of cobs plant^{-1}, cob length, grain weight and number of grains cob^{-1} of maize. The results obtained indicated that variety BR9922-DMRSF2 was outstanding with cob length of 27.7 cm and 26.7 cm in 2008 and 2009, respectively.

Bhuiyan (2012) conducted an experiment at the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 from December 2010 to May 2011 to determine optimum water requirement for the cultivation of hybrid maize varieties. There were two factors in this experiment, a) four hybrid maize varieties: V_1 (BARI Hybrid Maize-5). V_2 (Pacific 60), V_3 (NK 40) and V_4 (Ajanta) and b) three levels of irrigation: I_1 = Two irrigations at 25 and 50 DAS, I_2 = Three irrigations at 25. 50 and 75 DAS and I_3 = Four irrigations at 25, 50, 75 and 100 DAS, respectively. Cob length varied significantly among the varieties. BARI Hybrid Maize-5 performed better among the four varieties tested in this experiment.

Ahmed *et al.* (2010) carried out a research work for two consecutive years taking three varieties (DK-919, DK-5219 and Pioneer-30Y87) and found that during both the years of experimentation, yield-contributing characters like cob length significantly differed within the hybrids.

Fan *et al.* (2010) set up an experiment with a view to screening some new corn varieties with high yield and resistance suitable for planting in Xincheng county of Guangxi. Variety Lucheng 133 was characterized by short cob length.

2.5.5 Cob circumference

Hasan *et al.* (2018) executed an experiment to observe the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and 5 plants spacing *viz.*, 75 cm × 20 cm, 75 cm × 25 cm, 75 cm × 30 cm, 75 cm × 35 cm and 75 cm × 40 cm. The minimum circumference of cob was observed in Khoi bhutta. On the other hand, the maximum circumference of cob was observed in BARI hybrid maize 7.

Bhuiyan (2012) completed a research work at the field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 from December 2010 to May 2011 to determine optimum water requirement for the cultivation of hybrid maize varieties. There were two factors in this experiment, a) four hybrid maize varieties: V_1 (BARI Hybrid Maize-5). V_2 (Pacific 60), V_3 (NK 40) and V_4 (Ajanta) and b) three levels of irrigation: I_1 = Two irrigations at 25 and 50 DAS, I_2 = Three irrigations at 25. 50 and 75 DAS and I_3 = Four irrigations at 25, 50, 75 and 100 DAS, respectively. Cob diameter varied significantly among the varieties. BARI Hybrid Maize-5 performed better among the four varieties tested in this experiment.

Triveni *et al.* (2014) conducted an experiment to determine cob and technological properties of eight sweetcorn cultivars as main and second crops in 2003 in Turkey. There are statistically significant differences between cultivars for cob diameter in both growing periods.

Esiyok *et al.* (2004) recorded yield, quality and some plant characteristic during 2003 in 10 sweetcorn cultivars (ACX 232, ACX 942, GH 2547, Merit F1, Multi 500, Multi 610, ACX 945 Y, Martha Fl, ACX 935 Y and ACX 1072) grown in Izmir (Bornova-Menemen) and Aydn (Cine), Turkey. Significant differences were observed among the cultivars and locations for all characteristics except cob diameter.

Islam and Mian (2004) evaluated the results of comparative performance of ten maize hybrids (CTS-99 1058, CTS-991060, CTS-991062. CTS-993044, CTS- 993046, CTS-

9930501, Pacific-11, 1434, 3435 and 6734) during Rabi season of 2000–2001. The analysis of variance for cob diameter revealed significant variation among the hybrids.

2.5.6 100 grains weight

Akter (2018) carried out a research work at agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018 to investigate the influence of weeding regimes on the performance of white maize varieties. The experiment comprised of two varieties *viz.* YANGNUO-3000 and PSC-121, designated as V_1 and V_2 respectively combined with four weed control treatments *viz.* T_0 = No weeding, T_1 = One hand weeding at 60 DAS, T_2 = two hand weeding at 40 DAS and 60 DAS and T_3 = Weed free after 40 DAS. PSC23 121 showed the superior performance in terms of 100 seed weight (35.0837 g) over YANGNUO-3000.

Mannan (2018) performed an experiment at the agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018 to examine the varietal performances of white maize as influenced by different level of herbicides. The experiment comprised of two white maize varieties (PSC-121 and Yangnuo-3000) and six levels of weed control treatments, *viz.*, T_0 = No weeding, T_1 = Carfentrazone + Isoproturon 500g @ 1.5 g/ha (Affinity 50.75% WP), T_2 = Carfentrazone + Isoproturon 500g @ 2.0 g/ha (Affinity 50.75% WP), T_3 = Pendimethalin @ 2.0 l/ha (Panida 50EC), T_4 = Pendimethalin @ 3.0 l/ha (Panida 50EC) and T_5 = One Hand Weeding at 45 DAS. In the experiment, PSC- 121 showed the superior performance in terms of 100-seed weight (33.898 g) over YANGNUO-3000.

Hasan *et al.* (2018) carried out an experiment to investigate the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and 5 plants spacing *viz.*, 75 cm × 20 cm, 75 cm × 25 cm, 75 cm × 30 cm, 75 cm × 35 cm and 75 cm × 40 cm. The highest 100-grain weight was observed in BARI hybrid maize 7. On the other hand, the lowest 100- grain weight was observed from Khoi bhutta.

Ullah *et al*. (2016) conducted an experiment with four white maize varieties (Chamgnuo-1, Changnuo-6, Q-xiannuo-1 and Yangnuo-7) for evaluating yield and yield performance of transplanted white maize varieties under varying planting geometry. The lowest 100-seed weight was recorded from Yangnuo-7 (24.33 g, other varieties showed 31.83–34.67 g).

Islam (2015) performed a study to find the growth and yield of white maize varieties under fertilizer doses. The experiment consisted of two factors. Factor A: Fertilizer doses (five levels); F_1 = Recommended dose (100%); F_2 = Below 25% of recommended dose (75%); F_3 = Below 50% of recommended dose (50%); F_4 = above 25% of recommended dose (125%) and F_5 = above 50% of recommended dose (150%) and factor B: Varieties (two levels); V_1: KS-510 and V_2: PSC-121. Among the varieties, KS- 510 (V_1) showed the minimum 100-grain weight (35.04 g), whereas PSC-121 (V_2) showed the maximum 100-grain weight (36.78 g).

Bhuiyan (2012) conducted an experiment to determine optimum water requirement for the cultivation of hybrid maize varieties. There were two factors in this experiment, a) four hybrid maize varieties: V_1 (BARI Hybrid Maize-5). V_2 (Pacific 60), V_3 (NK 40) and V_4 (Ajanta) and b) three levels of irrigation: I_1 = Two irrigations at 25 and 50 DAS, I_2 = Three irrigations at 25. 50 and 75 DAS and I_3 = Four irrigations at 25, 50, 75 and 100 DAS, respectively. The findings revealed that, selected varieties individually had significant effect on yields and yield contributing characters. 1000-grain weight varied significantly among the varieties. BARI Hybrid Maize-5 performed better among the four varieties tested in this experiment.

Mukhtar *et al.* (2011) recorded response of maize to various NP levels 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 on two maize hybrids (YH-1898 and YH-1921) for growth and yield. They reported that, both hybrid varieties YH-1921 and YH- 1898 showed non-significant result (324.17 g and 378.44 g, respectively) for 1000-grain weight.

Ahmed *et al.* (2010) performed an experiment taking three varieties (DK-919, DK-5219 and Pioneer-30Y87) for two consecutive years and found that during both the years of experimentation, 100-grain weight significantly differed within the hybrids.

Asghar *et al.* (2010) conducted a study to investigate the effect of different NPK rates on growth and yield of maize cultivars: Golden and Sultan. The varieties V_1 (Golden) (248.83 g) and V_2 (Sultan) (246.74 g) did not show any difference in producing 1000-grain weight.

Malik *et al.* (2010) tested 18 hybrids and 13 open pollinated varieties of maize at the National Agricultural Research Centre, Islamabad during kharif 2007. Significant differences were observed for 100-grain weight. 100-grain weight ranged from 23 g (EV-6098) to 39 g (2512).

Msarmo and Mhango (2005) conducted an experiment to observe cropping season to assess the effect of fertilizer application practices on performance of maize with emphasis on improving the efficiency of using urea as a top-dressing fertilizer at Bunda College during the year 2003-04. There were three maize varieties with three fertilizer application practices. The maize varieties included local maize, Masika (composite) and DK8031 (hybrid). The result of the study revealed that, DK8031 had the highest 100-seed weight (41.45 g) as compared to local maize and Masika which had (35.17 g) and (34.60 g), respectively.

2.5.7 Grain yield

Akter (2018) carried out a research work at agronomy farm of Sher-e-Bangla Agricultural University, Dhaka to investigate the influence of weeding regimes on the performance of white maize varieties during November 2017 to April 2018. The experiment comprised of two varieties *viz.* YANGNUO-3000 and PSC-121, designated as V_1 and V_2, respectively. PSC-121 showed the superior performance in terms of grain yield (8.28 t ha^{-1}) over YANGNUO-3000.

Mannan (2018) conducted a study at the agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018 to evaluate the varietal performances of white maize as influenced by different level of herbicides. The experiment comprised of two white maize varieties (PSC-121 and Yangnuo-3000). In the experiment, PSC-121 showed the superior performance in terms of grain yield (7.758 t ha^{-1}) over Yangnuo-3000. Whereas, a grain yield of 6.44 t ha^{-1} was obtained from Yangnuo-3000.

Hasan *et al.* (2018) carried out an experiment to examine the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396. The maximum grain yield was observed from BARI hybrid maize-7. On the other hand, the lowest grain yield was observed in Khoi bhutta.

Khan *et al.* (2016) conducted an experiment considering three hybrid maize varieties, e.g., P-3025, P-32T78 and P-3203. From the experiment, they noted that among three hybrid maize varieties, grain yield (2.253 t ha^{-1}) was maximum in maize hybrid P-3025.

Ullah *et al*. (2016) conducted a research work to investigate yield and yield performance of transplanted white maize varieties under varying planting geometry. Out of four white maize varieties (Chamgnuo-1, Changnuo-6, Qxiannuo-1 and Yangnuo-7), the highest significant grain yield per hectare was resulted from Changnuo-6 (8.198 tons) which is preceded by Changnuo-1 (7.457 tons) and Qxinannuo-1 (6.718 tons). The lowest grain yield per hectare was obtained from Yangnuo-7 (4.393 tons) than others.

Ishaq *et al.* (2015) carried out a study to evaluate genetic potential, variability and heritability of various morphological and yield traits among maize synthetics and found highly significant differences ($P \leq 0.01$) for all the agronomic and genetic traits. Among the tested populations, Jalal-2003 proved to be superior for most of the traits studied. The highest values for grain yield (5927 kg ha^{-1}) were recorded for Jalal-2003.

Enujeke (2013) conducted an experiment to find out the effects of variety and spacing on yield indices of Open-pollinated maize. Four open-pollinated varieties (Suwan-1-SR, ACR97, BR9922-DMRSF2 and AMATZBRC2WB) were evaluated under three different plant spacing (75 cm × 15 cm, 75 cm × 25 cm and 75 cm × 35 cm) for yield indices. The results obtained indicated that variety BR9922-DMRSF2 was outstanding with its grain weight which was 4.70 t ha^{-1} in 2008 and 4.90 t ha^{-1} in 2009.

Aziz *et al.* (2011) conducted a field trial during the Rabi season of 2008-2009 to find out the suitable hybrid maize variety for hilly areas at the Hill Agricultural Research Station, Khagrachari, Ramgorh and Boropara (Farmers field), Khagrachari. Five varieties of hybrid maize viz., BARI Hybrid Maize-2, BARI Hybrid Maize-3, BARI Hybrid Maize-5, Pacific-11 and Pacific-984 were evaluated in this study. Among the varieties BARI Hybrid Maize-5 produced maximum grain yield at all the locations (Khagrachari: 10.07 t ha^{-1}, Boropara: 9.71 t ha^{-1} and Ramgorh: 6.71 t ha^{-1}). The lowest grain yield was obtained from Pacific-984 (7.53 t ha^{-1}) at Khagrachari, BARI Hybrid Maize-2 (6.42 t ha^{-1}) at Boropara and BARI Hybrid Maize-3 (4.51 t ha^{-1}) at Ramgorh.

Arellano Vazquez (2010) tested 42 Cacahuacintle maize landraces and the hybrids 'H-33', 'H-44' and 'H-137', in experiments established under rainfed conditions in Calimaya and Metepec, both in Toluca Valley, State of Mexico. Among landraces there were differences ($P<=0.01$) for grain yield. Grain yield in the best performing landraces ranged from 7.5 to 8.9 t ha^{-1}, while varieties 7, 11 and 32 stood out for their high values of grain yield.

Frigeri *et al.* (2010) evaluated the agronomic performance of recent releases of simple and triple hybrids of corn developed for high and medium technologies in 2007 to 2008 in Jaboticabal; State of Sao Paulo, Brazil. The high genetic variability of *Zea mays* allows the annual release of new cultivars with superior agronomic characteristics. An experimental design of randomized blocks with 45 corn cultivars with three replications was used. The experimental plot consisted of four rows of five meters, spaced 80 cm between rows, and an initial population of 90,000 seedlings per hectare. They concluded that the simple hybrids RB 9108, 30F35, DKB AS 390 and 1567 presented with the highest yields.

Malik *et al.* (2010) carried out a field experiment to evaluate 18 hybrids and 13 open pollinated varieties of maize at the National Agricultural Research Centre, Islamabad during kharif 2007. Significant differences were observed for grain yield. The hybrids NT- 6622 and NT-6651 ranked top and second in grain yield by producing 7842 and

7759 kg ha^{-1}, respectively. Generally, the hybrids produced more grain yield than the open pollinated varieties.

2.5.8 Stover yield

Akter (2018) carried out a study to investigate the influence of weeding regimes on the performance of white maize varieties at agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018. The experiment comprised of two varieties *viz.* YANGNUO-3000 and PSC-121, designated as V_1 and V_2 respectively combined with four weed control treatments *viz.* T_0 = No weeding, T_1 = One hand weeding at 60 DAS, T_2 = two hand weeding at 40 DAS and 60 DAS and T_3 = Weed free after 40 DAS. PSC- 121 showed the superior performance in terms of stover yield (6.56 t ha^{-1}) over YANGNUO-3000.

Mannan (2018) carried out a research work to examine the varietal performances of white maize as influenced by different level of herbicides at the agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018. The experiment comprised of two white maize varieties (PSC-121 and Yangnuo-3000) and six levels of weed control treatments, *viz.*, T_0 = No weeding, T_1 = Carfentrazone + Isoproturon 500g @ 1.5 g/ha (Affinity 50.75% WP), T_2 = Carfentrazone + Isoproturon 500g @ 2.0 g/ha (Affinity 50.75% WP), T_3 = Pendimethalin @ 2.0 l/ha (Panida 50EC), T_4 = Pendimethalin @ 3.0 l/ha (Panida 50EC) and T_5 = One Hand Weeding at 45 DAS. PSC-121 showed the superior performance in terms of stover yield (6.12 t ha^{-1}) over YANGNUO- 3000.

Hasan *et al.* (2018) set up an experiment to find the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised of 5 varieties *viz.*, Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and 5 plants spacing *viz.*, 75 cm × 20 cm, 75 cm × 25 cm, 75 cm × 30 cm, 75 cm × 35 cm and 75 cm × 40 cm. The maximum stover yield was observed from BARI hybrid maize 7. On the other hand, the lowest stover yield was observed in Khoi bhutta.

Islam (2015) performed an experiment to study the growth and yield of white maize varieties under fertilizer doses at the experimental field of Sher-e-Bangla Agricultural

University, Dhaka during the period from November 2015 to April 2016. The experiment consisted of two factors. Factor A: Fertilizer doses (5 levels); F_1 = Recommended dose (100%); F_2 = Below 25% of recommended dose (75%); F_3 = Below 50% of recommended dose (50%); F_4 = above 25% of recommended dose (125%) and F_5 = above 50% of recommended dose (150%) and factor B: Varieties (2 levels); V_1: KS-510 and V_2: PSC-121. Among the varieties, KS-510 (V_1) showed the lowest stover yield (11.64 t ha^{-1}) whereas PSC-121 (V_2) showed the highest stover yield (12.06 t ha^{-1}).

Nizamuddin *et al.* (2010) conducted a research work to find out the data on yield and yield components of five synthetic maize cultivars (EV-3001, Jalal, Kisan, Azam and Pahari) at Chilas Agriculture Farm, district Diamer, Northern Areas, Pakistan during 2005. Cultivars differed significantly for all parameters. The effect of cultivars on stalk yields significantly differed and check variety produced the lowest stalk yield (1.320 t ha^{-1}). Other cultivars were at par for stalk yield.

Msarmo and Mhango (2005) conducted a field experiment during the cropping season 2003-04 to measure the effect of fertilizer application practices on performance of maize with emphasis on improving the efficiency of using urea as a top-dressing fertilizer at Bunda College. There were three maize varieties and three fertilizer application practices. The maize varieties included DK8031 (hybrid), Masika (composite) and local maize. The fertilizer application practices were 100 kg ha^{-1} urea as basal and 100 kg ha^{-1} urea as top dressing (P_1), 100 kg ha^{-1} urea as basal and 75 kg ha^{-1} urea as top dressing (P_2) and 100 kg ha^{-1} as basal and 150 kg ha^{-1} urea as top dressing (P_3). The result of the study revealed that, variety DK8031 showed the highest biomass yield (16131 kg ha^{-1}) followed by local maize (15114 kg ha^{-1}) and then Masika (12408 kg ha^{-1}).

2.5.9 Biological yield

Islam (2015) set up an experiment to study the growth and yield of white maize varieties under fertilizer doses at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to April 2016. The experiment consisted of two factors. Factor A: Fertilizer doses (5 levels); F_1 =

Recommended dose (100%); F_2 = Below 25% of recommended dose (75%); F_3 = Below 50% of recommended dose (50%); F_4 = above 25% of recommended dose (125%) and F_5 = above 50% of recommended dose (150%) and factor B: Varieties (2 levels); V_1: KS-510 and V_2: PSC-121. Among the varieties, KS-510 (V_1) showed the lowest biological yield (18.20 t ha^{-1}) whereas PSC-121 (V_2) showed the highest biological yield (18.92 t ha^{-1}).

Mannan (2018) carried out a field research during November 2017 to April 2018 to evaluate the varietal performances of white maize as influenced by different level of herbicides at the agronomy farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment comprised of two white maize varieties (PSC-121 and Yangnuo-3000) and six levels of weed control treatments, *viz.,* T_0 = No weeding, T_1 = Carfentrazone + Isoproturon 500g @ 1.5 g/ha (Affinity 50.75% WP), T_2 = Carfentrazone + Isoproturon 500g @ 2.0 g/ha (Affinity 50.75% WP), T_3 = Pendimethalin @ 2.0 l/ha (Panida 50EC), T_4 = Pendimethalin @ 3.0 l/ha (Panida 50EC) and T_5 = One Hand Weeding at 45 DAS. In the experiment, PSC- 121 showed the superior performance in terms of biological yield (13.878 t ha^{-1}) over YANGNUO-3000.

Asghar *et al.* (2010) conducted an experiment to find the effect of different NPK rates on growth and yield of maize cultivars, Golden and Sultan. The varieties V_1 (Golden) (14.46 t ha^{-1}) and V_2 (Sultan) (14.43 t ha^{-1}) did not show any significant differences in producing biological yield.

2.5.10 Harvest index

Akter (2018) carried out a research work to assess the influence of weeding regimes on the performance of white maize varieties at agronomy farm of Sher-e-Bangla Agricultural University, Dhaka during November 2017 to April 2018. The experiment comprised of two varieties *viz.* YANGNUO-3000 and PSC-121, designated as V_1 and V_2 respectively combined with four weed control treatments *viz.* T_0 = No weeding, T_1 = One hand weeding at 60 DAS, T_2 = two hand weeding at 40 DAS and 60 DAS and T_3 = Weed free after 40 DAS. PSC- 121 showed the superior performance in terms of harvest index (55.58%) over YANGNUO-3000.

Mannan (2018) conducted an experiment during November 2017 to April 2018 to examine the varietal performances of white maize as influenced by different level of herbicides at the agronomy farm of Sher-e-Bangla Agricultural University, Dhaka. The experiment was laid out in Split Plot Design with three replications. The experiment comprised of two white maize varieties (PSC-121 and Yangnuo-3000) and six levels of weed control treatments, *viz.*, T_0 = No weeding, T_1 = Carfentrazone + Isoproturon 500g @ 1.5 g/ha (Affinity 50.75% WP), T_2 = Carfentrazone + Isoproturon 500g @ 2.0 g/ha (Affinity 50.75% WP), T_3 = Pendimethalin @ 2.0 l/ha (Panida 50EC), T_4 = Pendimethalin @ 3.0 l/ha (Panida 50EC) and T_5 = One Hand Weeding at 45 DAS. In the experiment, PSC- 121 showed the superior performance in terms of harvest index (55.651%) over YANGNUO-3000.

Islam (2015) set up a field study to evaluate the growth and yield of white maize varieties under fertilizer doses at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to April 2016. The experiment consisted of two factors. Factor A: Fertilizer doses (5 levels); F_1 = Recommended dose (100%); F_2 = Below 25% of recommended dose (75%); F_3 = Below 50% of recommended dose (50%); F_4 = above 25% of recommended dose (125%) and F_5 = above 50% of recommended dose (150%) and factor B: Varieties (2 levels); V_1: KS-510 and V_2: PSC-121. Among the varieties, KS-510 (V_1) showed the lowest harvest index (36.26%) whereas PSC-121 (V_2) showed the highest harvest index (36.41%).

Aliu *et al.* (2010) conducted an experiment in 2006 and 2007 in Kosovo, near Prishtina. For calculating and statistical analysis 10 plants per each plot were randomly chosen in the study, seven commercial maize hybrids belonging to different FAO groups (FAO 300, 400 and 600), originating from two breeding institutions: Maize Dept. of Bc Institute Rugvica - Croatia (Jumbo 48 [H-1], BC418 [H-2], BC408 [H-3], BC288 [H-4], BC394 [H-5]) and from Pioneer Hi-Bred Int. (Austria) (Pregia [H-6] and Colombo [H-7]) were included. The harvest index (HI) of the 1st year was of a higher value than the 2nd year. For HI, statistically significant differences were not obtained among the studied maize hybrids.

Asghar *et al.* (2010) recorded the effect of different NPK rates on growth and yield of maize cultivars. Two varieties Golden and Sultan were evaluated during the study. The varieties Golden (34.19 %) and Sultan (33.75 %) did not show any differences for harvest index.

According to gathered information it is cleared that landraces have a great diversity. All the characters based on proper descriptors can be helpful to recognize the prospective genotypes.

CHAPTER 3
MATERIALS AND METHODS

A brief overview of the experimental duration, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, intercultural operations, data collection and statistical analyses are described in this chapter.

3.1 Experimental duration

The experiment was conducted during the period from 14 March 2019 to 21 July 2019 in Kharif season.

3.2 Site description

3.2.1 Geographical location

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

3.2.2 Agro-Ecological Zone

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

3.3 Climate

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

3.4 Soil

The soil of the experimental field belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4-5.6 (Shamim *et al.*, 2019). The soil analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix II.

3.5 Planting materials

In this research work, 10 samples of local maize landraces were used as plant materials, which were collected from various location of Bandarban district, Bangladesh.

Table 1. Maize landraces used in this study.

Sample no.	Code	General description of kernel color
1	V_1	White
2	V_2	Off white
3	V_3	Purple
4	V_4	Black
5	V_5	Red
6	V_6	Yellow
7	V_7	Pink
8	V_8	Yellow and Brown scattered
9	V_9	Brown
10	V_{10}	Variegated

3.6 Description of the landraces

The indigenous maize landraces used as planting materials are cultivated in "Jhum cultivation" at hilly areas. They are mainly cultivated in Kharif season. The general kernel description of these varieties is given in Table 1. Source: Personal Communication: Prof. Dr. Md. Jafar Ullah, Dept. Of Agronomy, SAU, Dhaka.

3.7 Experimental details

Sowing Date: 14 March, 2019

Final Harvesting Date: 21 July, 2019 (Last landrace harvesting date).

3.8 Experimental design

The experiment was laid out in the Randomized Complete Block Design (RCBD) with three replications. The field was divided into 3 blocks and 30 plots. The size of each unit plot was 3.6 m^2 (2 m × 1.8 m). Each plot had 30 plants. Distance maintained between blocks were 1 m. Row to row and plant to plant distances maintained were 0.60 m and 0.20 m respectively. The genotypes were distributed in each block randomly.

3.9 Details of experimental preparation

3.9.1 Preparation of experimental land

The selected field for growing maize was first opened with power tiller and was exposed to the sun for a week. Then the land was prepared to obtain good tilth by several ploughing, cross ploughing and laddering. Subsequent operations were done with harrow, spade and hammer. Weeds and stubbles were removed; larger clods were broken into small particles and finally attained into a desirable tilth to ensure proper growing conditions. The plot was partitioned into the unit blocks according to the experimental design as mentioned earlier. Recommended doses of well decomposed cow dung, manure and chemical fertilizers were applied and mixed well with the soil each block. Proper irrigation and drainage channels were also prepared around the blocks.

3.9.2 Fertilizer application

Manures and fertilizers such as cow dung, urea, triple super phosphate (TSP), muriate of potash (MOP), gypsum and boric acid were applied at the rate shown in Table 2. Urea was applied by three installments. The entire cow dung, TSP, MOP, gypsum, zinc sulphate, boric acid and one third of the urea was applied at the time of final land preparation. The remaining amount of urea was applied as top dressing in two installments. First top dressing was done at 25 days after and second at 50 days after sowing. In this study fertilizer was applied as per the recommendation of Bangladesh Agricultural Research Institute (BARI, 2019).

Table 2. Doses of different fertilizers and manure applied in the experimental field.

Sl. No.	Manure and fertilizer	Doses
1	Cow dung	5 t ha^{-1}
2	Urea	500 kg ha^{-1}
3	TSP	250 kg ha^{-1}
4	MoP	200 kg ha^{-1}
5	Gypsum	250 kg ha^{-1}
6	Zinc Sulphate	10 kg ha^{-1}
7	Boric acid	7 kg ha^{-1}

3.9.3 Seed sowing

The local maize seeds were sown in lines maintaining row-to-row distance and plant to plant distance having 2 seeds $hole^{-1}$ under direct sowing in the well-prepared plot on 14 March, 2019.

3.10 Intercultural operations

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

3.10.1 Gap filling and thinning

Gap filling was done on 29 March 2019, which was 15 days after sowing (DAS). Where two plants were in same place they were pulled out and one was kept there.

3.10.2 Weeding

The hand weeding was done as when necessary to keep the plot free from weeds. During plant growth period two weeding were done. The weeding were done on 25 and 45 DAS.

3.10.3 Earthing up

Earthing up was done on 14 April, 2019 which was 30 DAS. It was done for better irrigation management, nutrition uptake and protection to the plant from lodging.

3.10.4 Irrigation

Irrigation was following flooding method, first irrigation was done as pre-sowing and other four were given at 20, 40,65 and 90 DAS. Due to pre-monsoon and monsoon splash and rainfall less amount of irrigation water needed during experimental period.

3.10.5 Drainage

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

3.10.6 Pest and disease control

Diseases: No specific disease was observed, minor leaf blight was found in some plants.

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

Major insect/pest and Management

Insect pests: Armyworm attack along with some other insect attack at vegetative stage of maize as well as Earworm attack in cob at reproductive stage in maize. After initiation to maturity of maize cob some birds specially parrot can cause damage by eating them.

Management

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

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

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

For Parrot: Proper netting was done to the all four sides and top of the experimental field. No scope of harmful birds and animals' entry was ensured.

3.10.7 General observations of the experimental site

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

3.11 Harvesting, threshing and cleaning

The mature cobs were harvested when the husk cover was completely dried and the grain base can be pulled easily from shell. The cobs of five randomly selected plants of each plot were separately harvested for recording yield attributes and other data. As different varieties matured different time harvesting done at several times.

3.12 Drying

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

3.13 Collection of data

To study the stable diagnostic characteristics, data on the morphological characters were collected from five randomly selected plants from each replicated plot. The plants were selected from middle of the plot to avoid border effect. Data were collected according to the protocol developed by (IBPGR, 1991). The observations for characterization were recorded under field condition as follows:

A. Crop growth parameters

1. Days to flowering
2. Days to harvesting
3. Plant height (cm)
4. Number of leaves plant^{-1} (no.)
5. Leaf length (cm)
6. Leaf Width (cm)
7. Stem base circumference (cm)
8. Root length (cm)
9. Root area circumference (cm)

B. Yield contributing parameters

1. Tassel length (cm)
2. Cob length (cm)
3. Cob circumference (cm)
4. Color of top kernel
5. Number of rows cob^{-1} (no.)

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

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

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

9. Shell weight plant^{-1} (g)

10. Chaff weight plant^{-1} (g)

11. 100 grains weight

C. Yield parameters

1. Grain yield (t ha^{-1})
2. Stover yield (t ha^{-1})
3. Biological yield (t ha^{-1})
4. Harvest index (%)

3.14 Procedure of recording data

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

3.14.1 Days to flowering

Days to flowering were recorded when 80% of the plants within a plot were showed up with flowers. Days to flowering were recorded by regular visits to the field and counted from the date of sowing.

3.14.2 Days to harvesting

Days to harvesting were recorded when 80% of the plants within a plot were showed maturity symptom and fully prepared for harvesting. Days to harvesting were recorded by regular visits to the field and counted from the date of sowing.

3.14.3 Plant height (cm)

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

3.14.4 Number of leaves plant^{-1}

The total number of leaves was counted from each of the sample plants and the average was taken.

3.14.5 Leaf length (cm)

It was measured in centimeter scale from the jointing point of leaf and to the tip point of leaf.

3.14.6 Leaf breadth (cm)

Leaf breadth was measured in cm scale at the middle of leaf where widest area is found.

3.14.7 Stem base circumference plant^{-1} (cm)

The stem base circumference was recorded in centimeter (cm) at flowering and harvesting stage. Data were recorded as the average of five plants selected from the inner rows of each plot. The circumference was measured at the just upper area of last node from ground level of the plant.

3.14.8 Root length and root area circumference (cm)

Root spreading area was measured by uprooting the whole plant along total root system with soil. Then after removing soil from root carefully, length and root area circumference were measured.

3.14.9 Tassel length (cm)

Tassel length was measured in centimeter from the base to the tip of the tassel from the five selected plants in each plot. Then average data were recorded.

3.14.10 Cob length (cm)

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

3.14.11 Cob circumference (cm)

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

3.14.12 Color of top kernel

It was observed after harvest in presence of sufficient sun light and categorized according to their different solid and variegated colors.

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

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

3.14.14 Number of grain row^{-1} (no.)

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

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

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

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

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

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

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

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

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

3.14.19 100-grains weight (g)

One hundred clean and dried seeds were randomly taken from each plot and the weight was measured in an electrical balance. The average result was recorded.

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

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

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

Final grain yield was adjusted at 14% moisture. The grain yield t ha^{-1} was

measured by the following formula:

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

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

All the dry plant parts except grains are gathered to calculate stover yield. The stover yield was measured according to the following formula:

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

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

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

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

3.14.24 Harvest Index (%)

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

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

3.15 Statistical analysis

The collected data were compiled and analyzed following the analysis of variance (ANOVA) techniques by Randomized Completely Block Design (RCBD) to find out the statistical significance of experimental results. The collected data were analyzed by data analysis software Statistix 10 (Statistix, 1985). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

The chapter comprises presentation and discussion of the results obtained from the study to draw the characterization of maize (*Zea mays* L.) landraces. Different maize varieties express different characters on some specific parameters. Data on different characters have been presented in Table 3-8 and Figure 2-4. The analyses of variance (ANOVA) on different parameters were calculated and presented in Appendices IV to X.

4.1 Days to flowering

Different maize landraces have significance difference to flowering days (Appendix IV and Table 3). V_{10} took the maximum time (67.67 days) for flowering which was statistically similar with V_8 (66.67 days) and V_6 (64.33 days). On the other hand, minimum time was taken by V_1 (53.67 days) which was statistically similar with V_2 (54.33 days), V_9 (55.67 days), V_3 (56.67 days) and V_5 (57.67 days). Ullah *et al.* (2017b) found that minimum time needed for maize landraces flowering was 53.66 days and maximum time was 65 days.

4.2 Days to harvesting

Days to harvesting was significantly influenced by the different maize landraces (Table 3 and Appendix IV). V_8 took highest time (128.67 days) which was statistically similar with V_7 (128 days) and V_{10} (126 days). Here lowest time was taken by V_1 (105 days). Ullah *et al.* (2017b) recorded highest 129 days and lowest 106 days for different maize landraces harvesting in Bangladesh.

Table 3. Maize landraces days to flowering and days to harvesting.

Landraces	Days to flowering	Days to harvesting
V_1	53.67 d	105.00 d
V_2	54.33 d	108.33 cd
V_3	56.67 d	111.33 cd
V_4	61.00 bc	113.67 bc
V_5	57.67 cd	118.00 b
V_6	64.33 ab	114.00 bc
V_7	61.67 bc	128.00 a
V_8	66.67 a	128.67 a
V_9	55.67 d	114.67 bc
V_{10}	67.67 a	126.00 a
LSD $_{(0.05)}$	**4.22**	**6.34**
CV (%)	**4.11**	**3.17**

Means followed by different letters in the same column differ significantly according to LSD test at 0.05 level of probability.

4.3 Plant height

Significant differences were observed on the plant height at flowering and harvesting stage of local maize landraces (Appendix V). Figure 2 shows the effect of variety on plant height. At flowering stage, V_{10} showed the tallest plant (202 cm) which was statistically similar to other 3 landraces, V_9 (198.50 cm), V_5 (195 cm) and V_8 (192.67 cm) respectively. Among the landraces, V_6 showed the shortest plant (150 cm) which was statistically similar to other 3 landraces, V_1 (150.50 cm), V_3 (153.33 cm) and V_2 (160.50 cm). Again at harvesting stage, V_{10} showed the tallest plant (210.50 cm) which was statistically similar to other three varieties (V_9, V_5 and V_4 with 209 cm, 204.95 cm and 202.50 cm respectively) and V_6 (160 cm) showed the shortest plant which was statistically similar to V_2 (166.50 cm). Other landraes showed intermediate result at both flowering and harvesting stage. Ullah *et al.*, (2017b) found landraces plant height ranges from 152 cm to 215 cm which almost close to the present study. Akter (2018) and Mannan (2018) reported that PSC-121 showed the superior performance in terms of plant height over YANGNUO-3000. Hasan *et al.* (2018) reported that the highest plant height was observed with BARI hybrid maize-7.

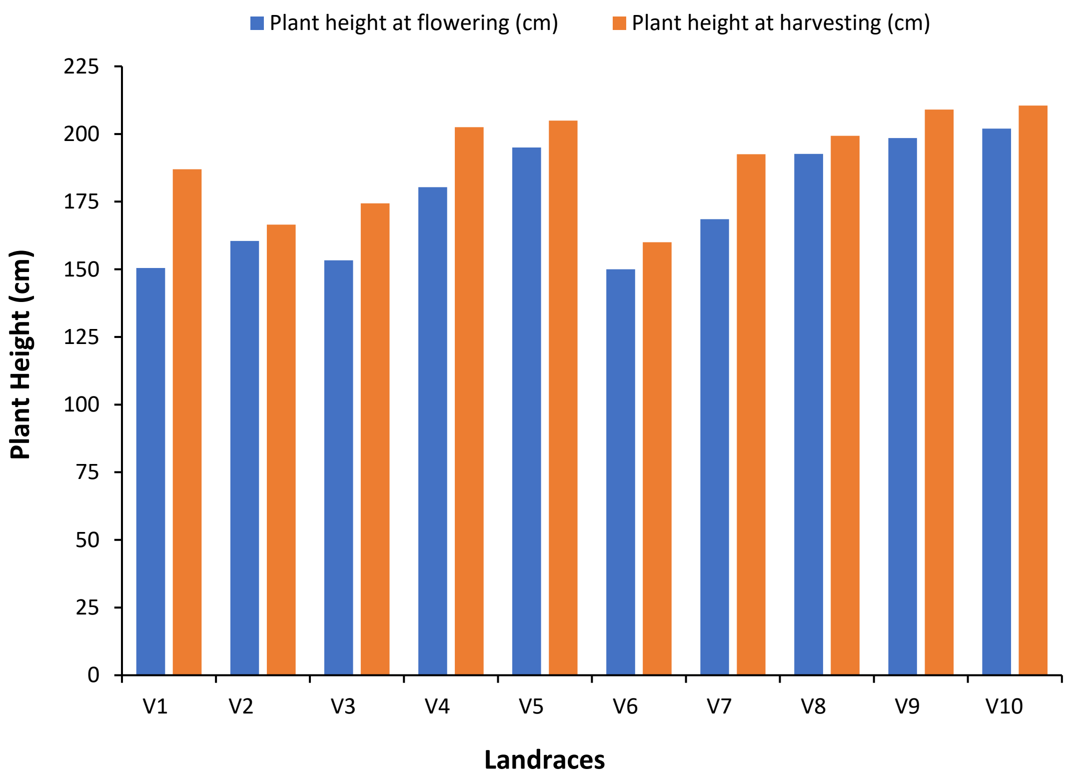

Figure 2. Local maize landraces plant height at flowering and harvesting stage (LSD value = 15.35 at flowering and 10.08 at harvesting).

4.4 No. of leaves plant^{-1}

Highest number of leaves per plant (18) were observed in V_8 followed by V_{10} (17.67), V_3 (17.67), V_7 (16.67), V_9 (16) and V_4 (15.67), while lowest (13) in V_1 followed by V_2 (13.67), V_6 (15) and V_5 (15). These results showed the variation to the maize landraces (Table 4 and Appendix VI). The findings are in line with those of Dijk *et al*. (1999) who observed significant differences while evaluating maize varieties for different morphological and yield traits. Triveni *et al*. (2014) found that number of leaves per plant of maize significantly correlated with its variety and grain yield.

Table 4. Number of leaves plant^{-1}, leaf length, leaf width of maize landraces.

Landraces	Number of leaves plant^{-1} (no.)	Leaf length (cm)	Leaf width (cm)
V_1	13.00 d	89.50 a	6.00 c
V_2	13.67 cd	95.00 a	6.50 bc
V_3	17.67 a	67.50 c	6.50 bc
V_4	15.67 a-c	77.50 b	7.50 ab
V_5	15.00 b-d	78.00 b	7.00 a-c
V_6	15.00 b-d	77.50 b	7.25 ab
V_7	16.67 ab	79.00 b	7.75 a
V_8	18.00 a	91.50 a	7.65 ab
V_9	16.00 a-c	81.50 b	6.65 a-c
V_{10}	17.67 a	82.50 b	7.00 a-c
LSD $_{(0.05)}$	**2.44**	**5.96**	**1.20**
CV (%)	**8.99**	**4.24**	**10.05**

Means followed by different letters in the same column differ significantly according to LSD test at 0.05 level of probability.

4.5 Leaf length

Maximum leaf length was noted in V_2 (95 cm) which was statistically similar to V_8 (91.5 cm) and V_1 (89.5 cm). Minimum was noted in V_3 (67.5 cm) (Table 4 and Appendix VI). Silva *et al.* (2010) reported that the leaf length variation was observed in maize varieties and longest 90.6 cm was AG7000 and shortest 74.7 cm was Master.

4.6 Leaf width

Maximum leaf width was found in V_7 (7.75 cm) and minimum was found in V_1 (6 cm) (Table 4 and Appendix VI). Other varieties showed intermediate value. Silva *et al.* (2010) observed a significant difference among the landraces according to leaf width.

Table 5. Stem base circumference, root length and root area circumference of maize landraces.

Landraces	Stem base circumference at flowering (cm)	Stem base circumference at harvesting (cm)	Root length (cm)	Root area circumference (cm)
V_1	4.95 de	5.05 e	19.40 cd	22.50 b
V_2	5.45 c-e	6.95 cd	19.90 cd	18.50 de
V_3	4.50 e	6.20 d	17.50 d	17.00 e
V_4	6.00 bc	7.15 c	23.50 ab	18.50 de
V_5	5.80 b-d	6.80 cd	17.95 cd	18.50 de
V_6	6.55 b	9.35 a	21.00 bc	16.50 ef
V_7	6.75 b	7.00 cd	19.00 cd	14.50 f
V_8	7.85 a	8.20 b	24.00 ab	20.00 cd
V_9	6.00 bc	7.00 cd	20.00 cd	25.00 a
V_{10}	8.40 a	8.45 b	24.50 a	21.50 bc
LSD $_{(0.05)}$	**1.04**	**0.83**	**3.07**	**2.47**
CV (%)	**9.71**	**6.68**	**8.65**	**7.49**

Means followed by different letters in the same column differ significantly according to LSD test at 0.05 level of probability.

4.7 Stem base circumference

At flowering stage, V_{10} (8.4 cm) showed the highest circumference of stem base at numerical number which was statistically similar with V_8 (7.85 cm) and V_3 (4.5 cm) showed the lowest circumference of stem base at numerical number. At harvesting stage, top numerical value was found in V_6 (9.35 cm) and least value was found in V_1 (5.05 cm) (Table 5 and Appendix VII). Ullah *et al.*, (2017b) reported that stem base circumference of maize varieties ranges from 9.11 cm to 6 cm.

4.8 Root length

Table 5 presents that longest root was observed in V_{10} (24.50 cm) and shortest was observed in V_3 (17.50 cm) which was statistically similar with other five varieties. Significant difference was observed among varieties (Appendix VII).

4.9 Root area circumference

Root area circumference was found maximum in V_9 (25 cm). Minimum root area circumference was found in V_7 (14.5 cm) followed by V_6 (16.5) (Table 5 and Appendix VII).

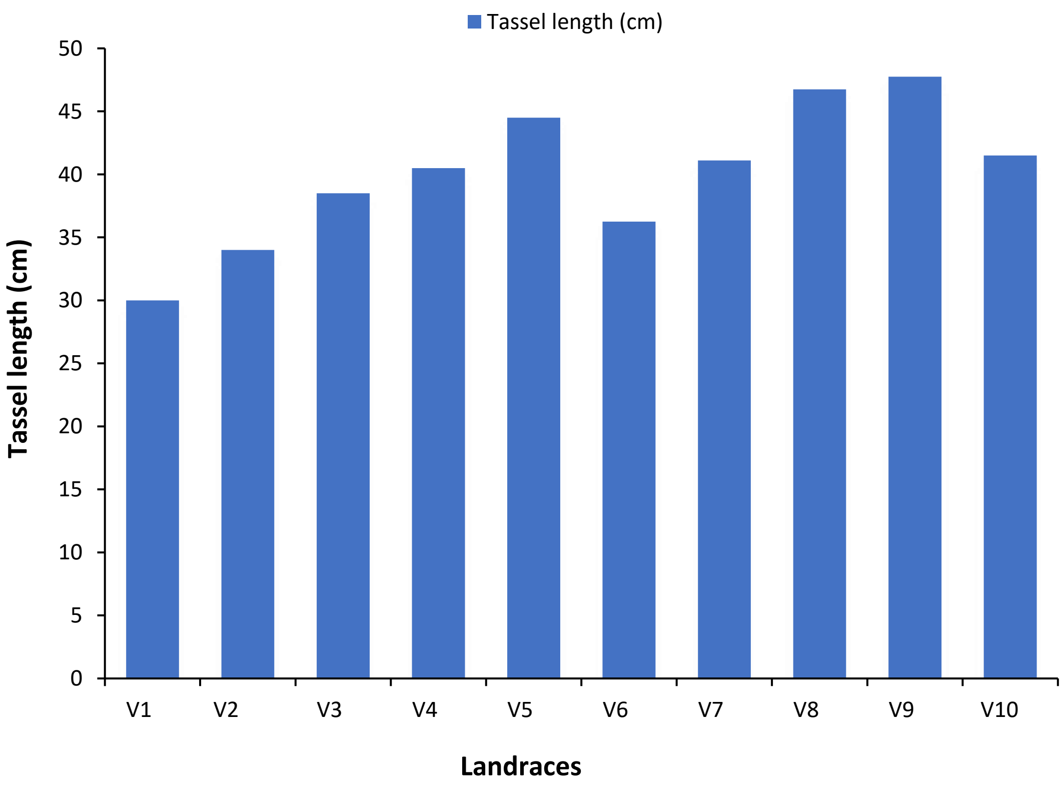

Figure 3. Tassel length of maize landraces (LSD value = 3.06).

4.10 Tassel length

Due to different maize varieties, tassel length showed positively significant result (Figure 3 and Appendix VII). Tassel length range from 47.75 cm to 30 cm among the varieties. The highest tassel length (47.75 cm) was recorded in V_9 and lowest (30 cm) was recorded in V_1.

4.11 Cob length

Effect of variety on cob length is shown in the Table 6. A statistically significant difference between varieties was revealed regarding cob length (Appendix VIII). The maximum cob length (28.40 cm) was reported from V_1 over V_2, which showed the cob length of about 27.25 cm. Minimum cob length (18.25 cm) was from V_3. Akter (2018) who reported that PSC-121 showed the superior performance in terms of cob length over YANGNUO-3000. Hasan *et al.* (2018) reported that the longest cob was observed in BARI hybrid maize 7. Enujeke (2013) carried out a study to evaluate the effects of variety and spacing on yield indices of open-pollinated maize and the results obtained indicated that variety BR9922-DMRSF2 was outstanding with cob length of 27.7 cm and 26.7 cm in 2008 and 2009, respectively.

4.12 Cob circumference

Cob circumference showed significant difference at different maize varieties (Table 6 and Appendix VIII). Due to different local maize varieties, a broad range of cob circumference was found. The numerical highest cob circumference (16.70 cm) was recorded in V_4 while numerical lowest cob circumference (10 cm) was recorded in V_{10}. Hasan *et al.* (2018) and Bhuiyan (2012) who reported that the maximum circumference of cob was observed in BARI hybrid maize 7. Ullah *et al.* (2017a) found that the landraces cob circumference ranged between 19.11 cm to 8.93 cm.

4.13 Grain color

Grain color of maize landraces displayed variation in this study. Some landraces were white, off white, red, pink, black, brown, purple, yellow and variegated (Plate 2).

Observed results showed similar findings with the findings of Ullah *et al.* (2017b). Angelo *et al*. (2008) conducted a study on maize displayed white, yellow and red color. V6 showed yellow color that can be used as gene donor for developing carotene rich variety. Goldstein and Jaradat (2013) reported that increasing yellow color in grain may reflect higher carotenoid content or lower fatty acid contents.

Table 6. Tassel length, cob length, cob circumference, rows cob^{-1}, grains row^{-1}, total no. of grains cob^{-1} of local maize varieties.

Landraces	**Cob length (cm)**	**Cob circumference (cm)**	**Grain rows cob^{-1}**	**Grains row^{-1}**	**Total number of grains cob^{-1}**
V_1	28.40 a	14.95 a-c	12.70 bc	26.70 a	335.17 a
V_2	27.25 a	15.60 ab	11.50 cd	14.33 f	172.10 f
V_3	18.25 e	13.00 c-e	16.17 a	19.75 c	312.88 b
V_4	24.25 b	16.70 a	12.25 bc	21.75 b	266.42 c
V_5	23.35 bc	13.95 b-d	11.50 cd	18.13 de	215.83 de
V_6	21.95 cd	12.70 de	10.75 d	18.00 de	200.50 e
V_7	18.50 e	11.00 ef	12.17 bc	25.50 a	301.83 b
V_8	21.55 cd	13.80 b-d	13.08 b	16.58 e	217.17 de
V_9	23.00 b-d	13.05 c-e	12.17 bc	13.50 f	164.31 f
V_{10}	21.00 d	10.00 f	12.33 bc	18.83 cd	231.67 d
LSD $_{(0.05)}$	**2.24**	**2.12**	**1.32**	**1.57**	**21.95**
CV (%)	**5.73**	**9.17**	**6.15**	**4.76**	**5.29**

Means followed by different letters in the same column differ significantly according to LSD test at 0.05 level of probability.

4.14 Number of rows cob^{-1}

Maize landraces presented a significant difference in respect of the number of grains row^{-1} (Table 6 and Appendix VIII). Among the varieties, V_3 had the maximum no. of rows cob^{-1} (16.17) and V_6 had the minimum no. of rows cob^{-1} (10.75) which was statistically similar with other two varieties V_5 and V_2. This result was different from the study of Asghar *et al*. (2010) who found that the varieties did not differ significantly for number of rows cob^{-1}. Akter (2018) who reported that PSC- 121 showed the superior performance in terms of number of grain row cob^{-1} over YANGNUO- 3000. Islam (2015) evaluated that KS-510 and PSC- 121 both showed the similar number of grain rows cob^{-1}.

4.15 Number of grains row^{-1}

Maize landraces showed significant difference in respect of the number of grains row^{-1} (Table 6 and Appendix VIII). Among the varieties, V_1 exhibited the maximum number of grains row^{-1} (13.5) which was statistically similar with V_7 (25.5) and V_9 exhibited the minimum number of grains row^{-1} (13) which was statistically similar with V_2 (14.33). This result was similar to the results of Mukhtar *et al*. (2011) and Asghar *et al*. (2010). However, Enujeke (2013) and Athar *et al.* (2012) found the different findings. They found that the maize varieties exhibited non-significant difference in respect of the no. of grains row^{-1}.

4.16 Total number of grains cob^{-1}

Significant difference was found in different maize varieties in terms of total number of grains cob^{-1} (Table 6 and Appendix VIII). Highest number of grains was counted at V_1 (335.17). Lowest number of grains was counted at V_9 (164.31) which was statistically similar to V_2 (172.10).

4.17 Stem dry weight plant^{-1}

From figure 4, it is exhibited that highest stem dry weight per plant was found in V_8

(80 g) which was followed by V_4 (73.25 g) and V_{10} (69 g). Lowest stem dry weight per plant was found in V_6 (49.75 g) which was followed by V_1 (50.80 g).

4.18 Leaf dry weight plant^{-1}

From figure 4, it is exhibited that highest leaf dry weight per plant was found in V_8 (55 g) which was followed by V_4 (52 g). Lowest leaf dry weight per plant was found in V_6 (24.5 g) which was followed by V_1 (26.40 g).

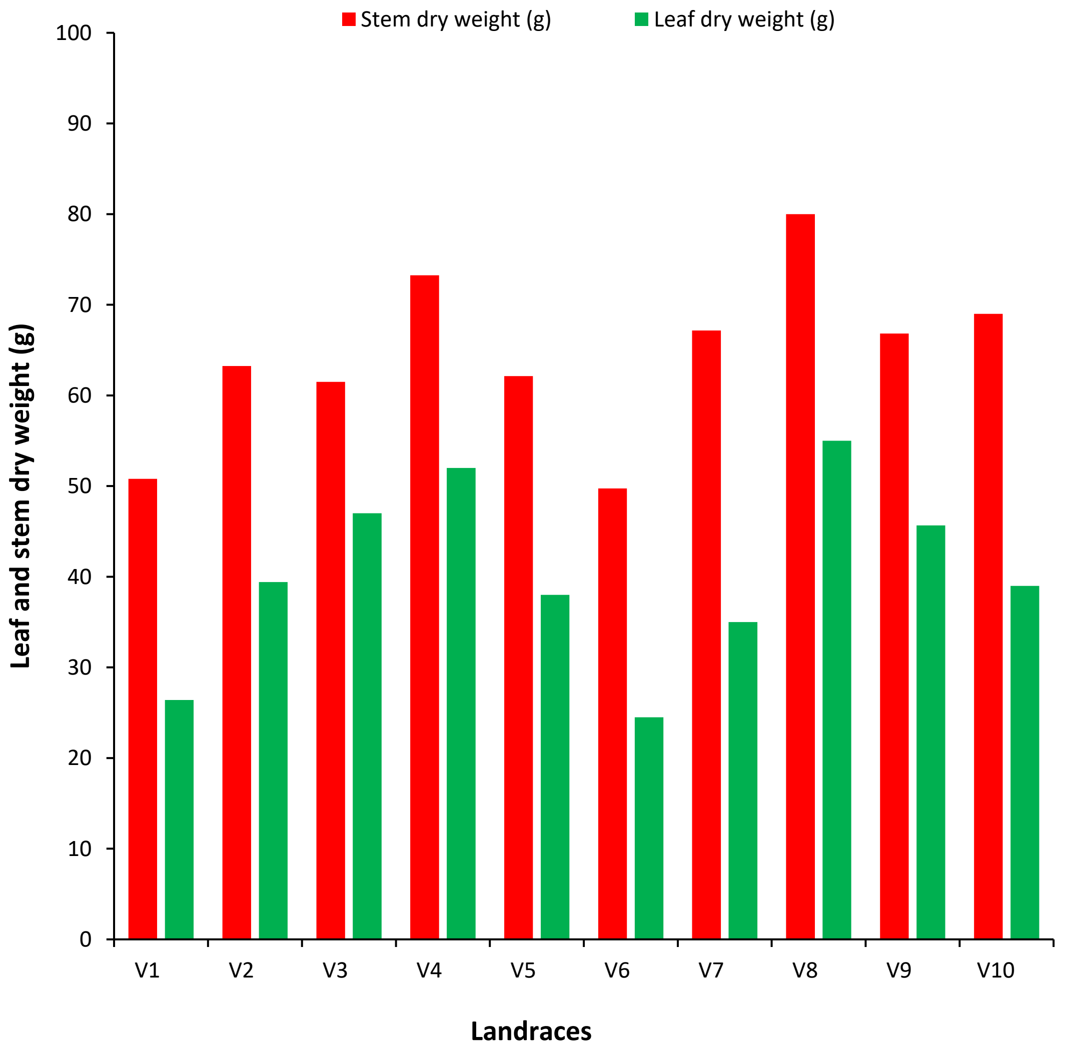

Figure 4. Maize landraces stem dry weight and leaf dry weight (LSD value = 11.57 and 6.29 respectively).

4.19 Total grains weight plant^{-1}

Different varieties had significant differences on total grain weight per plant (Appendix IX). Total grain weight per plant ranges from 62.55 to 27 g. Results represented in Table 7 indicated that the highest total grain weight per plant was attained in V_1 (62.55 g) followed by V_3 (55.67 g) whereas, the lowest was in V_6 (27 g) followed by V_5 (31.13 g).

Table 7. Total grain weight plant^{-1}, 100 grain weight, Chaff weight cob^{-1} and Shell weight cob^{-1} of maize landraces.

Landraces	Total grains weight plant^{-1} (g)	100 grains weight (g)	Chaff weight cob^{-1} (g)	Shell weight cob^{-1} (g)
V_1	62.55 a	23.36 a	9.30 bc	15.90 ab
V_2	40.17 ef	22.02 ab	8.78 c	15.71 a-c
V_3	55.67 b	21.84 ab	6.25 e	14.88 bc
V_4	50.13 c	18.90 cd	9.75 b	17.13 a
V_5	31.13 gh	15.44 e	9.94 b	13.63 cd
V_6	27.00 h	14.94 e	10.88 a	14.63 b-d
V_7	45.50 cd	17.65 d	7.08 d	15.00 a-c
V_8	42.46 de	19.48 cd	4.88 f	16.29 ab
V_9	35.75 fg	18.35 d	6.08 e	9.75 e
V_{10}	47.58 c	20.52 bc	4.75 f	12.67 d
LSD $_{(0.05)}$	**4.75**	**2.11**	**0.76**	**2.14**
CV (%)	**6.32**	**6.40**	**5.71**	**8.58**

Means followed by different letters in the same column differ significantly according to LSD test at 0.05 level of probability.

4.20 100 grains weight

A statistically significant difference between landraces was found regarding the 100 grains weight. Table 7 shows the effect of local varieties on 100 grains weight. Among the varieties, the maximum 100 grains weight (23.36 g) was found from V_1. V_6 showed the minimum 100 grains weight (14.94 g). The result was in line with that of Akbar *et al.* (2016). Mukhtar *et al*. (2011) and Asghar *et al*. (2010) found the different findings as they found that the varieties did not show any difference in producing 100-grain weight. Akter (2018) who reported that PSC-121 showed the superior performance in terms of 100 seed weight over YANGNUO-3000. Hasan *et al.* (2018) stated that the highest 100-grain weight was observed in BARI hybrid maize 7. Ullah *et al*. (2016) was reported that the lowest 100-seed weight was recorded from Yangnuo-7 (24.33 g, other varieties showed 31.83-34.67 g).

4.21 Chaff weight cob^{-1}

Local maize landraces showed a significant difference in respect of chaff weight per cob (Appendix IX and Table 7). Among the landraces, V_6 showed the maximum chaff weight (10.88 g) and V_{10} showed the minimum chaff weight (4.75 g) which was statistically similar with V_8 (4.88 g). Ullah *et al.* (2017a) observed that chaff weight of landraces ranges 8.64 to 4.34 cm which is similar to this study.

4.22 Shell weight Cob^{-1}

Significant variation was recorded in case of shell weight for different maize landraces (Table 7 and Appendix IX). The shell weight ranges from 17.13 g to 9.75 g due to different maize landraces. The highest shell weight (17.13 g) was recorded from V_4. On the other hand, the lowest shell weight (9.75 g) was recorded from V_9.

4.23 Grain Yield (t ha^{-1})

Maize landraces performed significant difference in respect of grain yield (Table 8 and Appendix X). Among the varieties, V_1 showed the highest grain yield (3.10 t ha^{-1}). On the other hand, V_6 showed the lowest grain yield (1.28 t ha^{-1}) which was statistically similar with V_5 (1.30 t ha^{-1}). This outcome was similar with that of Kizilgeci *et al.* (2019). Other varieties showed intermediate result. Akter (2018) who reported that PSC-121 showed the superior performance in terms of grain yield over YANGNUO-3000. Hasan *et al.* (2018) conducted that the maximum grain yield was observed from BARI hybrid maize-7. Khan *et al.* (2016) reported that among three hybrid maize varieties, grain yield was maximum in maize hybrid P-3025. Ishaq *et al.* (2015) conducted that the highest values for grain yield was recorded for Jalal-2003. Rahaman (2015) who reported that the maximum grain yield was recorded in the genotype of DEKALB-9120, whereas the minimum grain yield was from the genotype of BHM-7.

Table 8. Grain yield, stover yield, biological yield and harvest index of different maize landraces.

Landraces	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	3.10 a	4.52 c	7.62 bc	40.72 a
V_2	1.97 d	5.61 b	7.58 bc	25.96 c
V_3	2.60 b	5.72 b	8.32 ab	31.30 b
V_4	2.21 c	6.71 a	8.92 a	24.97 c
V_5	1.30 f	5.46 b	6.76 d	19.28 e
V_6	1.28 f	4.40 c	5.68 e	22.46 d
V_7	1.82 d	5.48 b	7.30 cd	25.06 c
V_8	1.87 d	6.89 a	8.76 a	21.33 de
V_9	1.60 e	5.66 b	7.26 cd	22.03 d
V_{10}	2.00 d	5.53 b	7.53 cd	26.57 c
LSD $_{(0.05)}$	**0.20**	**0.67**	**0.78**	**2.22**
CV (%)	**5.94**	**6.99**	**5.97**	**4.99**

Means followed by different letters in the same column differ significantly according to LSD test at 0.05 level of probability.

4.24 Stover Yield (t ha^{-1})

The effect of landrace varieties on stover yield is displayed in Table 8. In case of stover yield, a significant difference between varieties was found (Appendix X). V_8 showed the highest stover yield (6.89 t ha^{-1}) which was statistically similar with V_4 (6.71 t ha^{-1}) and V_6 showed the lowest stover yield (4.40 t ha^{-1}) which was statistically similar with V_1 (4.52 t ha^{-1}). Nizamuddin *et al.* (2010) who reported that the effect of cultivars on stalk yield significantly differed and check variety produced the lowest stalk yield. Msarmo and Mhango (2005) conducted that variety DK8031 showed the highest stover yield followed by local maize and then Masika.

4.25 Biological Yield (t ha^{-1})

Significant difference in respect of biological yield was observed in maize landraces (Table 8 and Appendix X). Among the varieties, V_4 exhibited the highest biological yield (8.92 t ha^{-1}) which was statistically similar with V_8 (8.76 t ha^{-1}) and V_3 (8.32 t ha^{-1}). On the other hand, V_6 showed the lowest biological yield (5.68 t ha^{-1}). Asghar *et al*. (2010) found the different findings as the varieties did not show any difference in producing biological yield. Mannan (2018) who reported that PSC-121 showed the superior performance in terms of biological yield over YANGNUO-3000.

4.26 Harvest Index (%)

Maize landraces harvest index differences are shown in Table 8. The conducted experiment revealed that there was significant statistical difference between local varieties regarding harvest index (Appendix X). V_1 showed the maximum harvest index (40.72%). On the other hand, V_5 showed the minimum harvest index (19.28%) which was statistically similar with V_8 (21.33%). This finding was at par with that of Mannan (2018) who also reported the maximum harvest index from PSC-121 (V2). Islam (2015) who reported that KS-510 showed the lowest harvest index whereas PSC-121 showed the highest harvest index. Asghar *et al.* (2010) conducted that the varieties Golden (34.19 %) and Sultan (33.75 %) did not show any differences for harvest index.

CHAPTER 5

SUMMARY AND CONCLUSION

Production of maize is increasing rapidly in Bangladesh. It has immense potentiality in near future. But most of the modern maize varieties available here are mainly developed from foreign parent materials which have the narrow genetic base. Landraces found in the country can be used as parent material to overcome this problem. Considering the above points an experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during the period from March 2019 to July 2019 in Kharif season. The experiment was conducted with 10 maize landraces which were collected from different areas of Bandarban district for characterization in aspect of some selected morphological traits. The experiment was laid out in RCBD with 3 replication and seeds of the different landraces were sown in separate plots. The result of this study is summarized as follows:

Analysis of variance showed significant difference among the varieties for all the characters. Maximum time (67.67 days) for flowering was taken by V_{10} whereas, minimum time (53.67 days) was taken by V_1. V_8 took highest time (128.67 days) and V_1 took lowest time (105 days) to be matured for harvesting. Tallest plant was found in V_{10} (202 cm and 210.50 cm at flowering and harvesting stage respectively) and shortest plant was found in V_6 (150 cm and 160 cm at flowering and harvesting stage respectively). The maximum number of leaves per plant (18) were observed in V_8 and minimum number of leaves per plant (13) were observed in V_1. Longest leaf was noted in V_2 (95 cm) and shortest leaf was noted in V_3 (67.5 cm). V_7 presented the maximum leaf width (7.75 cm) and V_1 presented the minimum leaf width (6 cm). Highest stem base circumference was found in V_{10} (8.4 cm) and V_6 (9.35 cm) at the flowering and harvesting stage respectively. On the other hand, lowest stem base circumference was found in V_3 (4.5 cm) and V_1 (5.05 cm) at the flowering and harvesting stage respectively. The longest plant root length was observed in V_{10} (24.5 cm) and shortest was observed in V_3 (17.5 cm). Root area circumference was recorded maximum in V_9 (25 cm) and minimum was in V_7 (14.50 cm). The highest tassel length (47.75 cm) was recorded in V_9 and lowest (30 cm) was recorded in V_1. The maximum cob length (28.4 cm) was reported from V_1 and minimum cob length (18.25 cm) was from V_3. The highest cob circumference (16.70 cm) was recorded in V_4 whereas, the lowest cob circumference (10 cm) was recorded in V_{10}. Grain color variation was displayed among the varieties as white, off white, red, pink, black, brown, purple, yellow and variegated color. Among the varieties, V_3 had the maximum no. of rows cob^{-1} (16.17) whereas, V_6 had the minimum no. of rows cob^{-1} (10.75). V_1 exhibited the maximum no. of grains row^{-1} (26.70) and V_9 exhibited the minimum no. of grains row^{-1} (13.50). Highest number of grains per cob was counted at V_1 (335.17) and lowest number was counted at V_9 (164.31). Maximum stem dry weight per plant was found in V_8 (80 g) and minimum stem dry weight per plant was found in V_6 (49.75 g). Highest leaf dry weight per plant was found in V_4 (55 g) and lowest leaf dry weight per plant was found in V_6 (24.5 g). The highest total grain weight per plant was attained in V_1 (62.55 g) whereas, the lowest was in V_6 (27 g). V_1 showed the maximum 100 grains weight (23.36 g) and V_6 showed the minimum 100 grains weight (14.94 g). Among the varieties, V_6 showed the maximum chaff weight (10.88 g) and V_{10} showed the minimum chaff weight (4.75 g). The highest shell weight (17.13 g) was recorded from V_4. On the other hand, the lowest shell weight (9.75 g) was recorded from V_9. At this time the highest grain yield showed V_1 (3.10 t ha^{-1}) and V_6 showed the lowest grain yield (1.28 t ha^{-1}). V_8 showed the highest stover yield (6.89 t ha^{-1}) and V_6 showed the lowest stover yield (4.40 t ha^{-1}). Highest biological yield (8.92 t ha^{-1}) was exhibited by V_4 whereas, lowest biological yield (5.68 t ha^{-1}) was exhibited by V_6. V_1 showed the maximum harvest index (40.72%) and V_5 showed the minimum harvest index (19.28%). The results obtained from all other varieties showed intermediate results compared to the highest and the lowest value of all parameters considered in this study.

Based on the experimental results, it may be concluded that:

1. White kernel landrace performed better yield than others and can be treated as the better genotype among the ten genotypes from the present study.
2. In case of stover production, yellow and brown scattered kernel landrace is higher than the other landraces. It can be used as silage producing genotype in kharif season.

Recommendations

The present experiment was conducted only one season and in a single location. Therefore, it is difficult to characterize the varieties completely without further study as sometimes morphological characters varies on location and climatic condition.

By considering the results of the present experiment, further studies in the following areas are suggested below:

1. Studies of similar nature could be carried out in different Agro Ecological Zones (AEZ) in different seasons of Bangladesh for the evaluation of their character variability and zonal adaptability.
2. Most of the landraces showed different traits which have excellent potentiality as well as some inferior traits at the same time. As a result, landraces having desired superior characteristics can be used for further breeding programs.

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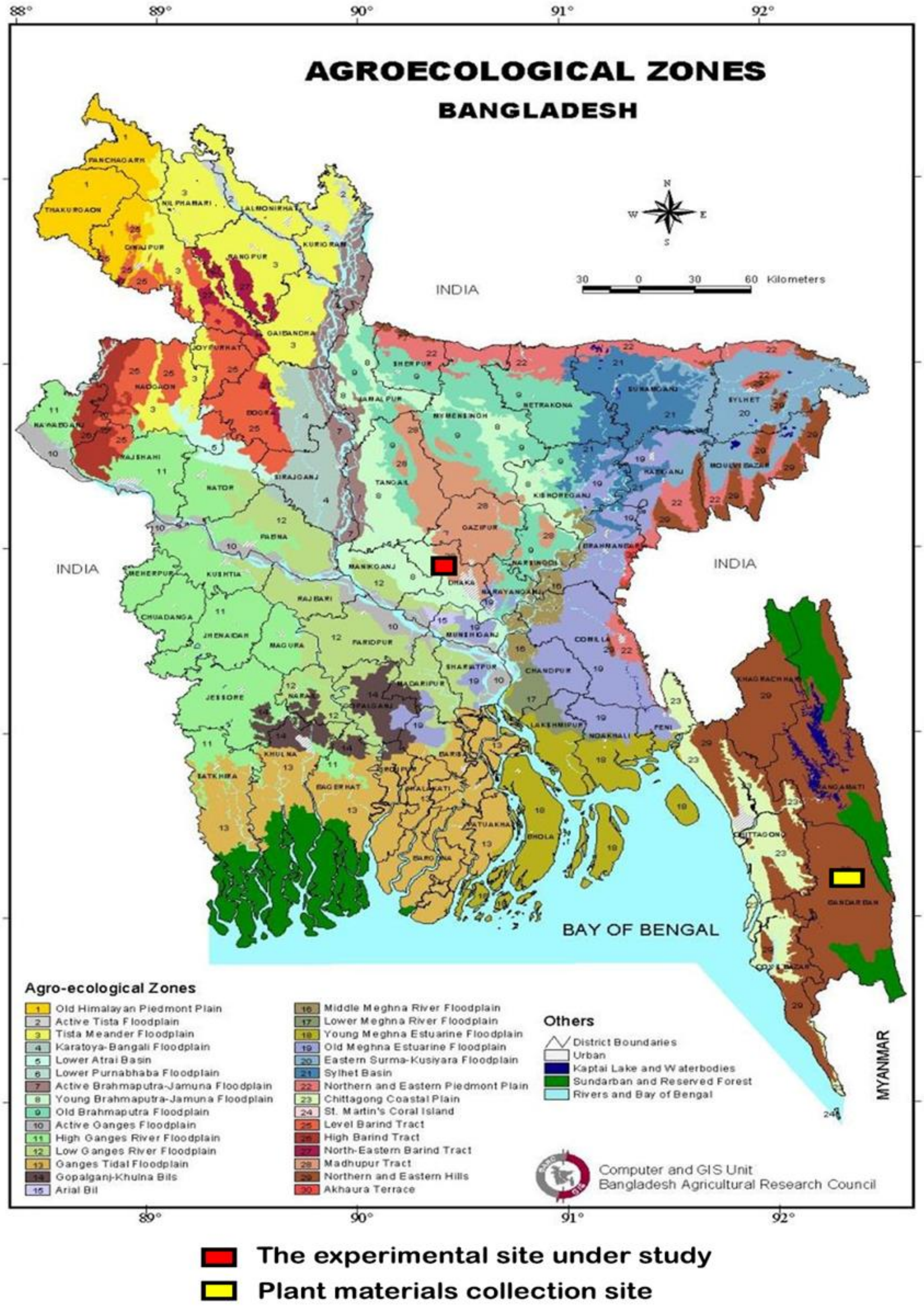
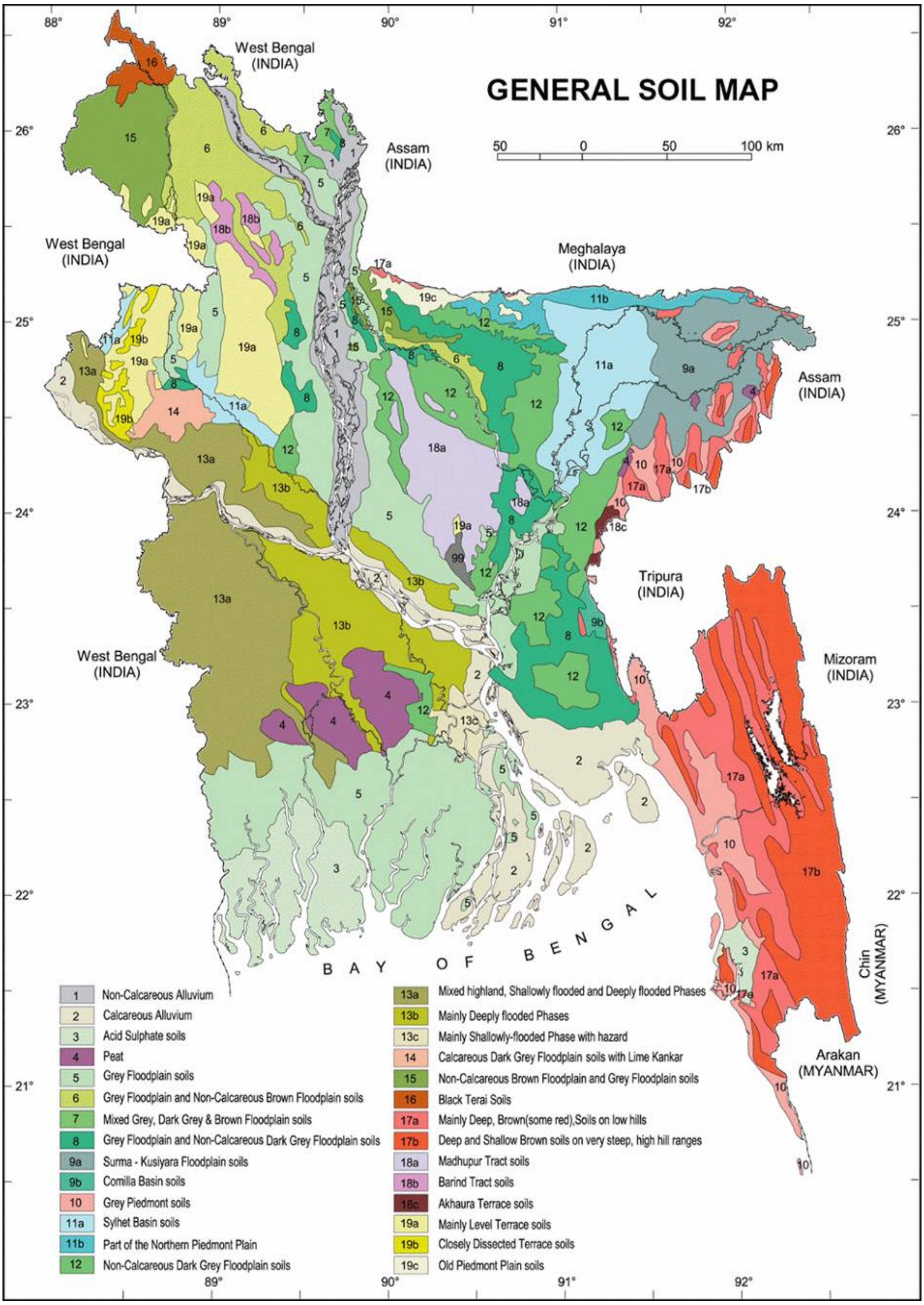
APPENDICES

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



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



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

A. Morphological characteristics of the experimental field.

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

B. Chemical properties of the initial soil

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

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

C. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30

Appendix III. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from March 2019 to July 2019.

Month	Air temperature (^{0}C)		R. H. (%)	Total rainfall (mm)
	Maximum	Minimum		
March, 2019	31.5	21.1	69	72
April, 2019	33.7	23.6	72	173
May, 2019	34.9	26.4	75	195
June, 2019	33.6	26.6	85	260
July, 2019	33.1	26.9	88	368

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

Appendix IV. Analysis of variance (ANOVA) of data on days to flowering and days to harvesting as influenced by maize landraces.

Source of variation	DF	Days to flowering	Days to harvesting
Replication	2	39.433	25.733
Variety	9	77.763**	205.115**
Error	18	6.063	13.659
CV		4.11	3.17

DF= Degrees of freedom, CV= Coefficient of variation

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

Appendix V. Analysis of variance (ANOVA) of data on local maize varieties plant height at flowering and harvesting stage.

Source of variation	DF	Plant height at flowering	Plant height at harvesting
Replication	2	5.23	77.215
Variety	9	1322.94**	985.502**
Error	18	80.09	34.527
CV		5.11	3.08

DF= Degrees of freedom, CV= Coefficient of variation

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

Appendix VI. Analysis of variance (ANOVA) of data on number of leaves plant^{-1}, leaf length, leaf width of maize landraces.

Source of variation	DF	No. of leaves plant^{-1}	Leaf length	Leaf width
Replication	2	0.433	9.025	0.289
Variety	9	8.759**	197.242**	0.972**
Error	18	2.026	12.081	0.492
CV		8.99	4.24	10.05

DF= Degrees of freedom, CV= Coefficient of variation

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

Appendix VII. Analysis of variance (ANOVA) of data on Stem base circumference, plant root length and root area circumference of maize landraces.

Source of variation	DF	Stem base circ. at flowering	Stem base circ. at harvesting	Plant root length	Root area circumference	Tassel length
Replication	2	0.042	0.420	0.380	0.025	6.642
Variety	9	4.412**	4.370**	18.922**	28.708**	93.942**
Error	18	0.366	0.232	3.197	2.081	3.184
CV		9.71	6.68	8.65	7.49	4.45

DF= Degrees of freedom, CV= Coefficient of variation, Circ.= Circumference

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

Appendix VIII. Analysis of variance (ANOVA) of data on tassel length, cob length, cob circumference, rows cob^{-1}, grains row^{-1} and total no. of grains cob^{-1} of local maize varieties.

Source of variation	DF	Cob length	Cob circumference	Rows cob^{-1}	Grains row^{-1}	Total no. of grains cob^{-1}
Replication	2	0.225	2.970	0.136	0.117	186.3
Variety	9	32.767**	12.210**	6.395**	56.127**	10644.1**
Error	18	1.700	1.526	0.588	0.843	163.7
CV		5.73	9.17	6.15	4.76	5.29

DF= Degrees of freedom, CV= Coefficient of variation

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

Appendix IX. Analysis of variance (ANOVA) of data on stem dry weight, leaf dry weight, total grain weight plant^{-1}, 100 grain weight, Chaff weight cob^{-1} and Shell weight cob^{-1} of maize landraces.

Source of variation	DF	Stem dry weight plant^{-1}	Leaf dry weight plant^{-1}	Total grains weight plant^{-1}	100 grains weight	Chaff weight cob^{-1}	Shell weight cob^{-1}
Replication	2	57.320	29.298	2.489	0.051	0.002	0.194
Variety	9	256.966**	301.756**	357.429**	23.155**	14.913**	13.528**
Error	18	45.454	13.434	7.655	1.517	0.197	1.558
CV		10.47	9.12	6.32	6.40	5.71	8.58

DF= Degrees of freedom, CV= Coefficient of variation

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

Appendix X. Analysis of variance (ANOVA) of data on grain yield, stover yield, biological yield and harvest index of different maize landraces.

Source of variation	DF	Grain yield	Stover yield	Biological yield	Harvest Index
Replication	2	0.067	0.350	0.113	19.361
Variety	9	0.943**	1.855**	2.737**	114.108**
Error	18	0.014	0.153	0.205	1.678
CV		5.94	6.99	5.97	4.99

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

DF= Degrees of freedom, CV= Coefficient of variation

Some photos of my research work

Plate 1. Landraces grains collected from Bandarban.

Plate 2. Different type cobs harvested from experimental field.

Plate 3. General view of experimental field.

Plate 4. Lodging due to sudden storm.

Plate 5. An unusual type cob formation.