PERFORMANCE OF WHITE MAIZE UNDER DIFFERENT SPACINGS AND INTEGRATED FERTILIZER MANAGEMENT

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PERFORMANCE OF WHITE MAIZE VARIETY DIFFERENT SPACINGS AND INTEGRATED FERTILIZER MANAGEMENT

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CERTIFICATE

This is to certify that the research work entitled , **"PERFORMANCE OF WHITE MAIZE UNDER DIFFERENT SPACINGS AND INTEGRATED FERTILIZER MANAGEMENT"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University , Dhaka, 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 **TAHMINA AHMMED** bearing Registration No. **12-4968** 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

DADICATED TO MY BELOVED PARENTS

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The author

PERFORMANCE OF WHITE MAIZE UNDER DIFFERENT SPACINGS AND INTEGRATED FERTILIZER MANAGEMENT

ABSTRACT

An experiment was conducted during December, 2017 to May, 2018 at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. The experiment comprised two different factors; (1) two different plant spacings *viz.* S_1 (60 cm × 20 cm) and S_2 (40 cm × 20 cm) and (2) four levels of integrated fertilizer application *viz*. T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose and T_4: vermicompost +½ of recommended dose. The experiment was set up in split plot design with three replications. Results revealed that both the individual and the interaction treatments had effect on different growth and yield parameters of white maize. In respect of the spacing effect, the wider spacing S_1 showed highest plant height, number of leaves plant^{-1}, cob length, cob circumference, number of grains cob^{-1}, shelling percentage, 100 grains weight and harvest index where S_2 showed higher grain yield. The integrated fertilizer had significant effect on different growth and yield parameters of white maize. In respect of the integrated fertilizer effect, the highest values in plant height, number of leaves plant^{-1}, leaf area index and crop growth rate, cob length, cob circumference, number of grains cob^{-1}, shelling percentage, 100 grains weight, grain yield, stover yield and biological yield were highest with T_3 whereas, the lowest corresponding values were recorded from T_2. Among the interaction treatments, higher seed yield was obtained with the interaction treatment S_2T_3 (10.01 t ha^{-1}) while S_1T_2 showed significantly lower seed yield (5.27 t ha^{-1}). The highest seed yield was mostly attributed to the number of grains per cob (328-433) and 100 seeds weight (29.67-35.33 g).

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
LAI	=	Leaf area index
Ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Murate of Potash
RCBD	=	Randomized complete block design
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
G	=	Gram (g)
Kg	=	Kilogram
Mg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
WUE	=	Water use efficiency
Wt.	=	Weight
LSD	=	Least Significant Difference
0C	=	Degree Celsius
NS	=	Non significant
Mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton

LIST OF ACRONYMS (Contd.)

Q	=	Quintal
J	=	Joule
viz.	=	Videlicet (namely)
Agri.	=	Agriculture
SAU	=	Sher-e-Bangla Agricultural University
BAU	=	Bangladesh Agriculture University
BARI	=	Bangladesh Agriculture Research Institute
FAO	=	Food and Agricultural Organization
KGF	=	Krishi Gobeshona Foundation

CHAPTER I

INTRODUCTION

Maize (*Zea mays L.*) is one of the most important cereal crops providing major source of food in many countries of world. It is a versatile crop and ranks third following wheat and rice in world production (FAO, 2002). It is grown as a fodder, feed and food crop. It is also used as raw material for manufacturing pharmaceutical and industrial products.

The main staple crops of Bangladesh are rice and wheat from where food grains for 16 million people is supplied. However, it is postulated that rice and wheat being C_3 in genetical nature, these two crops may not be able supplying food requirements at or after fifties as the population of Bangladesh is still in increasing trend with an alarming rate. So, maize being a C_4 crop may provide necessary amount of food along with those of rice and wheat as the potentials of the C_4 crop is much higher than that of C_3. It is also forecasted that due to the continued increase in global temperature due to climate change, the yield potential of wheat will be decreasing day by day if its grain filling could not be synchronized with period of low temperature.

Introduction of maize in Bangladesh as human food can be a viable alternative for sustaining food security as the productivity of maize much higher than rice and wheat (Ray *et al.*, 2013). It provides many of the B vitamins and essential minerals along with fiber, but lacks some other nutrients, such as vitamin B_{12} and vitamin C. People in many developed and developing countries produce and consume maize as staple food. Maize has been a recent introduction in Bangladesh. Rice maize cropping system has been expanded (Timsina and Majumdar, 2010) rapidly in the northern districts of Bangladesh mainly in response to increasing demand for poultry feed (BBS, 2016). Maize production of Bangladesh increased from 3,000 tons in 1968 to 3.03 million tons in 2017 growing at an average annual rate of 28.35 % (FAO, 2019).

There are two kinds of maize in respect of grain color; yellow and white. Worldwide, the yellow maize is mainly used as fodder while the white ones are consumed as human food (FAO, 2002). The currently grown maize in this country is yellow type which is mainly adapted importing genetic materials from CIMMYT. Again although there are some indigenous local maize in the south east hills those have also not improved for having higher yields (Ullah *et al*., 2016). However, there is no high yielding white maize varieties in Bangladesh and so Bangladesh has to generate technologies for the cultivation of white maize hybrids if imported from abroad (Ullah *et al*., 2017). In general the yield productivity of any crop in this country is low which is generally attributed to the poor agronomic management. Among the agronomic managements, setting optimum population density using the correct planting configuration and application of balanced fertilizers are two of the important agronomic operations. Moreover, as the application of chemical fertilizers pollutes land and reduces the quality of soil, it is also advised to apply integrating the chemical fertilizer along with the organic fertilizers as the later improves soil physical properties and crate favorable situation in the soil for crops growth and yield (Ullah *et al*., 2017).

Potential higher yields of modern hybrids obtainable with higher population encouraged planting maize at narrower spacing (Khan *et al.*, 2005).In Bangladesh, a population density of 83,000 planted in rows at 60 cm x 20 cm configuration gave the highest grain yield. Optimum plant density, however, depends largely on genotype, season, available growth resources and agronomic management conditions significantly (Khan *et al.*, 2005).

Highly fertilized soils are required for intensive cropping system and integrated plant nutrient management system helps to sustain those soils (Bationo and Koala, 1998). Chemical fertilizers become popular for their suitable, easy to use and satisfactory yield. On the contrary, chemical fertilizers are responsible for soil quality degradation, water source pollution, soil nutrient leaching, decline the soil physical structure, degradation of soil biological properties (like microorganisms which make the nutrient available for plant, friendly insects which protect the crop from disease and pathogen), disruption of soil chemical structure such as soil acidification or alkalization. According to Choudhary and Bailey (1994), organic manure has a lot of beneficial effects on soil such as improves soil fertility, aeration, water holding capacity and activate micro-organisms in the soil that make the nutrient available to the plant.

The activities of soil micro-organisms and enzymes and soil available nutrient contents can be increased by proper application of organic and inorganic fertilizers (He and Li, 2004; Saha *et al*., 2008). He and Li (2004) recommended that the activities of soil interties and available nutrient content can be enhanced by combined utilization of organic and inorganic fertilizers. Moreover, for increasing fertilizer use efficiency and maintaining or boosting soil fertility through integrated nutrient management method shows an excellent result where organic manure mixed chemical fertilizer. So that, the effect of application of organic manure combined with chemical fertilizer can be a useful study and attained attention for research through the world as integrated nutrient management system (Reganold, 1995).

Furthermore, it has been proved that integrated soil fertility management required the rational application of combined organic and inorganic resources which is a sensible method to overcome soil fertility constraints (Abedi *et al.*, 2010; Kazemeini *et al.*, 2010; Mugwe *et al.*, 2009). In our country, very few research works have been conducted with the effects of maize compost, cowdung and vermicompost on yield, quality and nutrient uptake by maize. Based on the above points, the current study was conducted with the following objectives:

Objectives:

1) To select the optimum maize spacing for achieving higher seed yield.

2) To find out the suitable combination of chemical and organic fertilizer(s) suitable for higher yield production.

3) To examine the interaction of spacing and applied fertilizer combination.

CHAPTER II

REVIEW OF LITERATURE

Integrated fertilizer management has a significance role in soil productivity, to improve soil health and maintained sustainable farming. In this system chemical fertilizers are used as inorganic sources and major organic sources are crop residues, FYM, compost, green manure, oil cakes, bio-fertilizers, bio-gas slurry etc. There are also some microbial fertilizers like *Rhizobium*, *Azotobacter*, Blue green algae, *Azolla* etc. They played a vital role in minimize the residual effect of harmful pesticide and herbicide as well as increased productivity. Nowadays, organic farming is one of the feasible projects for sustainable agriculture, so that we need sufficient recognition to pay this issue. To overcome the soil health problem, both types of nutrients are essential and synergistic application is crucial for sustainability, escalating price of chemical fertilizers and environmental pollution. Efficient utilization of plant nutrients is possible through integrated fertilizer management system. Moreover, spacing has a significant role to proper growth and yield of plant. Proper nutrient and spacing can ensure more efficient and feasible farming system. Many researchers are engaged themselves to find out more suitable doses and combinations. Some of them are discussing below:

2.1 Effect of spacing

Golla *et al.* (2018) conducted a field experiment at Bako research farm in the year 2017 to determine the optimum rate of nitrogen fertilization and intra row spacing. The experiment was laid out in a Randomized Complete Block Design in factorial arrangement with three replications. Three intra row spacing viz., 75 x 40 cm, 75 x 30 cm and 75 x 20 cm accommodating 33, 333, 44,444 and 66, 666 plants ha^{-1} respectively, with six nitrogen levels viz. 0, 23, 46, 69, 92 and 115 kg ha^{-1} were assigned to the experimental plot by factorial combinations. Based on the results, the maximum grain yield (10,207.8 kg ha^{-1}) was obtained when the hybrid was sown at the closest intra row spacing (20 centimeters) with application of the highest rate of nitrogen (115 kg ha^{-1}). This result showed 8.9% yield advantages compared to the standard check. However, statistically similar grain yield (9887 kg ha^{-1}) was also obtained under application of 92 kg nitrogen ha^{-1} in the same intra spacing (20 cm). But application of 115 kg N ha^{-1} on maize hybrid planted at 20 cm intra row spacing was the most profitable as compared to other combinations.

Eyasu *et al.* (2018) conducted a field study at Ofa district-Geleko irrigation site during the off-season of 2016/17 cropping season with the objective of evaluating different varieties and row spacing on growth, yield and yield components of maize. Four plant row spacing (45 cm, 55 cm, 65 cm and 75 cm) and three maize varieties ('BH-540', Lemu'P3812W'and Jabi 'PHB 3253') were tested in factorial arrangement laid out in RCBD replicated three times. Data on yield and yield components of the crop were recorded. The result indicated that most of the parameters such as number of ears per plant, ear circumference, 1000 kernel weight, number of kernels per ear, number of kernels per rows, grain yield per hectare were significantly influenced by the interaction effect of row spacing and varieties. Significantly highest grain yield were produced by maize variety Lemu grown at row spacing of 65 cm, which is statistically similar with variety BH-540 grown at row spacing of 65 and 75 cm and also the same variety grown at row spacing of 75 cm, while lowest was recorded for variety Jabi grown at row spacing of 45 cm. Based on these results, it can be concluded that under irrigated condition Lemu and BH-540 maize varieties at 65-75 cm row spacing resulted higher biomass and grain yield of maize and may be used by farmers of the area.

Hasan *et al.* (2018) conducted an experiment at the Agronomy Field Laboratory, Agricultural University, Mymensingh in Bangladesh during December 2015 to April 2016 to investigate the effect of variety and plant spacing on yield attributes and yield of maize. The experiment comprised five varieties *viz.,* Khoi bhutta, BARI hybrid maize 7, BARI hybrid maize 9, C-1921, P-3396 and five 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 experiment was laid out in a randomized complete block design with three replications. Results revealed that variety and plant spacing had significant effect on the studied crop characters and yield. The highest plant height, highest number of leaves plant^{-1}, longest cob, maximum circumference of cob, highest number of kernel cob^{-1}, the highest 1000-grain weight, maximum grain yield and stover yield were observed in BARI hybrid maize 7. On the other hand, the shortest plant, lowest number of cob, circumference of cob, lowest number of grains cob^{-1}, 1000-grain weight, grain yield and stover yield were observed in Khoi bhutta. The longest plant, highest cob, maximum circumference of cob, highest number of kernel cob^{-1} the highest 1000-grain weight, maximum grain yield and stover yield was observed in the spacing of 75 cm × 25 cm. In contrast, the spacing of 75 cm × 30 cm produced the lowest values of the above mentioned plant parameters and also showed the lowest grain yield. In regard to interaction effect of variety and spacing, the highest plant height (232.67 cm), maximum number of cob plant^{-1} (1.73), maximum circumference of cob (4.60 cm), highest number of kernel cob^{-1} (34), maximum stover yield (12.38 t ha^{-1}) were observed at the spacing of 75 cm × 25 cm with BARI hybrid maize 7 and resulting in the highest grain yield (9.04 t ha^{-1}). The lowest values of the above parameters were recorded in the narrowest plant spacing of 75 cm × 35 cm with Khoi bhutta. Based on the experimental results, it may be concluded that maize (cv. BARI hybrid maize 7) can be cultivated with a spacing of 75 cm × 25 cm for appreciable grain yield.

Ukonze *et al.* (2016) carried out a study to compare and analyze how spacing influenced the performance and yield of late maize in Egwi, Etche Local Government Area (LGA) of Rivers State, Nigeria between September-December in 2013 and 2014. The study adopted experimental research design. The experiment was laid out in a randomized complete block design (RCBD) with three replicates. One maize variety was evaluated under three spacing for performance data such as plant heights, stem girths, number of leaves, number of nodes and leaf area and for the yield, data were collected on cob length, cob weight, cob + husk weight, cob circumference and 1000-grain weight (yield).

The results obtained 56 days after planting (DAP) in the two years of study showed significant differences ($p < 0.05$) in plant height, stem girth and leaf area. The 70 x 30 and 60 x 40 cm spacing gave higher values of the morphological parameters than 80 x 20 cm. With regard to yield, 80 x 20 cm gave the highest average cob weight of 0.74 kg and 1000-grain weight (yield) of 0.27t/ha. Based on the findings of the study, the 80 x 20 cm spacing was recommended for local farmers in Etche for maximum yield and economic returns.

On-farm experiments were conducted by Akbar *et al*. (2016) in the Bandarban valley during dry season, October 2015 through March, 2016 to investigate the possibility of introducing white maize as human food evaluating seed yields under varying plant spacings. Yield response of two maize hybrids (PSC-121 and KS-510) planted in three different row arrangements was evaluated in one experiment. The other experiment determined the optimum fertilizer rate for maize hybrids. Grain yield ranged between 7,103 kg and 10,126 kg per ha across hybrids and planting arrangements. Hybrid PSC-121 recorded 19% more yield than KS-510. Generally grain yield increased with increasing planting density. Planting in twin-rows giving 80,000 plants per ha produced 17.7% higher yield compared with planting in single rows 60 cm apart giving 66,667 plants ha^{-1}. Planting in twin-rows produced significantly higher yield compared with single rows. Application of fertilizers at 100% and 50% of recommended rate produced identical but significantly higher grain yield compared to 25% of recommended rates. Increase of maize grain yield was associated with the number of grains per ear and individual grain weight.

Nand (2015) conducted a field experiment at Agronomy research Farm of C.S. University of Agriculture and Technology, Kanpur (U.P), during rabi season in 2010-11 and 2011-12 to evaluate the effect of spacing and fertility levels on protein content and yield of hybrid and composite maize (Zea mays L.) grown in rabi season. The experiment was laid out in split plot design with three replications. Where involved eighteen treatment combinations. The main plots were allotted by maize hybrid (DHM-117) and composite (Madhuri) along with three spacing, 45 cm x 20 cm, 60 cm x 20 cm and 60 cm x 25 cm. And sub plots, were tested three fertility levels viz, F_1- NPK and Zn of (120:60:40 and 15 kg ha^{-1}) F_2 -NPK and Zn of (160:80:60 and 20 kg ha^{-1}) and F_3 - NPK and Zn of (180:100:80 and 25 kg ha^{-1}). The result revealed that the maximum growth parameters likes, plant height (cm), no of leaves $plant^{-1}$, dry weight (g m^{-2}) and LAI were obtained with maize hybrid (DHM-117) followed by composite (Madhuri). The spacing of 60 cm x 20 cm significantly increased the cob length (16.87 and 17.09 cm), cob girth (11.23 and 11.80 cm), cob weight (205.90 and 205.90 g), grains weight cob^{-1} (170.52 and 173.94 g), grain yield (6.62 and 6.75 t ha^{-1}), protein content (8.78 and 8.87 %) and protein yield (58.20 and 60.00 kg ha^{-1}) than the spacing of 60 cm x 25 cm and 45 cm x 20cm, respectively. Significantly grain and protein yield was obtained under NPK and Zn of (180:100:80 and 25 kg ha^{-1}) as compare to NPK and Zn of (120:60:40 and 15 kg ha^{-1}) and NPK and Zn of (160:80:60 and 20 kg ha^{-1}). The interaction effect wet been variety x spacing was found significant ($P<0.05$) on protein yield in both the years of experiments.

Enujeke (2013) was carried out a study in Teaching and Research Farm of Delta State University, Asaba Campus from March, 2008 to June, 2010 to evaluate the effects of variety and spacing on growth characters of hybrid maize. It was a factorial experiment carried out in a Randomized Complete Block Design (RCBD) with three replicates. Three hybrid maize varieties were evaluated under three different plant spacing for such growth characters as plant height, number of leaves, leaf area and stem girth. The results obtained during the 8th week after sowing indicated that hybrid variety 9022-13 which had mean plant height of 170.0cm number of leaves of 13.2, leaf area of 673.2 cm^2 and stem girth of 99.4 mm was superior to other varieties investigated. With respect to spacing, plants sown on 75 cm x 15 cm had higher mean height and number of leaves of 176.7 cm and 13.8 respectively while plants sown on spacing of 75 cm x 35 cm had higher mean leaf area of 713.7 cm^2 and stem girth of 99.4 mm, respectively. Results of interaction showed that variety and spacing were significantly ($P<0.05$) different in 2008 and 2009. Based on the findings of this study, it is recommended that (i) hybrid variety 9022-13 be grown in the study area of enhanced growth characters which interplay to improve grain yield of maize (ii) spacing of 75 cm x 35 cm be used to enhance increased stem girth and leaf area whose photosynthetic activities could positively influence maize yield.

Yukui (2011) conducted an experiment with randomized block design of four cropping patterns and four replicates was used. Four cropping patterns; 65 cm × 65 cm, 40 cm×90 cm, 30 cm × 100 cm and 20 cm × 110 cm respectively were studied. The results showed that all wide and narrow rows patterns and free-sow patterns have higher yield than the same spacing patterns and 30 cm × 100 cm is the optimal pattern to obtain the highest yield, followed by 20 cm × 110 cm, 40 cm × 90 cm and 65 cm × 65 cm respectively. If all farmers carried out the 30 cm × 100 cm pattern, problems on food security in China would be obviously improved.

Fanadzo *et al.* (2010) conducted a study to determine the effects of inter-row spacing (45 and 90 cm) and plant population (40000 and 60000 plants ha^{-1}) on weed biomass and the yield of both green and grain materials of maize plants. The experiment was set up as 2 × 2 factorial in a randomized complete block design with three replications. Plant population had no significant effects and interaction among factors was not significant on weed biomass. Narrow rows of 45 cm reduced weed biomass by 58%. Growing maize at 40000 plants ha^{-1} resulted in similar green cob weight regardless of inter-row spacing. Cob length decreased with increase in plant population and with wider rows. Similar grain yield was obtained regardless of inter-row spacing when maize was grown at 40000 plants ha^{-1}, but at 60000 plants ha^{-1}, 45 cm rows resulted in 11% higher grain yield than 90 cm rows. Increasing plant population from 40000 to 60000 plants ha^{-1} resulted in a 30% grain yield increase. The study demonstrated that growers could obtain higher green plants and grain yield by increasing plant population from the current practice of 40000 to 60000 plants ha^{-1} and through use of narrow rows.

Alvarez (2006) conducted a field experiment in Minas Gerais, Brazil during 2001-02. The effects of row spacing (0.7 and 0.9 m) and plant density (55000 and 75000 plants ha^{-1}) on the performance of maize hybrids AG1052, AG9010 and DKB440 were determined. Dry matter and grain yield increased with increasing sowing density and decreasing row spacing. The hybrid AG1051 recorded the highest dry matter yield and ear height regardless of row spacing and experimental year, whereas the hybrids AG9010 and DKB440 recorded the highest grain yield regardless of planting density and experimental year.

Sener (2004) conducted a two-year study at Mustafa Kemal University, Agricultural Faculty, Research Farm, Turkey to determine the optimum intra-row spacing for maize hybrids commercially grown in Eastern Mediterranean Region during 2000 and 2001 growing seasons. Maize hybrids reacted differently to various plant density and intra-row spacing. Main plots were maize hybrids of Dracma, Pioneer 3223, Pioneer 3335, Dekalb 711 and Dekalb 626. Split-plots were intra-row spacing of 10.0, 12.5, 15.0, 17.5 and 20.0 cm. Split-plot size was 2.8 by 5.0 m with four rows per plot. The effects of intra-row spacing on the grain yield and some agronomic characteristics were statistically significant. Hybrid × intra-row spacing interaction effects were significant only at ear length and grain yield. The highest grain yields were obtained from Pioneer 3223 and Dracma at 15.0 cm intra-row spacing (11 718 and 11 180 kg ha^{-1}, respectively).

Jiotode (2002) conducted a field experiment with Maize cv. AMC-1 (Akola maize Composite-1) to evaluate its growth responses and water use influenced under varying irrigation levels at 40, 60 or 80 mm CPE and irrigation as per the critical growth stages of the crop, and three row spacing of 30, 45 and 60 cm during the rabi seasons of 1996-97 in Akola, Maharashtra, India. Irrigation at 40 mm CPE recorded the highest values in terms of all the growth parameters as well as consumptive use, potential evapotranspiration, soil moisture depletion, absolute water use rate and relative water use rate. However, water use efficiency was highest in the case of irrigation as per the critical growth stages of the crop and at 60-cm row spacing. A row spacing of 60 cm recorded the highest number of leaves, leaf area, and dry matter per plant. Plant height and leaf area index were highest at the 30-cm row spacing.

2.2 Effect of organic fertilizer

Naser *et al.* (2018) conducted a study to determine the effects of organic materials to remediate contaminated soil with heavy metals. A pot study was performed by growing maize (*Zea mays*) in metal contaminated soil (10 kg pot^{-1}) and soils amendments with cow manure dust, poultry manure dust, vermicompost dust, fern dust, water hyacinth dust, mustard stover dust and barnyard grass dust each at 5 g kg^{-1} soil. The results showed that Pb, Cd, Ni, Cr and Co uptake by maize depended on the organic materials type. Water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust addition led to decreased metal content in maize, and this decrease was better expressed with 20.5 to 33.3% for fern dust, 17.3 to 22.0 % for water hyacinth, 18.6 to 21.3% for mustard stover dust, 17.33 to 20.5% for barnyard grass dust. Cow manure dust, poultry manure dust and vermicompost dust led to increased metal content in the maize, and this increase was 6.80 to 18.7 % for cow manure, 18.9 to 86.7 % for poultry manure and 17.4 to 16.0 % for vermicompost. The different effectiveness of organic amendment on metal uptake by maize plant could be due to the nature of organic matter where water hyacinth dust, fern dust, mustard stover dust, and barnyard grass dust were mainly originated from plant. On the other hand, cow manure, poultry manure and vermicompost were mainly the excreta collected from cattle, poultry and earthworms. However, immobilization and phytoextraction techniques might be used to remediate soils which are contaminated with heavy metal.

Gama *et al.* (2018) conducted a research aiming at knowing the growth response of maize and soil moisture retention of the Luro-Entisol by applying organic matter. Field research was carried out in the Odofuro / Luro Timor Leste. Field experiment used the split plot design, consisting of two factors and four replications, resulting in 24 units of experiments. The first factor is organic matter (P) consisting of cow manure (P_1) and sheep manure (P_2), and the second factor is dosage of manure, including without fertilizer (D_0), manure 5 tons ha^{-1} (D_1) and manure of 10 tons ha^{-1}. Results showed that dosage of manure had significant effects on plant height, stem circumference, fresh weight and dry weight of stalk, but not significant affected the soil particle density, soil bulk density, total soil porosity and soil moisture.

Again Imran and Khan (2015) conducted an experiment to evaluate the influence of compost application and seed rates on production potential of late sown maize on high elevation, an experiment was overtaken at Farmer Field School (FFS), Swat Pakistan during summer 2013. The design of the experiment was used Randomized Complete Block Design (RCBD) with four replications. Sowing was done one month late (July 15th) than optimum time of sowing. Optimum time of sowing on high elevation in Swat-Pakistan starts from May 15th, to June 15th. Four levels of compost (5, 10, 15 and 20 tons ha^{-1}) and four seed rates (10, 20, 30 and 40 kg ha^{-1}) were used (cv. Baber). Each subplot was consisted of six rows having 75 cm row-to-row distance with row length of 3 m. Sowing of 40 kg seed ha^{-1} treated with 20 tons compost ha^{-1} produced cob length (19 cm), plant height (179.19 cm), 1000 grain weight (192.83 g) and grain yield (2712 kg ha^{-1}). While maximum grain cob^{-1} gave by 30 kg seed ha^{-1} treated with 20 tons compost ha^{-1} (375 grain cob^{-1}). On the basis of the above results, among the tested seed rate 40 kg ha^{-1} treated with 20 tons compost application is recommended for late sowing on high elevation in the agroecological conditions of swat valley

In 2013 Choudhary and Kumar conducted an experiment, the experiment was laid out on randomized block design with six treatments *viz.,* T_1: Vermicompost (VC; 2.5 Mg ha^{-1}), T_2: Poultry manure (PM; 1.25 Mg ha^{-1}), T_3: Swine manure (SM; 3.0 Mg ha^{-1}), T_4: Cow dung manure (CDM; 10.0 Mg ha^{-1}), T_5: Farm yard manure (FYM; 10.0 Mg ha^{-1}) and T_6: control and replicated thrice to study the effect of applied organic nutrients on growth and yield attributes of maize. when the crop was supplied with FYM followed by CDM, The physical parameters like porosity, maximum water holding capacity (MWHC), field capacity (FC), permanent wilting point (PWP), bulk density (BD) and moisture releasing pattern was measured better. On the other side, application of VC followed by PM over control gives a satisfactory result on chemical parameters like pH, soil organic carbon (SOC), available nitrogen (N), phosphorus (P) and potassium (K). The record of growth, physiological parameters, yield attributes and yield were higher on VC. Moreover, nutrient uptake like nitrogen, phosphorus and potassium was more on VC followed by PM, whereas least nutrients were taken up by control. Though B: C ratio was recorded higher on PM followed by CDM, VC followed by PM gives higher gross and net return. Similarly, Agronomic efficiency was recorded higher on VC followed by PM but economic returns were low on control.

Iqbal *et al*. (2010) conducted a field study to investigate the effectiveness of different nitrogen (N) sources i.e. farm yard manure (FYM), poultry manure (PM) and urea on growth and yield of spring planted maize. The results revealed that maximum increase up to 56, 82.5, 98.3, 77.3, 168, 41.8, 215.2 and 21.8% in plant height, number of grains per cob, 1000-grain weight, biological yield, grain yield, cob circumference, grains rows per cob and protein content were recorded respectively, while decrease in oil content was noted up to 19.2% in the treatments where 50% N from urea + 50% N from PM as compared to control. It is concluded that maize production can be increased by applying N in the form of urea (50%) and PM (50%) in agro-ecological conditions of Faisalabad, Pakistan.

Dong *et al.* (2005) studied the nitrogen transformation in maize soil after application of different organic manure to investigate the nitrogen mineralization on the surface soil, NO_3-N dynamics and distribution in the soil profile, and N_2O emission. The study was conducted at Yucheng Comprehensive Experimental Station in North China Plain. The experiment was laid out in 24 plots in random plot design with 8 treatments, each with 3 replicates: maize plantation without fertilizer (CK_1), bare soil without maize plantation and fertilizer application (CK_2), swine manure (S_1, S_2), poultry manure (P_1, P_2), and cattle manure (C_l, C_2). The result revealed that the emissions of N were affected by the application of organic manures in the order of $P_2 > S_2 > C_2 > P_1 > S_1 > C_l > CK_1 > CK_2$. All these results showed that organic manure applications significantly affect nitrogen transformation and distribution in maize soil.

Suri and Puri (1997) conducted a field experiment in the low-hill submontane zone of Himachal Pradesh during 1990-91 to evaluate the direct, and residual effects of farmyard manure (0 or 10 t ha^{-1}) and phosphorus (0, 13 or 6 kg ha^{-1}) application in a maize cv. Local/wheat cv. VL 616/maize cropping sequence. Farmyard manure and P showed significant direct and residual effects on the 3 sequential crops. The residual farmyard manure increased the gain yield of the next maize crop by 235 kg ha^{-1}. Application of 26 kg P ha^{-1} to the preceding wheat increased the grain yield of second maize crop by 300 kg ha^{-1}. A fresh P application of 13 kg ha^{-1} to the second crop increased its grain yield by 357 kg ha^{-1} All the interactions were significant.

Studies conducted by Vadivel *et al*. (2001a) revealed that application of enriched FYM@ 750 kg ha^{-1} increased the grain and stover yield of maize. In another trial, Ramamurthy and Shivashankar (1996) conducted a study at Hebbal, Bangalore, during 1990-92 on a sandy loam soil to determine the response of Deccan 101 sown in the rainy seasons, to the residual organic matter and phosphorus fertilizers present. From application to previous soybean crops, organic fertilizers were applied to the soybeans at 0, 5 or 10 t ha^{-1}

(1:1farmyard manure and rice straw) and inorganic P was applied at 37.5 or 56.25 kg P_2O_5 ha^{-1}. The residual effect of 10 t ha^{-1} organic fertilizer resulted a significant increase in dry matter production, grain yield, protein content and uptake of nutrients by maize. An increase in grain yield of 8% was observed due to a residual response to 56.25 kg P_2O_5 ha^{-1} compared with 37.5 kg P_2O_5 ha^{-1} application.

Agarwal *et al*. (1995) observed that farmyard manure improved root and leaf growth of maize. Organic amendments and nitrogen hastened leaf appearance and increased leaf area and leaf longevity. Maize grain yield was positively correlated with leaf area index (r:0.89) and leaf area duration (r:0.87) due to FYM applications.

2.3 Effect of inorganic fertilizer

A field experiment was conducted by Azeem *et al*. (2018) investigated the impact of different P sources (DAP (Diammonium Phosphate), NP (Nitrophos), TSP (Triple Super Phosphate) and SSP (Single super phosphate)) on growth, yield and yield component at two maize varieties (Azam vs. Jalal) at Dargai Malakand during summer. The experiment was laid out in randomized complete block design having three replications. Application of DAP delayed than other P-sources, application of TSP increased plant height, number of grains ear^{-1}, thousand grains weight, biological and grain yields. Azam had taller plants with higher thousand grains weight than Jalal, while Jalal with delayed maturity had more number of grains ear^{-1} and higher biological and grain yields. Application of TSP and use of variety Jalal could increase maize productivity in the study area.

Kareem *et al*. (2018) conducted a study to assess growth and yield performances of maize under the influence of inorganic fertilizer, population density and variety. Treatments used were factorial combinations of two maize varieties (DMR-ESR-Y and Suwan-1-SR), 70 × 30 cm and 100 × 40 cm plant spacing and three levels of NPK 15:15:15 (0, 60 and 120 kg NPK ha^{-1}). Data were collected on leaf production, plant height, ear height, leaf area, leaf area index, days to 50% flowering, days to tassel and silk appearances, stem dry weight, root dry weight, cob weight, kernel rows per cob, harvest index and final grain yield. It was revealed that combination of 120 kg N ha^{-1} with DMR-ESR-Y and 47619 plants ha^{-1} could improve dry matter, yield and yield components. Therefore, production of DMR-ESR-Y maize variety with application of 120 kg NPK ha^{-1} at population density of 47619 plants ha^{-1} can be used for better maize yield improvement to cater for the ever increasing population of consumers especially in the ecological zone where the research was conducted.

Ahmad *et al.* (2018) were conducted an experiment to study the effect of different nitrogen rates on the yield and yield components of maize cultivars (Azam and Jalal), at the New Developmental Form of The University of Agriculture Peshawar, during summer 2011 using Randomized Complete Block Design (RCBD) with split plot arrangement. The treatments comprised 0, 30, 60, 90, 120, 150, 180 and 210 kg N ha^{-1} assigned to main plot and maize cultivars (Azam and Jalal) to sub plots. Results revealed that maximum grain ear^{-1} (383.2), grain yield (3747.41 kg ha^{-1}) and harvest index (27.66 %) were recorded in Azam cultivar. However maximum ear length (16.33 cm), biological yield (14250 kg ha^{-1}) and thousand grains weight (258.65 g) were observed in Jalal cultivar. Maximum biological yield (16277.78 kg ha^{-1}) was recorded with the application of 180-210 kg N ha^{-1}. However maximum ear length (17.18 cm), grain ear^{-1} (411.32), grain yield (4888.9 kg ha^{-1}) and thousand grains weight (264.96 g) were observed with the application of 180 kg N ha^{-1}.

Mahamood *et al*. (2016) was conducted a field experiment (2009–2010) at FSRD site Lahirirhat, OFRD, Rangpur during rabi season 2009-2010 to evaluate Maximizing maize production through nutrient management. Five treatments viz.T_1= $N_{300}P_{50}K_{150}S_{30}$, T_2=$P_{50}K_{150}S_{30}$, T_3= $N_{300}K_{150}S_{30}$, T_4=

$N_{300}P_{50}S_{30}$ and T_5= $N_{300}P_{50}K_{150}$were evaluated for this purpose. The result indicated that the highest grain yield (8.37 t ha^{-1}) was found from T_1= $N_{300}P_{50}K_{150}S_{30}$ treatment. The lowest grain yield (7.33 t ha^{-1}) was obtained from T_2=$P_{50}K_{150}S_{30}$ treatment. The gross return (Tk.100107 ha^{-1}) and gross margin (Tk.44951 ha^{-1}) was higher with T_1 and T_3 treated plot. It may be concluded that proper nutrient management may be the good alternatives for maximizing maize yield and management of soil health at Rangpur region in Bangladesh.

Field experiments were conducted by Usman *et al*. (2015) at the Teaching and Research Farm, University of Agriculture, Makurdi to determine the effect of three levels of NPK fertilizer on growth parameters and yield of maize-soybean intercrop. The experimental design consisted of two factors: cropping system at two levels (sole and intercrops) and NPK fertilizer at three levels (0, 150 and 300 kg ha^{-1} of NPK 20:10:10). The treatments were laid out in a Randomized Complete Block Design (RCBD) in a split plot arrangement and replicated three times. From the results, application of fertilizer significantly ($p<0.05$) increased the growth parameters and yield of the component crops in both seasons. Increasing the quantity of NPK fertilizer resulted in significant increase in the yield and growth parameters of maize and soybean in both years. Intercropping resulted in yield advantage in 2013 and 2014 showing 35 % and 26 % land saved respectively.

This study was conducted by Asghar *et al*. (2010) to investigate the effect of different NPK rates on growth and yield of maize cultivars; Golden and Sultan. Application of NPK at increase rate delayed the number of days taken to tasseling, silking and maturity of the crop. The plant height was significantly affected by different rates of NPK. Treatment F_3 (250-110-85) of NPK produced tallest plants than two other treatments in both the varieties. Too low or high NPK levels reduced the yield and yield parameters of maize crop. Treatment F_2 (175-80-60) seems to be the most appropriate level to obtain maximum grain yield under the prevailing conditions. Application of NPK beyond treatment F_2 (175-85-60) seems to be an un-economical and wasteful practice. Varieties (Golden& Sultan) seem to have similar production potential under uniform and similar growing condition

Onasanya *et al*. (2009) conducted an experiment to show the effect of twelve different rates of nitrogen and phosphorus fertilizers on growth and yield of maize (*Zea mays L*.) in southern Nigeria was evaluated between June and October, 2007. The results of the study showed that application of 120 kg N ha^{-1} + 0 kg P ha^{-1} and 60 kg N ha^{-1} + 40 kg P ha^{-1} significantly increased the growth of maize than other treatments. The application rate of 120 kg N ha^{-1} + 40 kg P ha^{-1} significantly (P = 0.05) enhanced grain yield. This study further confirms the role of nitrogen and phosphorus fertilizers in increasing growth and grain yield in maize production. From the result of the study, application rate of 120 kg N ha^{-1} + 40 kg P ha^{-1} may be recommended for increasing maize yield particularly in the study area. However, application of 60 kg N ha^{-1} + 40 kg P ha^{-1} can also bring about increase in the yield of maize. These will greatly benefit farmers in area where supply of nitrogen fertilizer is low and cases where farmers cannot afford the cost of high fertilizer input.

Eltelib *et al.* (2006) studied the effect of nitrogen and phosphorus application on growth, forage yield and quality of fodder maize growing in Sudan. The variety used was Giza 2. Nitrogen was applied at the rates of (0, 40 and 80 kg ha^{-1}), while phosphorus levels were (0, 50 and 100 kg P_20_5 ha^{-1}). Parameters studied were plant height, number of leaves per plant, stem circumference and leaf area index (LAl), days to 50% tasseling, dry matter yield, crude protein and crude fibre contents were studied. Results showed that addition of nitrogen fertilizer significantly increased plant height, stem circumference and LAI, forage dry matter yield and protein content. Phosphorus fertilizer application had no significant effect on growth, days to 50% tasseling, dry matter yield and crude protein content. Neither nitrogen nor phosphorus had a significant effect on the crude fibre content.

Agba *et al.* (2005) conducted two field experiments to determine the efficacy of nitrogen fertilizer on the growth and yield of improved maize variety in the reaching and research farm department of Agronomy, Cross River University of Technology, Nigeria, during the 2003/2004 cropping seasons. The experiment comprised seven rates of urea (46% N) fertilizer at 0, 50, 90, 130, 170, 210 and 250 kg ha^{-1} with three replications. Urea application significantly increased plant height, number of leaves and ear weight, ear length and ear circumference per plant. The use of 210 kg N ha^{-1} produced the best maize grain yield of 2.43 and 2.96 ton ha^{-1} in 2003 and 2004, respectively.

Hassan (2005) studied the effect of NPK at the rate of 0-0-0, 150-100-50, 200-125-75, and 250-150-100 kg NPK ha^{-1} and observed that increased rate of NPK delayed tasseling, silking and maturity and increased the number of cobs per plant, number of grain rows per cob, number of grains per cob, 1000-grain weight, biological yield and grain yield ha^{-1} while plant height showed non - significant effect.

Yusuf *et al.* (2005) carried out a trial to examine the response of maize variety TZSR-Y1 grown on soils (mainly Alfisols and Entisols) collected from 30 different locations in northern Nigeria to applied zinc fertilizer application was examined in two greenhouse pot experiments. The Mehlich 1 extractable soil zinc (Zn) ranged from 0.6 to 4.1 mg kg^{-1} with a mean of 2.00 mg kg^{-1}. Due to the wide variations observed in the initial Mehlich 1 extractable Zn and the large sample soils involved, two fertilizer rates (0 and 10 mg kg) were used to determine maize response to applied Zn. In many of the soils, yield was increased by the addition of Zn and there were large differences in response pattern. Dry matter production was higher in the first crop, making 55% of the total against 45% from the second crop. This was attributed to the mineralization and subsequent utilization of Zn reserve in the organic complexes of the soil.

2.4 Effect of integrated fertilizer

Dhadge *et al*. (2018) conducted a field experiment during 2007 and 2008 to study the effect of integrated nutrient management on yield, economic and energy parameter in maize under irrigated condition. Application of 75% RDF + 25% N through FYM + Azo. + PSB were recorded significantly higher seed yield (40.30 q ha^{-1}), stover yield (54.96 q ha^{-1}), biological yield (95.26 q ha^{-1}) and harvest index (42.28%). The energy output (127941M J ha^{-1}) and energy balance (115423M J ha^{-1}) was higher in 75% RDF + 25% N through FYM + Azo. + PSB. However, the energy balance per unit input (9.47) and energy output/input ratio (10.47) were maximum due to 100% N through organic manure (50% N through FYM + 25% N through vermicompost + 25% N through neem cake + biofertilizers (Azo. + PSB). Maximum net returns (Rs. 32228 ha^{-1}) and B : C ratio (2.19) was recorded in 100% RDF through inorganic source alone. The lowest value in yield and energy parameter was observed in control treatment.

Kumar *et al*. (2018) studied the effect of "Integrated nutrient management in maize under rainfed condition in Eastern part of U.P" during kharif season of 2014-15 and 2015-16. The experiment was conducted in Randomized Block Design with three replications and twelve treatments. The results obtained during the course of investigation are being included here as under. The maximum grain yield of maize (50.85, 38.28 q ha^{-1}) was recorded with T_{12}, which was significantly superior over all the treatments except T_{10}, T_{11}, T_9. Application of $ZnSO_4$ @ 25 kg ha^{-1}or $FeSO_4$ @ 10 kg ha^{-1} or both jointly with 100 % RDF, the grain yield of maize was increased (10.20, 9.72, and 17.27%) and (7.99, 7.03, 19.30%), respectively over 100 % RDF alone during both years and (64.88, 64.16, 55.29, 53.10 and 71.56%) over control. Similarly, application of FYM @ 6 t ha^{-1} or $ZnSO_4$ @ 25 kg ha^{-1} or $FeSO_4$ @ 10 kg ha^{-1} or all three jointly applied with 75 % RDF, the grain yield of maize was increased by 11.63, 21.81, 20.64, 26.34% and 12.40, 22.40, 19.44 and 27.00% over 100

% RDF alone and 66.98, 82.29, 80.92 and 89.03% over control during both year.

Mahmood *et al.* (2017) investigated the effects of organic and inorganic manures on maize and their residual impacts on soil physico-chemical characteristics. Sheep manure (SM), poultry manure (PM) and farmyard manure (FYM) were applied as organic nutrient source while urea, diammonium phosphate (DAP) and sulphate of potash (SOP) were used at different concentrations as inorganic nutrients source viz., T_1: Unfertilized control; T_2: NPK at 250-150-125 kg ha^{-1}; T_3: SM at 15 t ha^{-1}; T_4: FYM at 16 t ha^{-1}; T_5: PM at 13 t ha^{-1}; T_6: NPK at 150-85-50 + 8 t ha^{-1} SM; T_7: NPK at 150-85-50 + 8.5 t ha^{-1} FYM and T_8: NPK at 150-85-50 + 7 t ha^{-1} PM. Results showed that growth and yield of maize were substantially improved by fertilizer application alongside organic manures whereas soil total organic C and total N, P, K contents increased when inorganic fertilizers were applied alone or in combined with organic manures. However, soil pH and soil bulk density decreased due to application of organic fertilizer and showed a negative correlation with grain yield. Further, a significant and positive correlation (R_2= 0.52, 0.91 and 0.55) was observed among maize grain yield and available N, P and K contents, respectively in the soil. Conclusively, integration of inorganic fertilizers with organic manures can be used with optimum rates to improve crop productivity on sustainable basis. This study will be helpful in crafting sustainable nutrient management programs in future to enhance crop productivity with high efficiency and minimum nutrient loss.

Bharath *et al*. (2017) conducted a field experiment during 2014-2015 and 2015-16 on integrated nutrient management in maize and its residual effect on groundnut under maize-groundnut crop sequence in Southern Telanagana region. The results of the present investigation reflected that the maize plant exhibited maximum values of uptakes of NPK by applying of 75% RDF+25% RDN through urban compost (T) during both years of study. During the both years of study highest NPK uptakes 5 was obtained by applying 75% RDF+25% RDN through urban compost (T) followed by 75% RDF+ 25% RDN through FYM 5 (T) and 100% RDF (T) of maize crop in maize-groundnut crop sequence. Nitrogen, phosphorus and potassium uptake at 3 2 initial stage was not significantly influenced by treatments. Post harvest available (N, P and K) content after *kharif* maize was significantly higher with 50% RDF+50% RDN through urban compost (T_6) on par with 50% RDF+50% RDN through FYM (T_4). Physicochemical properties of soil were not significantly influenced by different treatments during both the years.

Two field experiments were conducted by Essilfie *et al*. (2017) for two years from May to August, 2015 and 2016 respectively to evaluate varietal response of maize (Omankwa and Obatanpa) to integrated nutrient management of NPK and Chicken manure [3 t ha^{-1} CM, ½ CM + ½ NPK (32.5:19:19 kg ha^{-1} NPK) and ¾ CM + ¼NPK]. The experimental design was a 2 x 5 factorial arranged in randomized complete block design with three replicates. The result showed that there was a significant ($p < 0.05$) differences between Obatanpa and Omankwa and fertilizer type in total grain yield in both cropping seasons. Omank was grown under 65:38:38 kg ha^{-1} NPK and 3 t ha^{-1} CM produced higher grain yield and longer cob length during the 2015 and 2016 cropping seasons respectively. Obatanpa grown on 65:38:38 kg ha^{-1} NPK produced thicker cob circumference, higher dry matter accumulation, taller plants at 77 days after planting, and total grain yield in both cropping seasons. Obatanpa grown under 3 t ha^{-1} CM produced the longest cob length and heaviest 100 seed weight during the 2016 cropping season. Obatanpa grown under ¾ CM + ¼ NPK produced thicker cob circumference during the 2016 cropping season. In conclusion (i) Farmers are encouraged to grow Omankwa on 65:38:38 kg ha^{-1} NPK or 3 t ha^{-1} CM for higher grain yield and longer cob length. (ii) Farmers who prefer inorganic fertilizers for increased grain yield, cob length and thicker cob circumference of Obatanpa maize should apply 65:38:38 kg ha^{-1} NPK. (ii) Farmers who practice organic agriculture in transitional agro-ecological zone of Ghana should apply 3 t ha^{-1} CM and ¾ CM + ¼ NPK to enhance maize grain weight, cob length and cob circumference respectively.

Wailare and Kesarwani (2017) conducted a field experiment during the winter season of 2013 at a main research field of the School of Agriculture Lovely Professional University, Phagwara, Punjab (India) to study the influence of integrated nutrient management on growth and yield parameters of maize (*Zea mays* l.) as well as soil physico-chemical properties. The growth parameters (plant height and leaf area) were found to be highest under INM (Integrated Nutrient Management) of poultry manure (PM) or farm yard manure (FYM)and recommended dose of fertilizers (RDF) which are statistically on par but comparatively higher than T_1 (100% RDF). The yield parameters (number of grains per cob, cobs weight per plant, Test weight and stover yield) were significantly higher under INM compared to T_1 (100% RDF). Furthermore, post harvest soil physico-chemical properties (organic carbon and available nitrogen) were significantly improved under T_3 (5t PM + 50% RDF), whereas soil available phosphorus was recorded maximum under T_5 (5t PM + 100% RDF) compared to control and rest of the treatments combination. Therefore, the integration of 50% RDF along with either 5 t ha^{-1} FYM or PM or both resulted in maximum maize productivity on par compared with sole used of 100% RDF.

Rahman *et al*. (2013) were conducted field experiments over three years during 2005 to 2007 at Bangladesh Agricultural University farm, Mymensingh, Bangladesh, using maize-legume-rice cropping pattern to see the effect of inorganic fertilizers along with organic manure and mungbean residue on soil properties and crop yields. For the first crop (maize), there were five treatments. After maize, seeds of mungbean and dhaincha (*Sesbania*) were sown as per treatments as legume crop. For rice (third crop), each of the treatments (T_2 and T_3 plots) were subdivided into six, so there were altogether 15 treatments. Integrated use of manure and inorganic fertilizers or Integrated

Plant Nutrient System (IPNS) basis produced comparable seed yield of maize with the chemical fertilizers alone irrespective of moderate or high yield goal basis. The incorporation of *Sesbania* biomass and mungbean residue along with inorganic fertilizers for moderate yield goal produced identical grain yields of rice compared to fertilizers applied for high yield goal. After three years of cropping, the nutrient status of soils in control, fallow and mungbean residue removal plots showed a decreasing trend while incorporation of *Sesbania* biomass and mungbean residue had a positive effect on soil fertility. Therefore, addition of mungbean residues or *Sesbania* biomass to the fertilizer schedule ensures higher crop productivity and sustains soil fertility in maize-legume-rice cropping pattern.

Verma *et al*. (2012) conducted an experiment during rabi season of 2006-07 and 2007-08 to study the effect of sowing dates and integrated nutrient management on growth, yield and quality of winter maize. The trial was laid out in split plot design with three replications, assigning total 27 treatment combinations i.e. three sowing dates (15 Oct, 25 Oct and 5 Nov) in main plots and three levels of nitrogen from inorganic fertilizer urea (50, 100 and 150 N_20 kg ha^{-1}) and two organic fertilizer (FYM, *Azospirillum*) and control in sub plots. The crop sown on 25 Oct significantly enhanced the growth and grain yield than early sowing 15 Oct and late sowing 5 Nov While, 150 kg of N_2O ha^{-1} application significantly increased over 100 and 50 kg N_2O ha^{-1}. However, N_2O application through FYM was found statistically at par with N_2O application through the *Azospirillum*in growth and grain yield during both years. But, application of 100 kg ha^{-1} with 7.50 t ha^{-1} FYM at the sowing of 25 Oct significantly influenced the growth, yield and quality of maize and was recorded 9.35 and 23.07 percent more grain yield over the other treatment combinations.

Seerat *et al.* (2012) conducted a Dry Land Agriculture Project, University of Agricultural Sciences, Bangalore, Karnataka to study the crop growth and yield of maize in response to recommended fertilizers as well as integration of different organics nutrient sources. Treatments were: 100% NPK through fertilizers (T_1), 50% N through fertilizer + 50% N through FYM + balance P and K as fertilizers (T_2), 50% N through fertilizer + 50% through city compost + balance P and K as fertilizers (T_3), 50% N through fertilizer + 50% N through sewage sludge + balance P and K as fertilizers (T_4), 50% N through fertilizer + 50% N through poultry manure + balance P and K as fertilizers (T_5), 50% N through fertilizer + 50% N through gliricidia green manure + balance P and K as fertilizers (T_6) and 50% N through fertilizer + 50% N through composted parthenium + balance P and K as fertilizers (T_7). Application of recommended NPK through fertilizers resulted significantly in higher leaf area index and leaf area duration at 60 DAS (3.92 plant^{-1} and 109.3 days) followed by 50% N through fertilizer + 50% N through poultry manure + balance P and K as fertilizers (3.72 plant^{-1} and 102.7 days), respectively. Application of recommended NPK through fertilizers produced higher grain and stover yield (4374 kg and 6.68 t ha^{-1}, respectively) with a harvest index of 0.40, followed by 50% N through fertilizer + 50% N through poultry manure + balance P and K as fertilizers (3996 kg ha^{-1} grain and 6.46 t ha^{-1}stover) with a harvest index of 0.38 over rest of the treatments. The results of the study clearly indicates that the application of recommended NPK through fertilizers (100: 50: 25 kg ha^{-1} N, P_2O_5 and K_2O) recorded significantly higher grain yield (4374 kg ha^{-1}) and stover yield (6.68 t ha^{-1}) with a harvest index of 0.4, followed by the application of 50% N through fertilizer + 50% N through poultry manure + balance P and K as fertilizers (3996 kg ha^{-1} grain and 6.0 t ha^{-1} stover yields).

Nasim *et al*. (2012) conducted a field experiment at Agronomic Research Area, University of Agriculture, Faisalabad-Pakistan to examine the effect of organic and inorganic fertilization on maize productivity. The experiment was laid out in Randomized Complete Block Design (RCBD), with four replications. Two maize hybrids were used in this experiment. The results showed that maize yield and its component such as cobs per plant, cob length, number of grains cob^{-1}, 1000- grain weight were maximum when the plots were fertilized at 100 kg N ha^{-1} as urea + 100 kg N ha^{-1} as poultry manure. Further research is desired to investigate maximum yield by using organic source of fertilizer than inorganic source of fertilizer to avoid lethal effects on human health created by inorganic fertilizers.

Mohsin *et al.* (2011) tested the effect of two inorganic phosphorus (P) fertilizer, di-ammonium phosphate (DAP); triple super phosphate (TSP) and three organic materials farm yard manure (FYM), poultry manure (PM), compost (COM) on growth, yield, energy content and P utilization efficiency (PUE) of maize. DAP and TSP alone or in combination with each of organic materials i.e. FYM, PM and COM in combination (50:50 ratio) were applied to supply 90 kg P ha^{-1}. Both inorganic P fertilizers when applied in combination with either organic material significantly increased plant height, leaf area and chlorophyll content over control. Grain, dry matter, biomass yield and protein content increased by 74-101, 43-60, 55-75 and 42-70% over control. P uptake increased from 14 g kg^{-1} in control to 36 g kg^{-1} where DAP and PM was combined while increase in PUE was 10-27%. When applied in combination with organic materials, DAP+PM was the best treatment among P sources to be utilized.

Aspasia *et al.* (2010) conducted an field experiment to determine the effects of inorganic and combined organic/inorganic fertilization on growth, photosynthesis and yield of a sweet maize crop (*Zea mays* L. F1 hybrid Midas), under Mediterranean climatic conditions. A randomized complete block design was employed with four replicates per treatment (inorganic fertilizer: 21-0-0), control and 12 combined organic (poultry, cow manure and barley) and inorganic fertilization (synthetic fertilizer: 21-0-0) treatments. The amount of N contributed to the soil via the different fertilization treatments was the same (240 kg N ha^{-1}). Organic soil amendments increased the level of soil organic matter and total nitrogen. The highest height, dry weight, leaf area index and yield were recorded with the cow manure treatments (with or without chemical fertilizer). Moreover, combined organic and inorganic fertilizers resulted in higher increase in photosynthetic rate and stomatal conductance compared with those found under inorganic fertilization. A high correlation coefficient ($r=0.926$, $p<0.001$) between yield and photosynthetic rate was found. Sustainability yield indices (sustainable yield index and agronomic efficiency) showed that the maize crop is more stable under combined organic and inorganic fertilization compared with mineral fertilization.

Quansah and Gabriel (2010) conducted an experiment to characterize poultry manure and two composted materials (Household waste + poultry manure and Market waste + faecal sludge mixes in 3:1 ratio) based on their nutrient content and water holding capacity and to evaluate the influence of organic and inorganic fertilizers and their combination on the growth and yield of maize (*Zea mays*) in pot and field experiments at Soil Research Institute of CGSIR, Kwadaso, Kumasi, Ghana. The treatments were studied in a complete randomized design (CRD) in the pot experiment and in a randomized complete block design (RCBD) in the field experiment with three replications each. The experimental results showed that poultry manure was high in nutrients containing 2.06 % N, 0.52 % P and 0.73 % K whilst the composted materials were moderate in N and K but low in P. Percentage moisture of poultry manure at three stages; saturation, field capacity and 16 DAS were 119.51 %, 92.68 % and 63.41 % respectively which were higher than the values obtained under the composted materials. Water use efficiency (WUE) increased significantly with increasing dry matter production in the pot experiment. The combined treatments had WUE values higher than the values obtained by the sole organic or inorganic treatments alone. There were no significant differences ($P > 0.05$) in the vegetative growth of maize for the various treatments; however, the combined treatments gave higher values of plant height, girth, leaf area and number of leaves than organic and inorganic fertilizers used separately. The field experiment showed trends that were similar to those observed in the pot experiment. The combined applications produced yields, which were significantly higher than organic or inorganic alone and the control. The highest grain and stover yields of 8.0 t ha^{-1} and 8.9 t ha^{-1} respectively was recorded by the combined treatment of poultry manure with mineral fertilizer at a rate of 60 kg ha^{-1} N poultry manure and 60-40-40 kg ha^{-1} NPK mineral fertilizer, with the control recording the lowest grain and stover yields of 2.10 t ha^{-1} and 4.30 t ha^{-1} respectively. The combined treatments had significantly higher nutrient uptake values than the sole organic and inorganic fertilizers alone. The highest nutrient uptake values of 142.09 kg ha^{-1} N, 41.10 kg ha^{-1} P and 50.87 kg ha^{-1} K was recorded by the combined treatment of household waste and poultry manure mix compost with mineral fertilizer high rate. Differences in soil nutrient concentrations after harvest were marginal for all the treatments. Soil pH and total N decreased in all the treatments while percentage C and available P and K increased generally. Residual nutrients sustained maize plant growth and had yields, which were approximately 50% lower, with the sole application of mineral fertilizer as well as poultry manure high rate performing better than the combined applications contrary to what was observed in the major season.

An experiment was conducted by Ayoola and Makinde (2009) in the growing seasons of 2005 and 2006 at Ibadan, Nigeria, in the degraded tropical rain forest zone to assess the growth and yield of maize with Nitrogen-enriched organic fertilizer made from municipal waste and cow dung (2.5 t ha^{-1} Pacesetter fertilizer + 100 kg ha^{-1} urea) and also with Nitrogen-fortified poultry manure. Their performance was compared with those of inorganic NPK fertilizer and no fertilizer control. Maize growth was significantly ($P = 0.05$) affected by an enrichment of the organic manures. They had plants comparable in height with inorganic fertilizer application. At harvest, plants treated with fortified poultry manure were about 259 cm tall while those treated with fortified Pacesetter fertilizer and the plants treated with inorganic fertilizer were about 253 cm tall. Average plant leaf areas were similar with the fortified fertilizers and with inorganic fertilization. Length of days taken to achieve 50% tasselling was also reduced with fertilization. Inorganic fertilizer application gave plants that achieved 50% tasselling in 50 days while fortified poultry manured - plants took 52 days and the fortified Pacesetter fertilizer – treated plants took 53 days. Fertilization of maize gave significantly (P = 0.05) higher seed yield. Fortified poultry manure gave an average yield of 3.97 t ha^{-1} while fortified Pacesetter fertilizer had an average of 3.78 t ha^{-1}. Inorganic fertilizer gave a yield of 3.70 t ha^{-1} while a significantly lower yield of 2.48 t ha^{-1} was given by the unfertilized plants. Maize growth and yield from the enriched organic manures were comparable with inorganic fertilizer, indicating the potentials of the use of fortified organic manures as alternatives to inorganic fertilizers. Poultry manure required lesser N-fortification to give comparable seed yield as cow dung. Although both organic manures increased the soil N and P, poultry manure gave higher values while the soil K, Ca and Mg contents were more increased with the cow dung than poultry manure. Poultry manure, fortified with 100 kg Urea can be applied at 2.5 t ha^{-1} to cultivate maize. It gives a comparable yield as inorganic fertilizer and increases the soil N and P.

Shah *et al*. (2009) conducted a field experiment to study growth and yield response of maize to organic and inorganic sources of N at the Agronomic Research Area, Univ. of Agriculture, Faisalabad. Two maize varieties namely Composite-78 and Composite-79 were fertilized with farm yard manure @15000 kg ha^{-1} and urea @ 260 kg ha^{-1} on a sandy clay loamy soil. Composite varieties differed significantly in plant height, numbers of cobs per plant, number of grains per cob, 1000-grains weight, grains yield and harvest index. Composite -78 performed best with respect to all growth and yield parameters expect numbers of plants per unit area and number of cob bearing plants. Combined use of urea and farm yard manure performed best than their sole application in respect of grain yield which was 6.13 t ha^{-1}.

Mugwe *et al.* (2009) observed that use of green manures viz. *Calliandra calothyrsus*, *Leucaena trichandra* and *Tithonia diversifolia* or cattle manure contributing 30 kg N ha^{-1} in combination with chemical fertilizer (30 kg N ha^{-1}) produced higher maize yields compared to that with only chemical fertilizer (60 kg N ha^{-1}). Alone use of these manures contributing 60 kg N ha^{-1} also gave maize yields superior to that from N fertilizer alone at the same rate.

The FYM 20 t ha^{-1} + 60 kg N ha^{-1} increased plant height, 1000-grain weight, leaf area index and yield of maize over sole 120 kg N ha^{-1} (Khan *et al.,* 2009).

Efthimiadou *et al.* (2009) observed that growth and yield of sweet corn were significantly higher with poultry manure than obtained from conventional fertilizers. Moreover, poultry manure increased the photosynthesis rate, stomatal conductance and chlorophyll content in the plants. Similarly, an increase from 83.9 to 108.7 % in yield of maize grain was recorded with the integration of organic and inorganic fertilizers (Sial *et al.,* 2007).

Yadav *et al.* (2006) observed that combined use of N, FYM and Zn proved the best in term of maize grain and stover yield, nutrient uptake, gross return, net return and benefit cost ratio against their sole application and farmers' practice. Macro and micro nutrient concentrations in leaves were greater with organic manure than with mineral fertilizer.

Wakene *et al.* (2005) initiated an experiment in 1997 cropping season to study the effect of supplementing low rates of NP fertilizers with farmyard manure FYM in the maize based farming systems of western Oromia, Ethiopia. The treatments used were 0/0, 20/20, 40/25 and 60/30 kg N/P ha^{-1} and 0, 4, 8, and 1 2 metric tonnes (t) of FYM ha^{-1} in factorial combination. The residual effects of FYM were investigated for Lagakalla, Walda and Shoboka during the 1998 cropping season. The result revealed that the main effects of N/P fertilizers and FYM significantly increased maize grain yields in all locations except for Valda in case of N/P fertilizers and except for Harato in case of FYM in 1997. In the same year, the interaction effects of the FYM and the low rates of NP fertilizers on grain yield were significant at all locations except for Shoboka.

The interaction of the residual effects of the FYM and the low rates of NP fertilizers on grain yield were significant at Shoboka and LagaKalla sites during the 1998 season. Therefore, the integrated use of properly handled FYM and low rates NP fertilizers could be used for improved maize production in the areas under consideration.

El-Kholy *et al.* (2005) implemented a field experiment during the two successive seasons of 2002 and 2003 at the Agricultural Experimental Station of National Research Centre located at Qalubeya, Egypt involving *Azospirillum brasilense* and *Rhodotorula glutinis* in the presence of low rates of NPK and sulfur on maize crop. In comparison with the positive control (100 % NPK), comparable results for plant height, ear height and straw yield were obtained due to the bio fertilization associated with half doses of NPK in the presence of either half or full dose of sulfur. Inclusion of sulfur to the recommended doses of NPK resulted in significant increases for the straw weight parameter. Application of *Azospirillum* significantly augmented maize growth parameters while the associative effect of *Azospirillum* and *Rhodotorula* was more pronounced. Maize yield and its attributes responded well to bio fertilization supported with half doses of NPK and sulfur where the differences were not significant when compared with the positive control. A positive and significant correlation was found between maize yield and each of plant height, ear weight, ear length, ear circumference, grains weight, shelling percent, grain index, straw yield and biological yield while this correlation was not significant with rows number ear^{-1}, grains number row^{-1}, crop index and harvest index. Comparable results to the positive control were observed due to the associative action of biofertilizers, low rates of NPK and sulfur for the nutrient elements content of maize grains i.e., nitrogen, phosphorus, potassium sulfur, zinc, iron and manganese.

Oad *et al.* (2004) conducted an experiment at experimental farm, Sindh Agriculture University ,Tandojam, Pakistan to assess the maize growth and fodder yield under varying combinations of organic manure Farm Yard Manure (FYM) at the rate of 1500, 3000, 4500 kg ha^{-1} and inorganic fertilizers (0, 60, 90, 120 and 150 kg N ha^{-1}). The results revealed that all the maize plant parameters were significantly affected with the incorporation of FYM and nirtrogen levels. Among the plant characters, tall plants, maximum stem girth, more green leaves and highest maize fodder yield were observed with the application of 120 kg N ha^{-1} with the application of 120 kg N ha^{-1} with combination of 3000 kg FYM. It was concluded that the inorganic nitrogen application is the common practice of the farmers, but if, farmyard manure will be supplemented there may be significant increase in maize fodder yield.

Pursushottani and Pun (2001) conducted a field experiment in Salooni, Himachal Pradesh India, during the rainy seasons of 1996 and 1997 to study the response of maize cultivars (Earlycomposite, parvati, and Salooni Local) to farmyard manure (0 and 15 t ha^{-1}) and N (0, 45, and 90 kg ha^{-1}) application. Among the cultivars, Salooni Local gave the tallest plant and longest cobs as well as his highest number of cobs, 1000grain weight stover yield and grain yield. The application of 90 kg N and 15 t farmyard manure ha^{-1} gave the highest cob length, number of grains per cob, 1000 grain weight, grain and stover yields, and harvest index. The highest agronomic efficiency was obtained with 45 kg N and 15 t farmyard manure ha^{-1}. Grain yield was also highest with 90 kg N + 15 t farmyard manure ha^{-1}. Without farmyard manure, the yield obtained with 90 kg N ha^{-1} was equal to that obtained with 45 kg N + 15t farmyard manure ha^{-1}.

Vadivel *et al.* (2001 b) conducted a field experiment in Coimbatoire, Tamil Nadu, India, during winter of 1995-96 and 1996-97 to study the effects of organic N sources and N rate (0, 20, 40, and 60 kg ha^{-1}) on the growth and yield of maize cv. Co 1. The organic N sources were composted coir pith (6.25

t ha^{-1}) and enriched farmyard manure (750 kg supplied as basal and *Azospirillum* inoculated on seeds and soil. Enriched farmyard manure and 60 g N ha^{-1} gave the tallest plants and the highest leaf area index; cob length, girth and weight; 1000-grain weight; dry matter production; and grain and straw yields in both years.

2.5 Interaction effect of spacing and integrated nutrient management

Kumar *et al*. (2018) conducted a field experiment during the *rabi* season of 2017-18 on fodder maize crop (var. SHIATS Makka-2) at the Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Allahabad (U.P.).The experiment comprised of three planting geometry *viz.,* 40 × 10 cm, 50 × 10 cm, 60 × 10 cm and 2 nitrogen levels 90 kg N ha^{-1} and 120 kg N ha^{-1} respectively, with 18 treatments replicated thrice and laid out in Randomized Block Design. The experiment was conducted to evaluate the growth and yield of fodder maize (*Zea mays* L.). The result revealed that treatment T_{17} [120 kg N ha^{-1} + (50% N through vermicompost + 50%N through urea) + Seed inoculated with *Azotobacter*+ 50 x 10 cm] recorded higher crude protein (9.567), Ash (5.270 %), Gross return (89120 ha^{-1}), Net Return (51351.6 ha^{-1}), B : C (2.36) ratio.

Amaral Filho, (2009) carried out a study in Jaboticabal, Sao Paulo, Brazil, in 2000/01. The treatments comprised 2 row spacing (0.60 and 0.80 m), 3 population densities (40 000, 60 000 and 80 000 plants ha^{-1}) and 4 N rates (0, 50, 100, and 150 kg N ha^{-1}). Increased N rates in top-dressing led to an increase in the leaf N and estimated chlorophyll concentration, number of grains ear^{-1}, mass of thousand grains, grain yield and protein content of grains. Higher grain yield was achieved with increasing top-dressed N rates in combination with 0.80 m row spacing and a plant density of 80 000 plants ha^{-1}.

Badr and Othman (2006) conducted two field experiments in Gharbia Governorate, Egypt, in 2003 and 2004 to investigate the effects of 3 planting densities (16 000, 20 000 and 24 000 plants $feddan^{-1}$), 3 organic manure (OM) and biofertilizer Microbin (B) treatments (0, OM and B) and 4 N levels (0, 60, 80 and 100 kg $feddan^{-1}$) on the growth, yield and yield components of maize, as well as soil fertility status at harvest. Plant and ear heights were increased significantly by increasing plant density in both seasons, whereas area of topmost ear leaf was decreased significantly by increasing plant density in both seasons. Number of grains per row and 100-grain weight decreased significantly due to increasing plant density in the 2 seasons. Grain yield was increased significantly in the first season, while the differences were not significant in the second season as the plant density increased. All the growth characters were increased significantly by adding OM or treating the seeds with the B. Grain yield and its components followed the same trend. The increasing N level significantly increased the growth, yield and yield components. The increases in grain yield were 80.41, 122.62 and 156.08% with N levels of 60, 80 and 100 kg $feddan^{-1}$ compared with the control in the first season and 32.43, 49.19 and 56.77% in the second season, respectively. Grain yield was affected significantly due to the interaction of plant densities and N levels in 2003. In 2003 and 2004, OM and B interacted with N to alter the grain yield. The treatments of 24 000 plants $feddan^{-1}$ +B+60 kg N $feddan^{-1}$ resulted in the highest value of N use efficiency (NUE). The highest value of grain N uptake was due to the combination of 16 000 plants $feddan^{-1}$+B+100 kg N $feddan^{-1}$. The combination of 16 000 plants $feddan^{-1}$ +B+100 kg N $feddan^{-1}$ proved the best in terms of soil fertility. NUE increased as plant density increased. Addition of organic fertilizer or treating the seeds with B seemed to increase NUE. Increasing N level resulted in reduced NUE values. Increasing the plant density slightly decreased the grain N uptake, while addition of organic fertilizer or treating the seeds with B enhanced this character. The grain N uptake gradually increased due to increasing N up to 100 kg $feddan^{-1}$. The values of residual soil N decreased as plant density increased, while an opposite trend was observed under addition of organic fertilizer or treating the seeds with B. Increasing N level resulted in gradual increases in this character.

Chandankar *et al*. (2005) conducted a field experiment during the monsoon season of 2003 in Maharashtra, India to evaluate the effects of farmyard manure (FYM at 0 and 5 t ha^{-1}), N:P:K rates (90:45:22.5, 120:60:30 and 150:75:37.5 kg ha^{-1}), and plant density (83 333 and 111 111 plants ha^{-1}) on maize yield and economics. FYM increased plant height. The highest NPK rate showed 34.1% higher grain yield over the lowest rate. Low plant density produced taller plants, with broader and heavier ears.

From the above discussed review of literature, it may be concluded that plant spacing and integrated fertilizer is very much promising for higher maize yield. Spacing and integrated fertilizer is very much crucial factor for growing maize.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted over December 2017 to May 2018 to come across the optimum combination of chemical fertilizer, cowdung, vermicompost and maize compost to reduce the usage of chemical fertilizer on maize variety PSC-121 under 2 spacing. The materials and methods of this experiment are presented in this chapter under the following headings-

3.1 Experimental Site

The experiment was done at the Agronomy field of Sher-e-Bangla Agricultural University (SAU). It is situated at 23°74/ North latitude and 90°35/ East longitude (Anon., 1989). It belongs to Madhupur Tract (AEZ 28). The land was 8.6 m above the sea level. For better understanding about experimental site it is shown in the Map of AEZ of Bangladesh in Appendix- I.

3.2 Climate

The experimental site climate was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al*., 1979).

3.3 Soil

The field belongs to the general soil type which was characterized by shallow red brown terrace soil. The land of the selected experimental plot was medium high under the Tejgaon series. There was available sunshine during the experimental period. Soil sample was collected from 15 cm depth of the experimental site and was sent to SRDI, Dhaka for analysis. The result of analysis was given in Appendix-II.

3.4 Materials

(a) Seeds- PSC-121was collected from KGF (Krishi Gobeshona Foundation).

(b) Fertilizers- Urea, TSP, MP, Gypsum, ZnSO4, Boric Acid, Cowdung, maize compost and vermicompost. Vermicompost was collected from a project named — Shobuj Polli, Haluaghat, Mymenshingh. All chemical fertilizer along with cowdung and compost were collected from the Farm Office of Sher-e-Bangla Agricultural University (SAU).

3.5 Description of the variety

PSC-121 (White)

Identifying character: Bold grain quality, good crop stand ability and drought tolerant.

Type: Medium duration, double cross hybrid.

Crop duration: 135-145.

Yield: 10.2-13.8 t ha^{-1}.

Suitable area: All over Bangladesh.

Sowing time:15th November – 15th December.

Harvesting time: After attaining physiological maturity.

Maturity period: 90-100 days and stay green at maturity.

Major diseases and Management

Diseases: Mainly leaf blight disease occurs at vegetative stage.

Management: Clean cultivation with timely sowing and balance fertilizer application. Seed treatment with vitavax- 200 @ 2.5g kg^{-1} seed, spraying with Tilt or Folicure @ 0.5% and burning of crop residues.

Major insect/pest and Management

Insect pests: Cut worm and Stem borer attack at vegetative stage of maize as well as Ear worm attack in cob at reproductive stage in maize.

Management

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

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

3.6 Layout of the experiment

The experiment was laid out according to the split plot design. The field was divided into 8 blocks to represent 3 replications. There were 24 unit plots altogether in the experiment. The size of each unit plot was 4.6m × 1.8m. Row to row was 60 cm and 40 cm and plant to plant distance was 20 cm respectively. Distance maintained between replication and plots were 1.5m and 70cm respectively.

3.7 Experimental treatments

Two factors are used as a combination 8 for treatment. Two levels of spacing and four levels of fertilizer doses are used as eight treatments.

The experiment comprised with the following factors and treatments were,

Factor A (Spacing)

S_1=60 cm x 20 cm, S_2= 40 cm x 20 cm

Factor B (Integrated Fertilizer management)

Treatment

T_1: All chemical fertilizer (recommended dose)

T_2: maize straw compost +½ of recommended dose

T_3: cowdung+½ of recommended dose

T_4: vermicompost +½ of recommended dose

Recommended dose: Doses of cowdung, maize straw compost and vermicompost were 5.0 t ha^{-1} , 5.0 t ha^{-1} and 2 t ha^{-1} and for chemical fertilizer Urea, TSP, MP, Gypsum, ZnSO4, Boric acid -525-250-200-250-12.5-6 kg ha^{-1} respectively.

3.8 Detail of experimental preparation

3.8.1 Land preparation

The plot selected for the experiment was opened in the fourth week of November 2017 with a power tiller and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed.

3.8.2 Fertilization

Well rotten cowdung, maize straw compost and vermicompost were applied @ 25 kg, 25 kg and 10 kg respectively before final land preparation according to treatment. The recommended chemical fertilizer used for hybrid variety was 7 kg, 1.5kg, 1.56 kg, 5 kg, 0.25 kg and 0.12 kg of Urea, TSP, MP, Gypsum, ZnSO4, Boric acid respectively. Fertilization (basal dose) was completed on 1st December, 2017. One third of urea along with full amount of other fertilizers as per treatment applied during final land preparation as basal dose and the rest urea as per treatment was applied in two equal installments as side dressing.

The first installment of fertilizer was given on 15th January, 2018 and the second installment of fertilizer was given on 20th February, 2018.

3.8.3 Seed sowing

Seeds of the hybrid variety PSC-121 were sown on 9th December, 2017 in lines, maintaining a line to line distance of 60 cm and 40 cm, plant to plant distance of 20 cm having 2 seeds hole^{-1} in the well prepared plot.

3.9 Intercultural operations

3.9.1 Irrigation

First irrigation was given on 17th December, 2017 which was 7 days after sowing. Second irrigation was given on 9th January, 2018 which was 30 days after sowing. Third irrigation was given on, 14th February 2018 which was 65 days after sowing and fourth irrigation was given on 6th March, 2018 which was 85 days after sowing.

3.9.2 Gap filling, thinning and weeding

Gap filling was done on 19th December, 2017 which was 10 days after sowing. During plant growth period one thinning and two weeding were done, thinning was done on 23rd December, 2017 which was 14 days after sowing and the weeding was done on 30th December, 2017 and 8th February, 2018 which were 20 and 60 days after sowing.

3.9.3 Earthing up

Earthing up was done on 9th January, 2018 which was 30 days after sowing. It was done to protect the plant from lodging and for better nutrition uptake.

3.9.4 Plant protection measures

Insecticides Diazinon 60 EC @ 2 ml litre^{-1} water was sprayed to control Stem borer on 5th, 15th and 24th January, 2018 and Ripcord 10 EC @2 ml litre^{-1} water were sprayed to control ear worm on 10th and 17th March, 2018 to protect the crop.

3.9.5 Harvesting

The crops were harvested when the husk cover was completely dried and black coloration was found in the grain base. The cobs of five randomly selected plants of each plot were separately harvested for recording yield attributes and other data. The inner two lines were harvested for recording grain yield and stover yield. Harvesting was done on 16th May, 2018.

3.9.6 Drying

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

3. 10 Data collection

At harvesting, 5 plants were selected randomly from each plot to record the following data,

i. Plant height (cm)

ii. Number of leaves plant $^{-1}$

iii. Leaf area index

iv. Crop growth rate (g m^{-2} d^{-1})

v. Cob length (cm)

vi. Cob circumference (cm)

vii. Number of grains cob^{-1}

viii. 100 grains weight (g)

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

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

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

xii. Harvest index (%)

3.10.1 Plant height

At different stages of crop growth (45, 90 DAS and at harvest), the height of five randomly selected plants from the inner rows per plot was measured from ground level to the tip of the plant portion and the mean value of plant height was recorded in cm.

3.10.2 Number of leaves plant^{-1}

Number of leaves of 5 randomly selected plants were counted and recorded. Average value of 5 plants was recorded as number of leaves per plant.

3.10.3 Leaf Area Index

Leaf area index were estimated manually by counting the total number of leaves per plant and measuring the length and average width of leaf and multiplying by a factor of 0.70 (Kluen and Wolf, 1986). It was done at 90 days after sowing (DAS).

$$\text{Leaf area index} = \frac{\text{Surface area of leaf sample } (m^2) \text{ x correction factor}}{\text{Ground area from where the leaves are collected}}$$

3.10.4 Crop Growth Rate

The crop growth rate values at different growth stages were calculated using the following formula (Beadle, 1987).

$$CGR = \frac{1}{GA} \times \frac{W_2 - W_1}{T_2 - T_1} \quad g\ m^{-2}\ d^{-1}$$

Where,

W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

GA= Ground area (m^2)

3.10.5 Cob length

Five randomly selected cobs were taken from each plot to measure the length from the base to the tip of the ear. The average result was recorded in cm.

3.10.6 Cob circumference

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

3.10.7 Number of grains cob^{-1}

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

3.10.8 100 grains weight

From the seed stock of each plot 100 seeds were counted and the weight was measured by an electrical balance. It was recorded in gram.

3.10.9 Shelling percentage

Five cobs were randomly selected plot^{-1} and shelling percentage was calculated by using the following formula –

$$\text{Shelling percentage} = \frac{\text{Grain weight}}{\text{Cob weight}} \times 100$$

3.10.10 Grain yield

Grain yield was calculated from cleaned and well dried grains collected from the 3.95 m^2 area of all 2 inner rows of the each plot and expressed as t ha.$^{-1}$

3.10.11 Stover yield

Stover yield was determined from the 3.95 m^2 of all 2 inner rows. After threshing, the sub sample was oven dried to a constant weight and finally converted to t ha^{-1}.

3. 10. 12 Biological yield

It was the total yield including both the economic and stover yield.

3.10.13 Harvest index (HI)

Harvest index is the ratio of economic (grain) yield and biological yield. It was calculated by dividing the economic yield grain from the harvested area by the biological yield of the same area (Donald, 1963) and multiplying by 100.

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

Here, Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Stover yield (t ha^{-1})

3.11 Statistical analysis

The obtained data for different characters were statistically analyzed with the computer based software Statistix 10 to find out performance of white maize variety under different spacing and integrated fertilizer management and the mean values of all characters were evaluated and analysis of variances were performed by the F-test. The significance of the difference among treatment means were estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

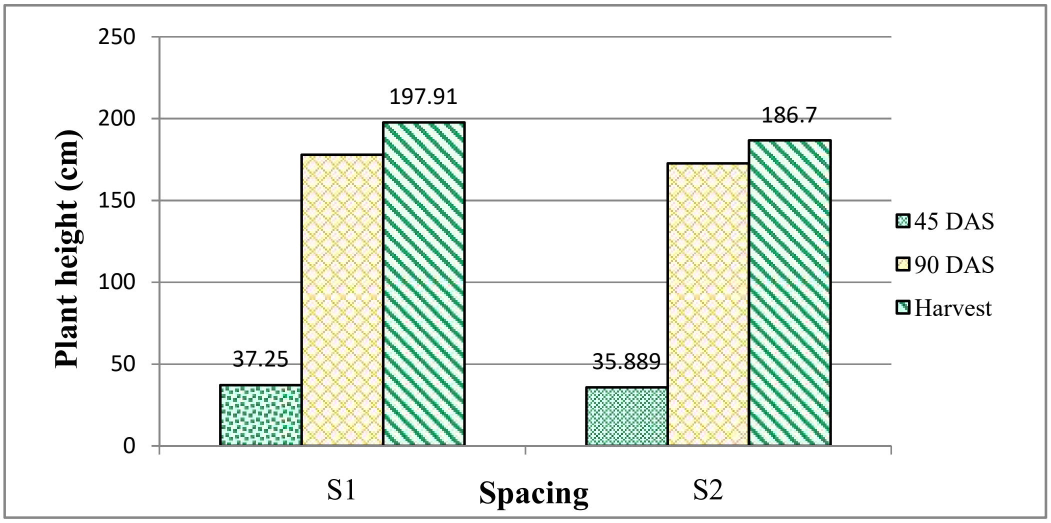
The experiment was conducted to study the performance of white maize variety under different spacings and integrated fertilizer management. Data on different growth, yield contributing characters and yield of maize were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix. The results have been presented and discussed with the help of Tables and Graphs and possible interpretations given under the following headings:

4.1 Growth parameter

4.1.1 Plant height

4.1.1.1 Effect of spacing

Plant height is an important morphological character that acts as a potent indicator of availability of growth resources in its vicinity. The data on plant height was recorded at 45 DAS, 90 DAS and harvest is given in the Figure 1. At 45, 90 DAS and harvest, plant height did not change significantly between two spacing (Appendix III). The highest plant height at 45, 90 DAS and at harvest were 37.25, 177.94 and 197.91 cm respectively with S_1 (60 cm × 20 cm) where the lowest were 35.889, 172.81 and 186.70 cm respectively with S_2 (40 cm × 20 cm). This finding was directly related with Nand (2015) who reported maximum plant height observed in S_1 (60 cm × 20 cm). This result also collaborate the findings of Enujeke (2013), Ukonze *et al*. (2016) and Hasan *et al.* (2018).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm,

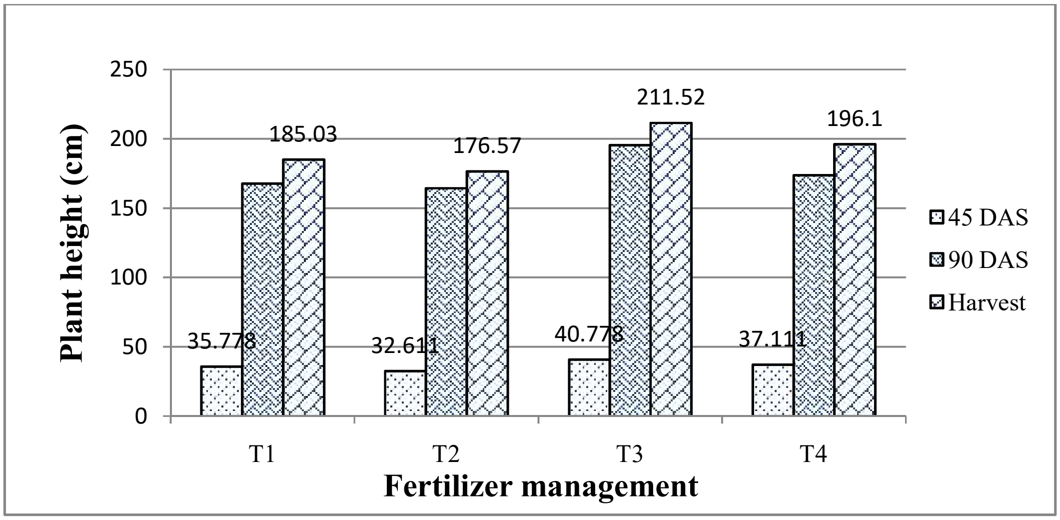
($LSD_{(0.05)}$ = NS, NS and NS at 45 DAS, 90 DAS and harvest respectively)

NS= Non Significant

Fig 1. **Effect of spacing on plant height at different days after sowing of white maize variety**

4.1.1.2 Effect of integrated fertilizer management

Plant height varied significantly at 45, 90 DAS and at harvest for different chemical and organic fertilizer and their combinations under the present trial (Appendix III). The longest plants (40.78 cm, 195.48 cm and 211.52 cm) were recorded at 45, 90 DAS and harvest respectively from T_3 (cowdung+½ of recommended dose). The plant height of 45 DAS was statistically similar with T_4 (vermicompost+½ of recommended dose). On the other side, the shortest plant (32.61cm, 164.44cm and 176.57 cm) were obtained from T_2 (maize straw compost +½ of recommended dose) at 45, 90 DAS and harvest respectively which followed by T_1 at 45 DAS, T_1 and T_4 at 90 DAS and again T_1 at harvest. Application of all chemical fertilizer in recommended doses ensured the essential macro and micro nutrients for the vegetative growth of the maize and the ultimate results were the longest plant. Combination of cow dung, compost and chemical fertilizers half in recommended doses also created a favorable condition for the growth and development of maize plant for that combination of cow dung, compost and half chemical fertilizers also gave the similar results. The variation of plant height due to different fertilizer use was also reported by Aspasia *et al*. (2010), Eltelib *et al.* (2006) and Agba *et al.* (2005). These results also collaborate the findings of Gama *et al*, 2018), Quansah and Gabriel (2010), Mohsin *et al.* (2011), Oad *et al.* (2004), Akbar *et al*. (2016), Vadivel *et al.* (2001b) and Ali *et al.* (1999).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose,T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 4.23, 13.83 and 14.88 at 45 DAS, 90 DAS and harvest respectively)

Fig 2. Effect of integrated fertilizer management on plant height at different days after sowing of white maize variety

4.1.1.3 Interaction effect of spacing and fertilizer management

Plant height was influenced by the interaction of different levels of organic and chemical fertilizer combination and spacing at different growth stages of maize (Table 1). Interaction of spacing and fertilizer management had no significant effect on plant height (Appendix III). T_3 (cowdung+½ of recommended dose) along with S_1 (60 cm × 20 cm) gave the tallest plant; 42.22, 204.19, 225.03 cm at 45, 90 DAS and at harvest respectively. The treatment combination S_2T_2 gave the lowest plant height at 45, 90 DAS and at harvest (30.44, 161.78 and 174.20 cm respectively). The finding under the present study was in conformity with Kumar *et al.* (2018).

Table 1. Interaction of spacing and fertilizer management on plant height at different days after sowing of white maize variety

Interaction(spacing x fertilizer management)	Plant height (cm) at		
	45 DAS	90 DAS	Harvest
S_1T_1	35.22	168.56	187.20
S_1T_2	34.78	167.11	178.93
S_1T_3	42.22	204.19	225.03
S_1T_4	36.78	171.89	200.47
S_2T_1	36.33	167.00	182.87
S_2T_2	30.44	161.78	174.20
S_2T_3	39.33	186.78	198.00
S_2T_4	37.44	175.67	191.73
$LSD_{(0.05)}$	**NS**	**NS**	**NS**
CV (%)	**9.19**	**6.27**	**6.15**

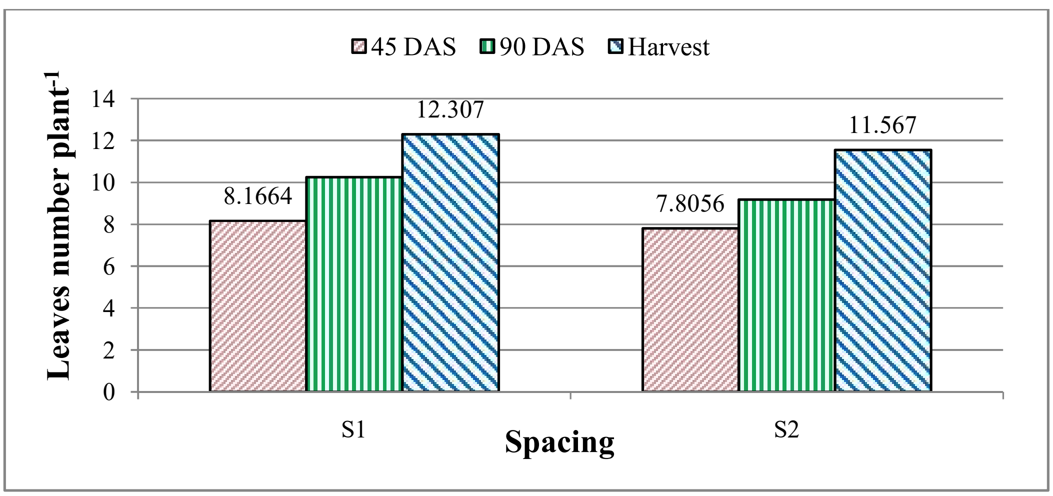
NS= Non Significant

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.1.2 Number of leaves plant^{-1}

4.1.2.1 Effect of spacing

The spacing effect on number of functional leaves (green leaves above the ground) per plant at different growth stages during experimentation has been presented in Fig 3. Data showed that higher leaves number plant^{-1} was achieved with higher plant spacing where lower plant spacing showed lower leaf number plant^{-1}. The highest leaves number plant^{-1} at 45, 90 DAS and at harvest were 8.17, 10.26 and 12.31 respectively S_1 (60 cm × 20 cm) where the lowest were 7.8056, 9.194 and 11.567 respectively which was with S_2 (40 cm × 20 cm). At 90 DAS, the leaves number variation between two spacing noticed significantly (Appendix IV). This finding was directly related with Nand (2015) who reported maximum number of leaves observed in S_1 (60 cm × 20 cm). This result also collaborate the findings of Enujeke (2013) and Ukonze *et al*., (2016).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

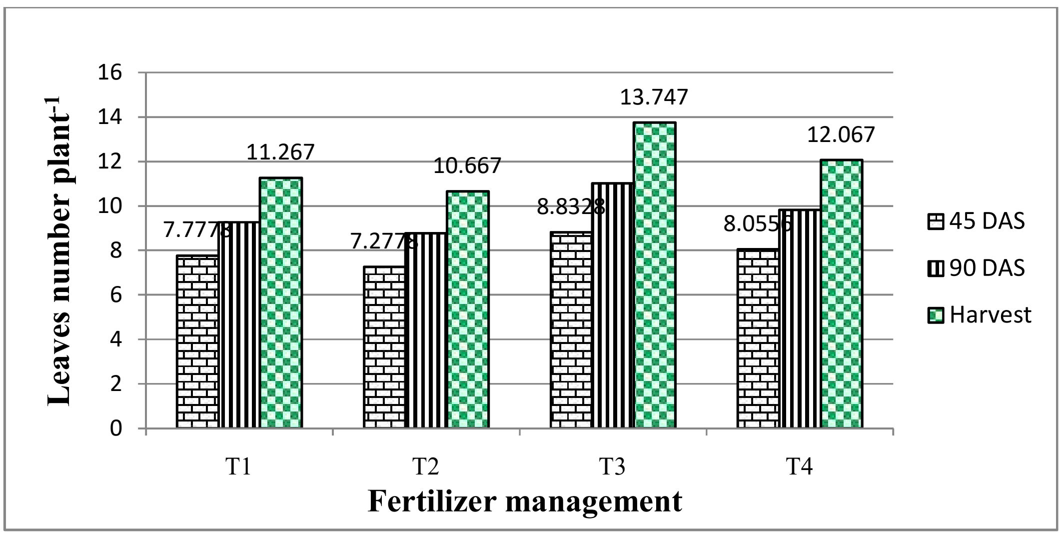
($LSD_{(0.05)}$= NS, 1.06 and NS at 45 DAS, 90 DAS and harvest respectively)

NS= Non Significant

Fig 3. Effect of spacing on number of leaves plant^{-1} at different days after sowing of white maize variety

4.1.2.2 Effect of integrated fertilizer management

Number of leaves plant^{-1} was influenced significantly by different level of organic and chemical application at different days after sowing (DAS) (Appendix IV). Results showed that T_3 was evident for highest number of leaves plant^{-1} at all growth stages. The highest leaves number plant^{-1} at 45, 90 DAS and at harvest were 8.83, 11.01 and 13.75 respectively which was obtained with T_3 (cowdung+½ of recommended dose). The lowest number of leaves plant^{-1} viewed with T_2 (maize straw compost +½ of recommended dose) and that were 7.28, 8.78 and 10.67 at 45, 90 DAS and at harvest respectively which per with T_1 (all chemical fertilizer (recommended dose)). The result under the present study was in conformity with Quansah and Gabriel (2010).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$ = 0.66, 0.95 and 1.23 at 45 DAS, 90 DAS and harvest respectively)

Fig 4. Effect of integrated fertilizer management on number of leaves plant^{-1} at different days after sowing of white maize variety

4.1.2.3 Interaction effect of spacing and fertilizer management

Effect of spacing and fertilizer management on leaf number plant^{-1} was presented by Table 2. The treatment combination, S1T3 gave the highest leaf number plant^{-1} 9.22, 12.02 and 14.89 at 45, 90 DAS and at harvest respectively. The treatment combination S_1T_2 at 45 DAS and S_2T_2 gave the lowest leaf number plant^{-1} at 90 DAS and at harvest (7.22, 8.44 and 10.53 respectively). This finding was indirectly related with Kumar *et al.* (2018).

Table 2. Interaction of spacing and fertilizer management on leaves number plant^{-1} at different days after sowing of white maize variety

Interaction(spacing x fertilizer management)	Leaves number plant^{-1} at		
	45 DAS	90 DAS	Harvest
S_1T_1	8.00	9.56	11.33
S_1T_2	7.22	9.11	10.80
S_1T_3	9.22	12.02	14.89
S_1T_4	8.22	10.33	12.20
S_2T_1	7.56	9.00	11.20
S_2T_2	7.33	8.44	10.53
S_2T_3	8.44	10.00	12.60
S_2T_4	7.89	9.33	11.93
$LSD_{(0.05)}$	**NS**	**NS**	**NS**
CV(%)	**6.58**	**7.74**	**8.18**

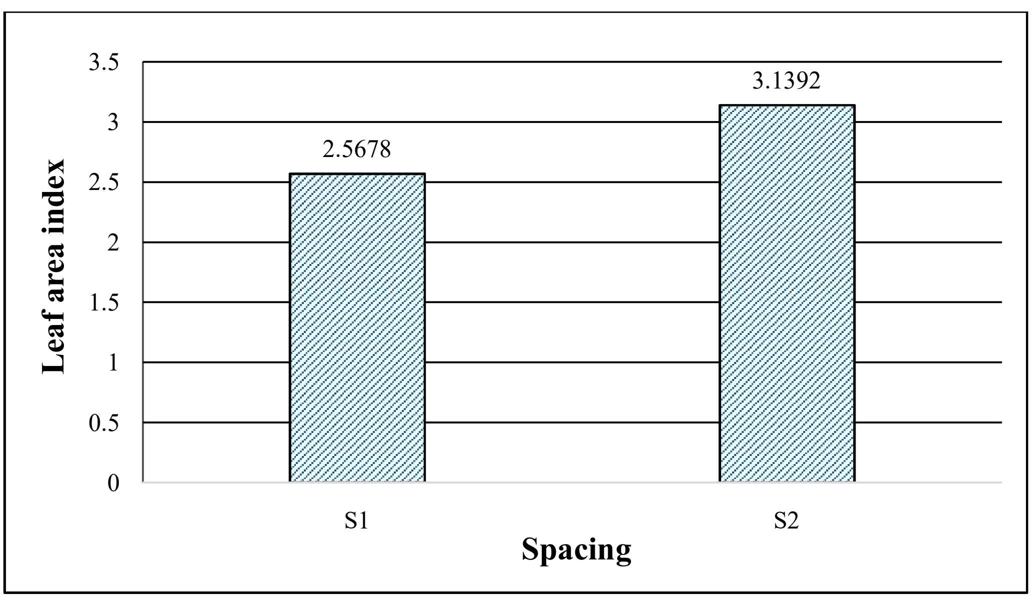
NS= Non Significant

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.1.3. Leaf Area Index (LAI)

4.1.3.1 Effect of spacing

Leaf Area Index (LAI) expresses the ratio of leaf surface area to the ground area. It is one of the important determinants of dry matter (DM) production. Crop production practically means the efficient interception of photo synthetically active radiation (PAR) and its conversion into food and other useable materials. Efficient interaction of PAR by a crop canopy requires adequate leaf area expansion. According to Gay and Bloc (1992), LAI values above 5.0 under typical conditions in Europe are suggestive of a high yield potential of maize. Significant variation was observed in case of leaf area index between the spacing treatments under the present study (Appendix V). Data represent in Fig 5 showed that higher leaf area index was achieved with lower plant spacing where lower plant spacing showed higher leaf area index. The highest leaf area index at 90 DAS was 3.14 with S_2 (40 cm × 20 cm) where the lowest was 2.57 with S_1 (60 cm × 20 cm). The result under the present study was in conformity with Nand (2015) and Jiotode (2002).

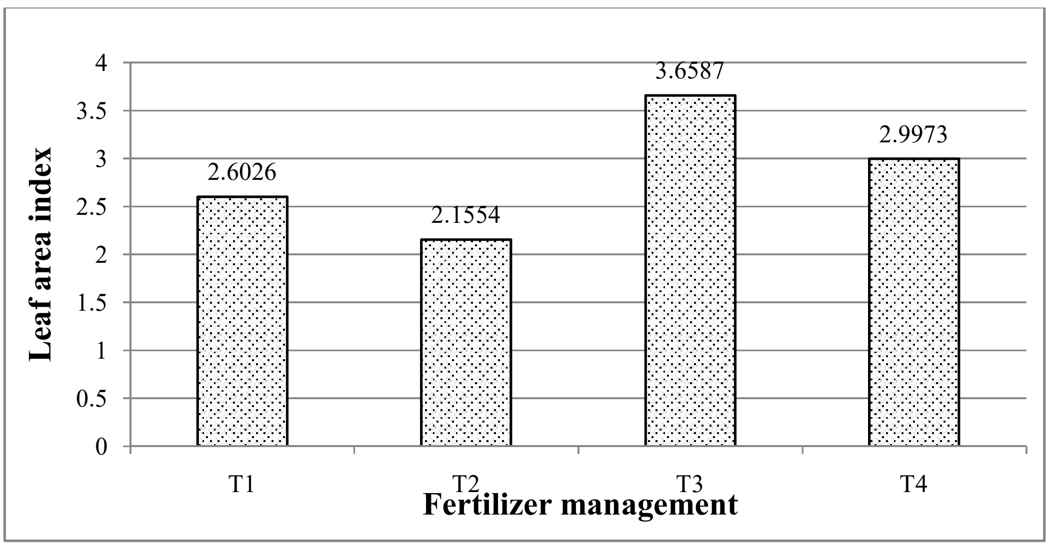


S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm **($LSD_{(0.05)}$= 0.39)**

Fig 5. Effect of spacing on leaf area index of white maize variety

4.1.3.2 Effect of integrated fertilizer management

Statistically significant variation was recorded for leaf area index at 90 DAS for different chemical and organic fertilizers and their combinations (Appendix V). At 90 DAS, the maximum leaf area index (3.66) was recorded from T_3: cowdung+½ of recommended dose, whereas the minimum leaf area index (2.16) was found from T_2: maize straw compost +½ of recommended dose. The variation of LAI due to different fertilizer use was also reported by Aspasia *et al.(*2010), Agarwal *et al.* (1995), Khan *et al.* (2009), Eltelib *et al.* (2006) and Vadivel *et al.* (2001b).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 0.24)

Fig 6. Effect of integrated fertilizer management on leaf area index of white maize variety

4.1.3.3 Interaction effect of spacing and integrated fertilizer management

Leaf area index was influenced by the combined effect spacing and integrated fertilizer management at 90 DAS of white maize variety. The treatment combination S_2T_3 gave the highest leaf area index (4.02) at 90 DAS. The treatment combination S_1T_2 gave the lowest leaf area index (1.92) at 90 DAS.

Table 3. Interaction of spacing and fertilizer management on leaf area index (LAI) of white maize variety

Interaction(spacing x fertilizer management)	**Leaf area index at 90 DAS**
S_1T_1	2.32
S_1T_2	1.92
S_1T_3	3.29
S_1T_4	2.74
S_2T_1	2.89
S_2T_2	2.39
S_2T_3	4.02
S_2T_4	3.26
$LSD_{(0.05)}$	**NS**
CV (%)	**6.46**

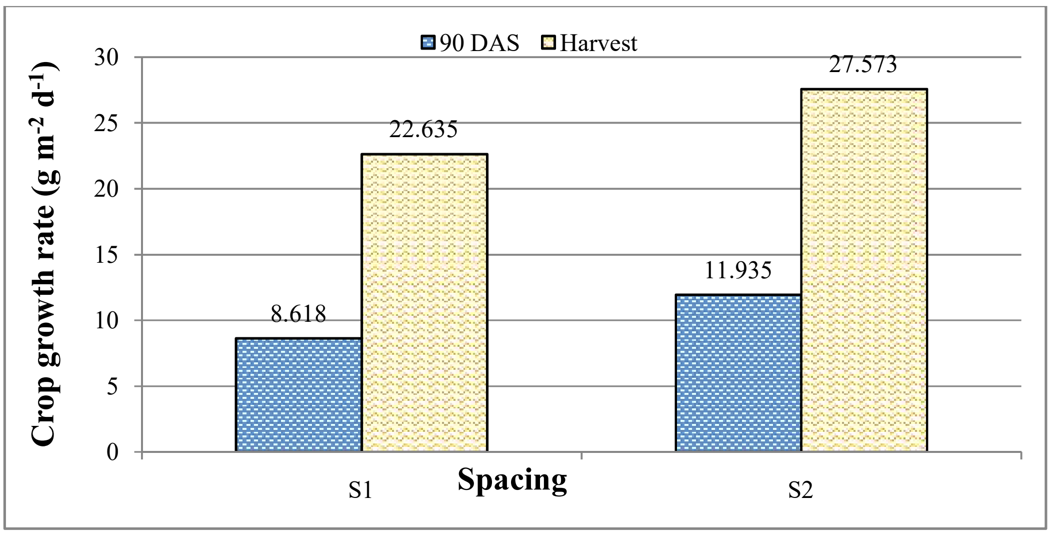
NS= Non Significant

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.1.4 Crop Growth Rate

4.1.4.1 Effect of spacing

Different plant spacing of maize regulated crop growth rate of maize variety. Data showed that higher crop growth rate was achieved with lower plant spacing where lower plant spacing showed higher crop growth rate due to higher plant number per area. It was observed that the highest crop growth rate at 90 DAS and at harvest were 11.94 g m^{-2} d^{-1} and 27.57 g m^{-2} d^{-1} respectively with S_2 (40 cm × 20 cm) where the lowest were 8.62 and 22.64 g m^{-2} d^{-1} respectively was with S_1 (60 cm × 20 cm).



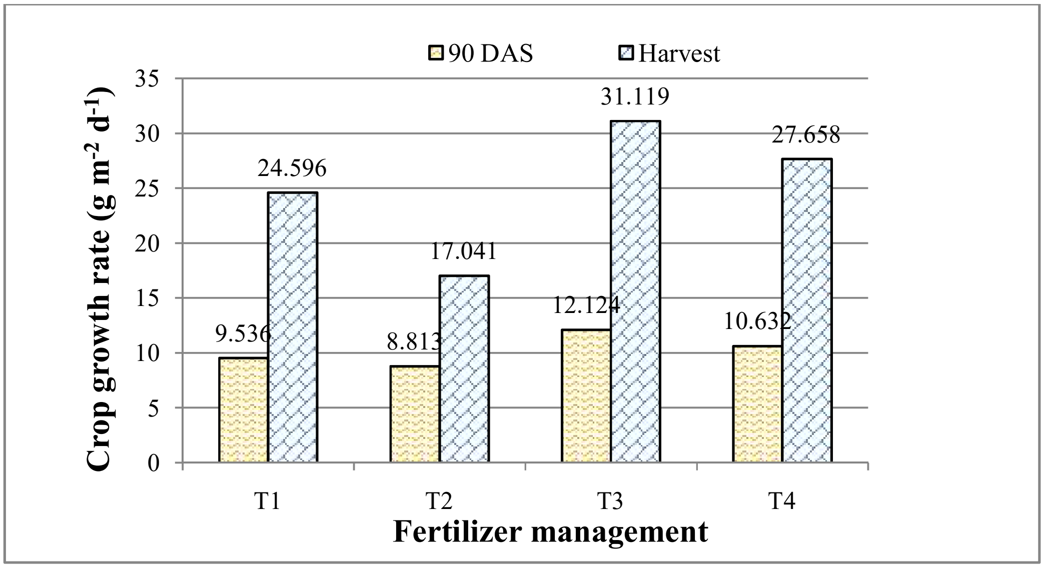
S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm **($LSD_{(0.05)}$= NS and NS at 90 DAS and at harvest respectively)**

NS= Non Significant

Fig 7. Effect of spacing on crop growth rate at different days after sowing of white maize variety

4.1.4.2 Effect of integrated fertilizer management

Crop Growth Rate (CGR) varied significantly for different chemical and organic fertilizers and their combinations at 90 DAS and harvest (Appendix VI). At 90DAS, the highest CGR was found in T_3 (12.12 g m^{-2} d^{-1}), while the lowest CGR was recorded in T_2 (8.81g m^{-2} d^{-1}) which is statistically similar with T_1. At harvest, the highest CGR was found in T_3 (31.12 g m^{-2} d^{-1}) which is statistically similar with T_4, while the lowest CGR was recorded in T_2 (17.04 g m^{-2} d^{-1}).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 1.03 and 4.22 at 90 DAS and at harvest)

Fig 8. Effect of different fetilizer management on crop growth rate at different days after sowing of white maize variety

4.1.4.3 Interaction effect of spacing and integrated fertilizer management

Interaction of spacing and integrated fertilizer management also effected crop growth rate (g m^{-2} d^{-1}) at different growth stages of maize (Table 4). It was observed that the treatment combination, S_2T_3 gave the highest crop growth rate; 14.28 and 32.75 g m^{-2} d^{-1} at 90 DAS and at harvest respectively. S_1T_2 gave the lowest at 90 DAS and at harvest (7.46 and 15.55 g m^{-2} d^{-1} respectively).. This finding was indirectly related with Kumar *et al.* (2018).

Table 4. Interaction of spacing and fertilizer management on crop growth rate at different days after sowing of white maize variety

Interaction(spacing x fertilizer management)	Crop growth rate (g m^{-2} d^{-1}) at	
	90 DAS	**Harvest**
S_1T_1	8.21	21.19
S_1T_2	7.47	15.55
S_1T_3	9.97	29.49
S_1T_4	8.83	24.31
S_2T_1	10.86	28.01
S_2T_2	10.17	18.53
S_2T_3	14.28	32.75
S_2T_4	12.43	31.00
$LSD_{(0.05)}$	**NS**	**NS**
CV(%)	**7.95**	**13.37**

NS= Non Significant

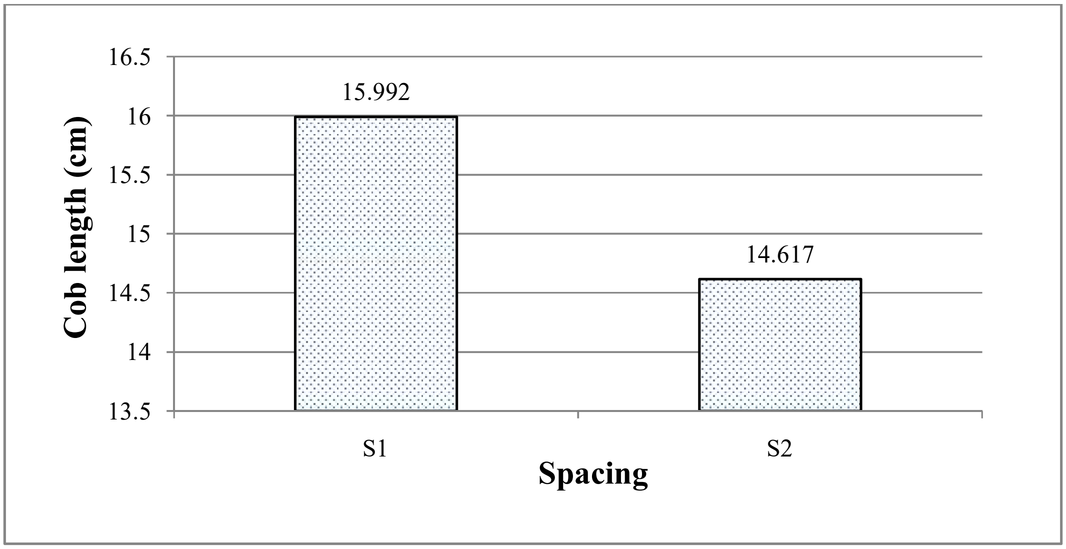
S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.2 Yield contributing parameters

4.2.1 Cob length

4.2.1.1 Effect of spacing

Different spacing had no significant effect on cob length of maize (Appendix VII). Results represented in Fig 9 indicated that the longest cob (15.99cm) was attained with S_1 (60 cm × 20 cm) where the shortest (14.62 cm) was with S_2 (40 cm × 20 cm). Both treatments showed significantly different results in respect of highest and lowest value of cob length. This finding was directly related with Nand (2015) who reported longest cob observed in S_1 (60 cm × 20 cm). This result also collaborate the findings of Ukonze *et al*. (2016), Hasan *et al*. (2018) and Fanadzo *et al*. (2010).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

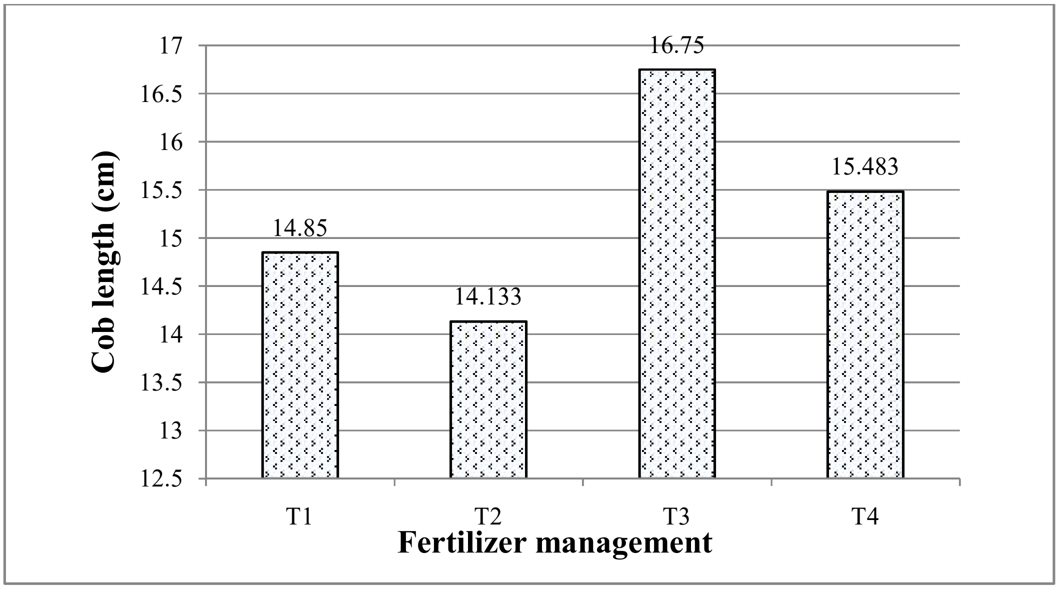
($LSD_{(0.05)}$ = NS)

NS= Non Significant

Fig 9. Effect of spacing on cob length of white maize variety

4.2.1.2 Effect of integrated fertilizer management

Significant variation was recorded in case of cob length for different chemical and organic fertilizers, and their combinations (Appendix VII). The longest cob was observed in T_3 (16.75 cm), which was statistically similar with T_4 (15.48 cm) again the shortest cob was recorded from T_2 (14.13 cm) which was statistically similar with T_1 (14.85 cm). Application of cowdung and half of recommended dose of chemical fertilizer gave longest cob with ensuring optimum vegetative growth as well as reproductive growth of Maize followed by the combination of vermicompost and chemical fertilizers half in recommended doses. The result was in agreement with those stated by Nasim *et al.* (2012), Agba *et al*. (2005) and Hassan (2005) who observed the similar result. With the reduction of chemical fertilizer, the cob length was also reduced.



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 1.18)

Fig 10. Effect of integrated fertilizer management on cob length of white maize variety

4.2.1.3 Interaction effect of spacing and integrated fertilizer management

Interaction effect of spacing and integrated fertilizer management determined the cob length of maize (Table 5). Results in table 5 showed that the longest cob (17.9 cm) was achieved with the combined effect of S_1T_3. On the other hand, the shortest cob length (13.60 cm) was observed by S_2T_2.

Table 5. Interaction of spacing and fertilizer management on cob length of white maize variety

Interaction(spacing x fertilizer management)	Cob length (cm)
S_1T_1	15.20
S_1T_2	14.67
S_1T_3	17.90
S_1T_4	16.20
S_2T_1	14.50
S_2T_2	13.60
S_2T_3	15.60
S_2T_4	14.77
$LSD_{(0.05)}$	**NS**
CV(%)	**6.15**

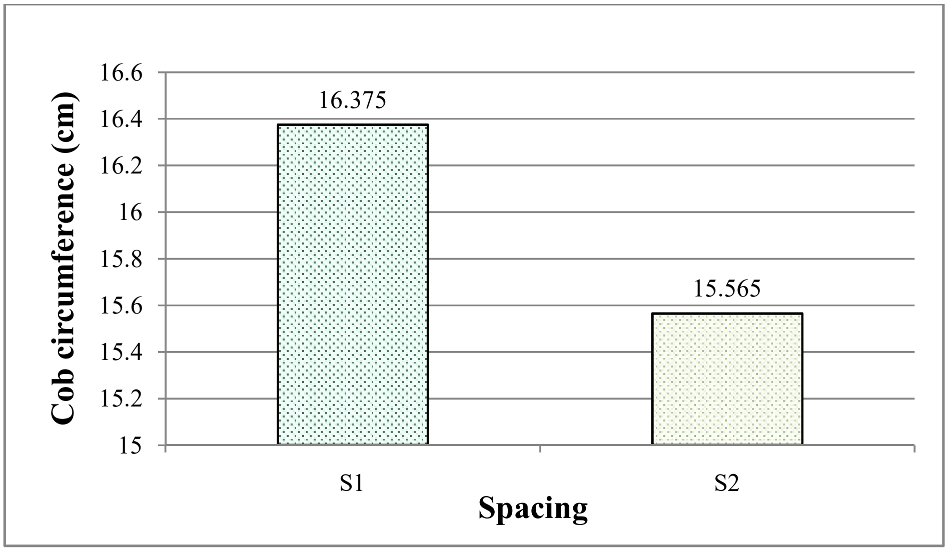
NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.2.2 Circumference of cob

4.2.2.1 Effect of spacing

Different spacing had significant effect on cob circumference of maize (Appendix VIII). Results represented in Fig 11 indicated that the highest cob circumference (16.38 cm) was attained with S_1 (60 cm × 20 cm) where the lowest (15.57 cm) was with S_2 (40 cm × 20 cm). The results showed significantly different results in respect of the highest and the lowest value of cob circumference. This finding was similar with Nand (2015) who reported maximum cob circumference observed in S_1 (60 cm × 20 cm). This result also relate to the findings of Ukonze *et al*. (2016) and Hasan *et al*. (2018).

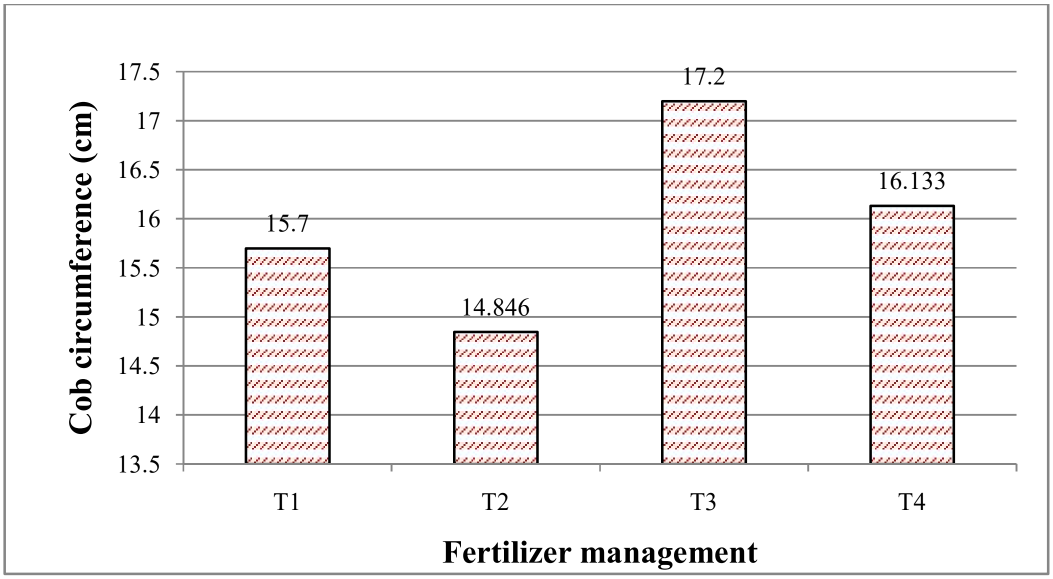


S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm **($LSD_{(0.05)}$= 0.51)**

Fig 11. Effect of spacing on cob circumference of white maize variety

4.2.2.2 Effect of integrated fertilizer management

The different chemical and organic fertilizers and their combinations had significant effect on cob circumference (Appendix VIII). Agba *et al*. (2005) and Vadivel *et al*. (2001b) also reported that the similar higher cob circumference was found due to the various level fertilizer application. According to Figure 12, the highest cob circumference (17.20 cm) was obtained with T_3 treatment (cowdung and half recommended dose of chemical fertilizer). The lowest cob circumference (14.85 cm) was found in the T_2 (maize straw compost and half recommended dose of chemical fertilizer) which was statistically similar with T_1 all chemical fertilizer (recommended dose).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 1.06)

Fig 12. Effect of integrated fertilizer management on cob circumference of white maize variety

4.2.2.3 Interaction effect of spacing and integrated fertilizer management

Interaction effect of spacing and integrated fertilizer management influenced the cob circumference of maize. Results in Table 6 showed that the highest cob circumference (18.033 cm) was achieved with the combined effect of S_1T_3 where the lowest cob circumference (14.69 cm) was observed by S_2T_2.

Table 6. Interaction of spacing and fertilizer management on cob circumference of white maize variety

Interaction(spacing x fertilizer management)	Cob circumference (cm)
S_1T_1	15.93
S_1T_2	15.00
S_1T_3	18.03
S_1T_4	16.53
S_2T_1	15.47
S_2T_2	14.69
S_2T_3	16.37
S_2T_4	15.73
$LSD_{(0.05)}$	**NS**
CV(%)	**5.30**

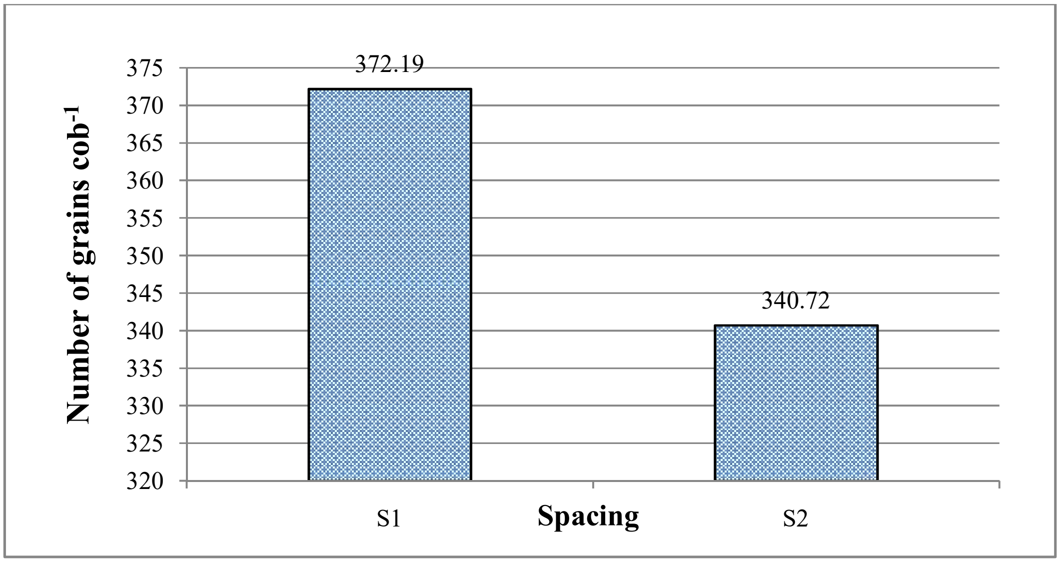
NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm, T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.2.3 Number of grains cob^{-1}

4.2.3.1 Effect of spacing

Different spacing had no significant effect on grains cob^{-1} of maize (Appendix IX). Results represented in Figure 13 indicated that the highest grains cob^{-1} (372.19) was attained with S_1 (60 cm × 20 cm) where the lowest (340.72) was with S_2 (40 cm × 20 cm). Higher spacing gave the highest number of grains cob^{-1}. This result also collaborate the findings of Akbar *et al*, (2016) and Hasan *et al*, (2018).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

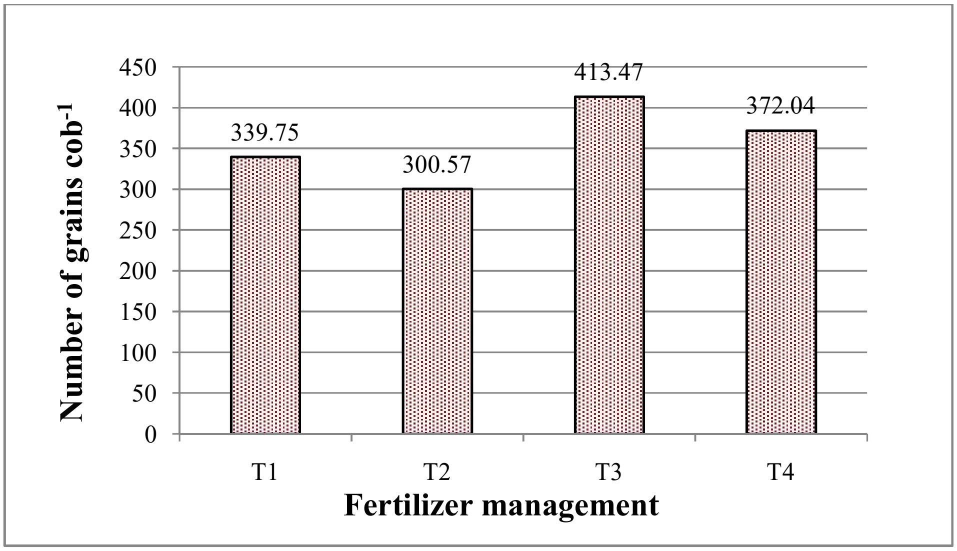
($LSD_{(0.05)}$= NS)

NS= Non Significance

Fig 13. Effect of spacing on number of grains cob^{-1} of white maize variety

4.2.3.2 Effect of integrated fertilizer management

Statistically significant variation was recorded for grains cob^{-1} for different chemical and organic fertilizers and their combinations (Appendix IX). The highest total grains cob^{-1} was obtained from T_3 (413.47), while the lowest total grains cob^{-1} was recorded from T_2 (300.57), (Figure 14). Similar findings were reported by Wailare and Kesarwan (2017), Nasim *et al.* (2012) and Hassan (2005).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 24.03)

Fig 14. Effect of integrated fertilizer management on number of grains cob^{-1} of white maize variety

4.2.3.3 Interaction effect of spacing and integrated fertilizer management

Table 7 represent the result of interaction effect on number of grains cob^{-1}.Results in table 7 showed that the highest number of grains cob^{-1} (433.95) was achieved with the combined effect of S_1T_3 where the lowest number of grain cob^{-1} (282.27) was observed by S_2T_2. This finding was indirectly related with Kumar *et al.* (2018) and Badr and Othman (2006)

Table 7. Interaction of spacing and fertilizer management on number of grains cob^{-1} of white maize variety

Interaction(spacing x fertilizer management)	Number of grains cob^{-1}
S_1T_1	351.33
S_1T_2	318.87
S_1T_3	433.95
S_1T_4	384.60
S_2T_1	328.16
S_2T_2	282.27
S_2T_3	392.99
S_2T_4	359.48
$LSD_{(0.05)}$	**NS**
CV(%)	**5.36**

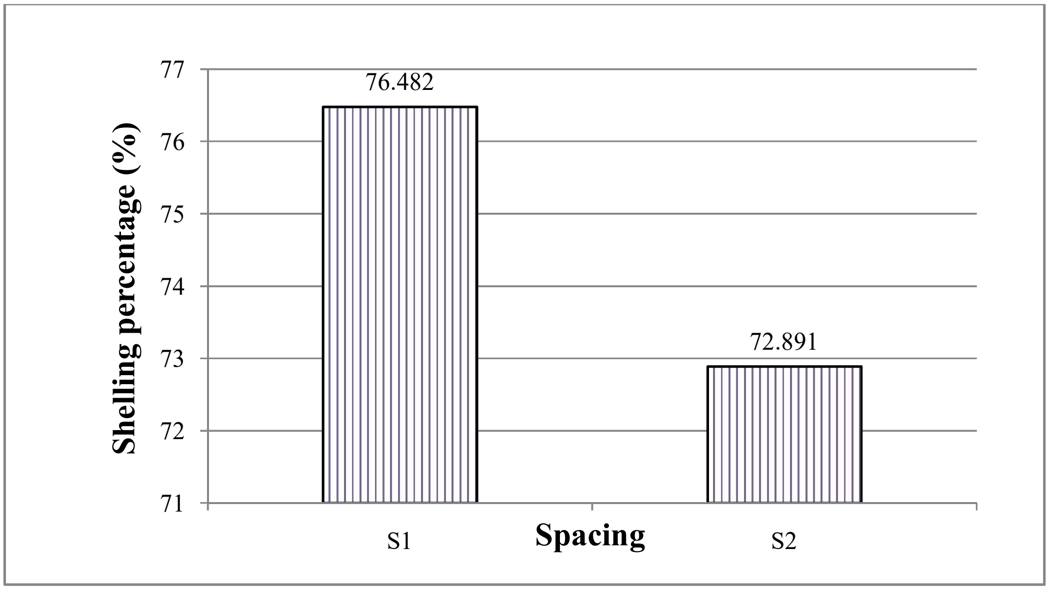
NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose.

4.2.4 Shelling percentage

4.2.4.1 Effect of spacing

Different spacing influenced shelling percentage. However, no remarkable change observed between two spacings in term of shelling percentage (Appendix X). Results represented in Figure 15 indicated that the highest shelling percentage (76.48%) was attained with S_1 (60 cm × 20 cm) where the lowest (72.89%) was with S_2 (40 cm × 20 cm). Higher spacing gave the highest shelling percentage.



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

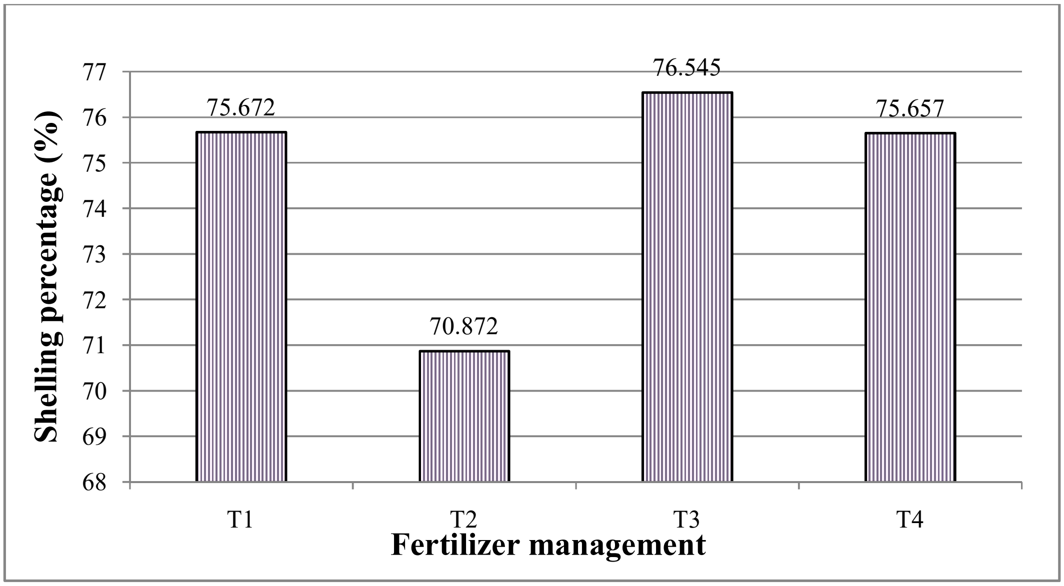
($LSD_{(0.05)}$= NS)

NS= Non Significance

Fig 15. Effect of spacing on of shelling percentage of white maize variety

4.2.4.2 Effect of integrated fertilizer management

Shelling percentage did not change significantly due to different chemical and organic fertilizers, and their combinations (Appendix X). The highest shelling percentage was recorded from cowdung and half of recommended dose of chemical fertilizer, T_3 (76.55 %) and the lowest shelling percentage recorded from maize straw compost and half of recommended dose of chemical fertilizer, T_2 (70.87 %) (Figure 16). The similar result was found by El-Kholy *et al.* (2005).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$=NS)

NS= Non Significance

Fig 16. Effect of on fertilizer management of shelling percentage of white maize variety

4.2.4.3 Interaction effect of spacing and integrated fertilizer management

Interaction effect of spacing and integrated fertilizer management regulated the shelling percentage of maize (Table 8). Results in table 8 showed that the highest shelling percentage (78.67 %) was achieved with the combined effect of S_1T_3 where the lowest (67.60 %) was observed by S_2T_2.

Table 8. Interaction of spacing and fertilizer management on shelling percentage of white maize variety

Interaction(spacing x fertilizer management)	Shelling Percentage (%)
S_1T_1	75.97
S_1T_2	74.14
S_1T_3	78.76
S_1T_4	77.05
S_2T_1	75.37
S_2T_2	67.60
S_2T_3	74.33
S_2T_4	74.26
$LSD_{(0.05)}$	**NS**
CV(%)	**4.70**

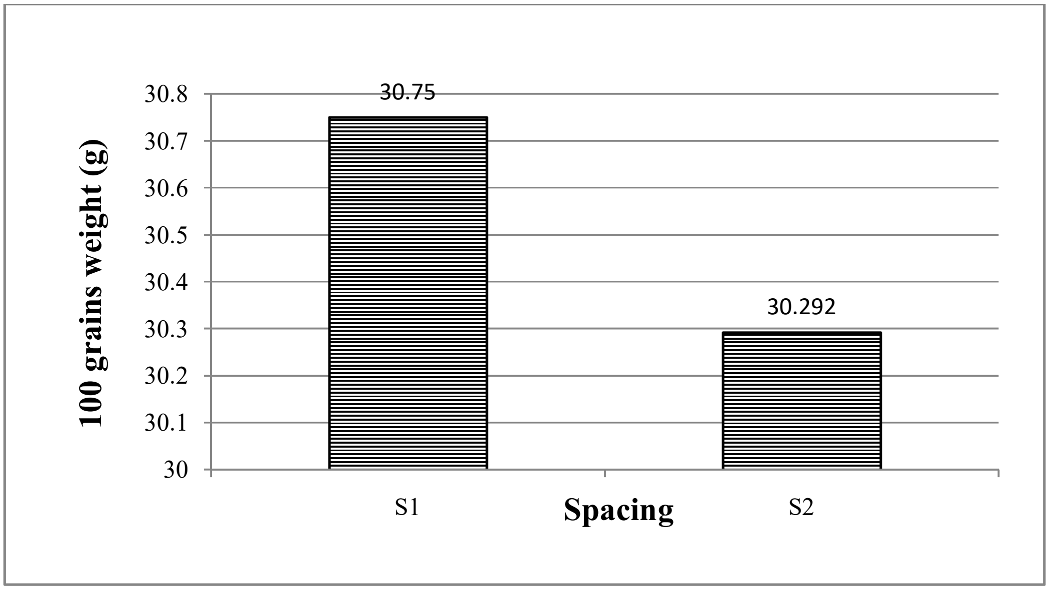
NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.2.5 100 grains weight

4.2.5.1 Effect of spacing

Different spacing had no significant effect on 100 grains weight of maize (Appendix XI). Results represented in Figure 17 indicated that the highest 100 grains weight (30.75 g) was attained with S_1 (60 cm × 20 cm) where the lowest (30.29 g) was with S_2 (40 cm × 20 cm).This result also relate to Akbar *et al*., (2016).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

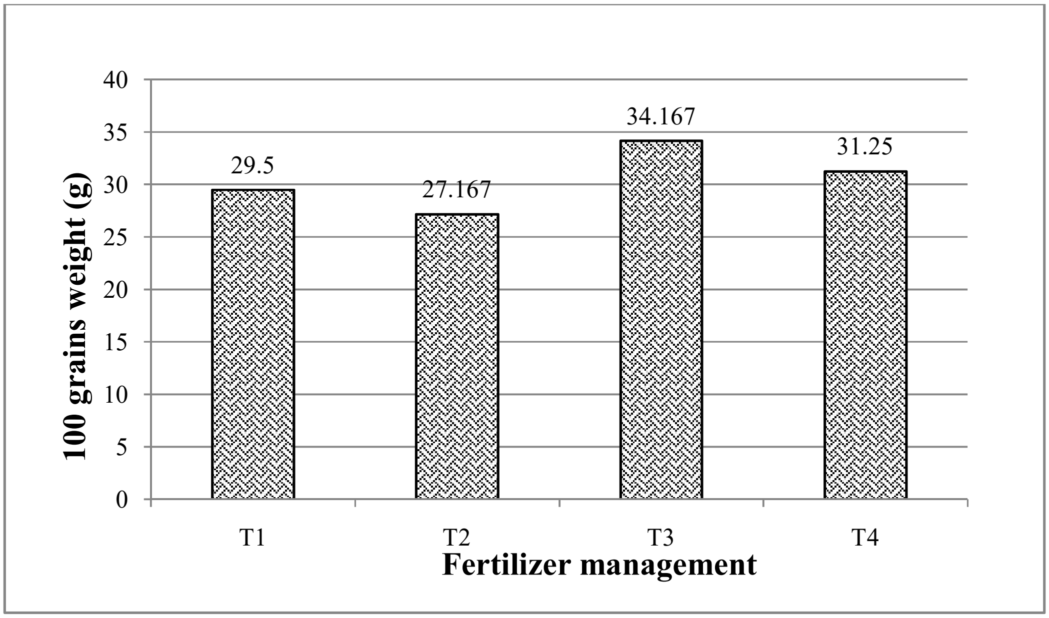
($LSD_{(0.05)}$= NS)

NS= Non Significance

Fig 17. Effect of spacing on 100 grains weight of white maize variety

4.2.5.2 Effect of integrated fertilizer management

Weight of 100 grains varied significantly due to different chemical and organic fertilizers, and their combinations treatments (Appendix XI). The highest weight of 100 grains was recorded from T_3 (34.17 g) and the lowest weight was recorded from T_2 (27.17 g) (Figure 18). Similar findings observed by Hassan (2005).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

(LSD$_{(0.05)}$=2.52)

Fig 18. Effect of fertilizer management on 100 grains weight of white maize variety

4.2.5.3 Interaction effect of spacing and integrated fertilizer management

Interaction effect of spacing and integrated fertilizer management determined the 100 grains weight of maize (Table 9). Results in Table 9 showed that the highest 100 grains weight (35.33 g) was achieved with the combined effect of S_1T_3 where the lowest 100 grains weight (26.67 g) was observed by S_1T_2. The result under the present study was conformity with Amaral Filho, (2009).

Table 9. Interaction of spacing and fertilizer management on 100 grains weight of white maize variety

Interaction(spacing x fertilizer management)	100 grains weight (g)
S_1T_1	29.33
S_1T_2	26.67
S_1T_3	35.33
S_1T_4	31.67
S_2T_1	29.67
S_2T_2	27.67
S_2T_3	33.00
S_2T_4	30.83
$LSD_{(0.05)}$	**NS**
CV(%)	**5.59**

NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

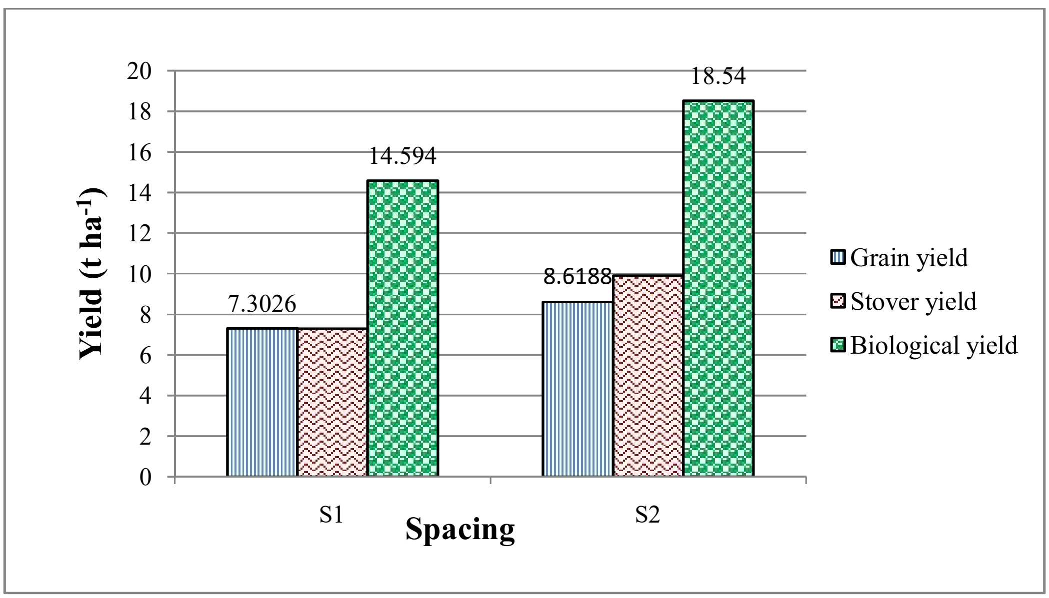
4.2.6 Grain yield, Stover yield and Biological yield

4.2.6.1 Effect of spacing

Different spacing significantly affected the result of grain yield of maize (Appendix XII). Results represented in Figure 19 indicated that the highest grain yield (8.62 t ha^{-1}) was obtained with S_2 (40 cm × 20 cm) where the lowest (7.30 t ha^{-1}) was with S_1 (60 cm × 20 cm). Similar results were also found by Sener (2004). Generally grain yield increased with increasing planting density (Akbar *et al*, 2016).This finding was directly related with Nand (2015) who reported maximum grain yield observed in S_1 (60 cm × 20 cm). This result also related with the findings of Fanadzo *et al.* (2010), Golla *et al*., (2018) and Hasan *et al*, (2018).

Different spacing had significant effect on stover yield (t ha^{-1}) of maize (Appendix XIII). Results represented in Figure 19 indicated that the highest stover yield (9.92 t ha^{-1}) was attained with S_2 (40 cm × 20 cm) where the lowest (7.29 t ha^{-1}) was with S_1 (60 cm × 20 cm). The result obtained by Hasan *et al*., (2018) was similar with the present findings.

Effect of spacing on biological yield of maize was remarkable (Appendix XIV). Results represented in Figure 19 indicated that the highest biological yield (18.54 t ha^{-1}) was obtained with S_2 (40cm × 20 cm) where the lowest (14.59 t ha^{-1}) was with S_1 (60 cm × 20 cm).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

($LSD_{(0.05)}$= 0.33 , 1.89 and 1.42 for grain yield, stover yield and biological yield)

Fig 19. Effect of spacing on grain yield, stover yield and biological yield of white maize variety

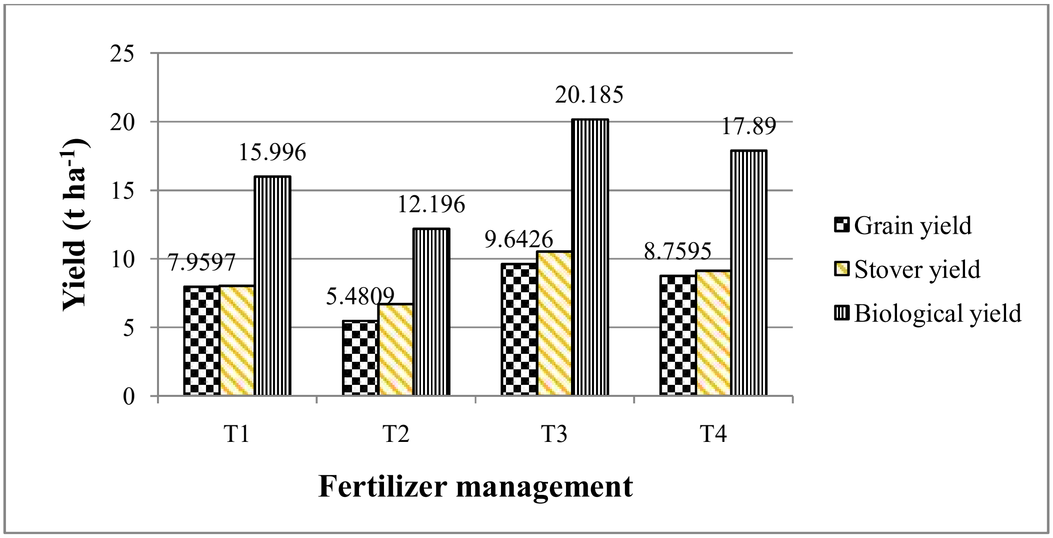
4.2.6.2 Effect of integrated fertilizer management

Different chemical and organic fertilizers and their combinations exerted significant variation on grain yield of maize (Appendix XII). The highest grain yield was observed in T_3 (9.64 t ha^{-1}), which was statistically at par with T_4 (8.76 t ha^{-1}). Again the lowest yield was recorded from T_2 (5.48 t ha^{-1}) (Figure 20). This finding relate to Aspasia *et al.* (2010), Quansah and Gabriel (2010), Shah *et al.* (2009) and Mugwe *et al.* (2009).

Different chemical and organic fertilizers and their combinations exerted notable variation on stover yield of maize (Appendix XIII). The highest stover yield was observed in T_3 (10.54 t ha^{-1}). Again the lowest yield was recorded from T_2 (6.71 t ha^{-1}) (Figure 20). Other treatments were showed intermediate result. This finding related to Wailare and Kesarwani (2011), Yadav *et al.* (2006) and Vadivel *et al.* (2001a).

Significant variation was recorded in biological yield of maize for different chemical and organic fertilizers, and their combinations (Appendix XIV). The highest biological yield was found in T_3 (20.19 t ha^{-1}) and that of the lowest 12.20 t ha^{-1} from T_2 (Figure 20). This finding related to Gama *et al.* (2018) and Ahmad *et al.* (2018).

Application of all chemical fertilizer in recommended doses ensured the essential macro and micro nutrients for the vegetative and reproductive growth of maize and the ultimate results were the highest grain and straw yield as well as maximum biological yield. Combination of cowdung and chemical fertilizers half in recommended doses also created a favorable condition for the growth and yield of maize plant for that combination of cowdung and half chemical fertilizers also gave the similar results. Similar findings also reported by Khan *et al.* (2009), Hassan (2005) , Akbar *et al.* (2002), Vadivel *et al.* (2001b) and Ali *et al.* (1999).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= 0.24, 1.19 and 1.75 for grain yield, stover yield and biological yield)

Figure 20. Effect of integrated fertilizer management on grain yield, stover yield and biological yield of white maize variety

4.2.6.3 Interaction effect of spacing and integrated fertilizer management

Interaction effect of spacing and integrated fertilizer management influenced significantly the grain yield of maize (Appendix XII). Results in Table 10 showed that the highest grain yield (10.02 t ha^{-1}) was recorded from the combined effect of S_2T_3 where the lowest grain yield (5.27 t ha^{-1}) was observed by S_1T_2. These results are in conformity with Amaral Filho (2009).

Interaction effect of spacing and integrated fertilizer management regulated stover yield of maize (Table 10). Results in Table 10 showed that the highest stover yield (12 t ha^{-1}) was recorded from the combined effect of S_2T_3 where the lowest stover yield (5.548 t ha^{-1}) was observed by S_1T_2. The results obtained from all other treatments showed intermediate results compared to the highest and the lowest value of stover yield.

Interaction effect of spacing and integrated fertilizer management had no remarkable effect on biological yield of maize (Appendix XIV). Results in Table 10 showed that the highest biological yield (22.02 t ha^{-1}) was recorded from the combined effect of S_2T_3 where the lowest biological yield (10.82 t ha^{-1}) was observed by S_1T_2. The results obtained from all other treatments showed intermediate results compared to the highest and the lowest value of biological yield. This finding was indirectly related with Kumar *et al.* (2018) and Badr and Othman (2006).

Table 10. Interaction of spacing and fertilizer management on grain yield, stover yield and biological yield of white maize variety

Interaction(spacing x fertilizer management)	**Grain yield (t ha^{-1})**	**Stover yield (t ha^{-1})**	**Biological yield (t ha^{-1})**
S_1T_1	6.81 e	6.93	13.75
S_1T_2	5.27 g	5.55	10.82
S_1T_3	9.27 bc	9.09	18.35
S_1T_4	7.85 d	7.60	15.46
S_2T_1	9.13 c	9.14	18.24
S_2T_2	5.69 f	7.88	13.58
S_2T_3	10.01 a	12.00	22.02
S_2T_4	9.67 b	10.66	20.33
$LSD_{(0.05)}$	**0.34**	**NS**	**NS**
CV(%)	**11.52**	**10.95**	**8.42**

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

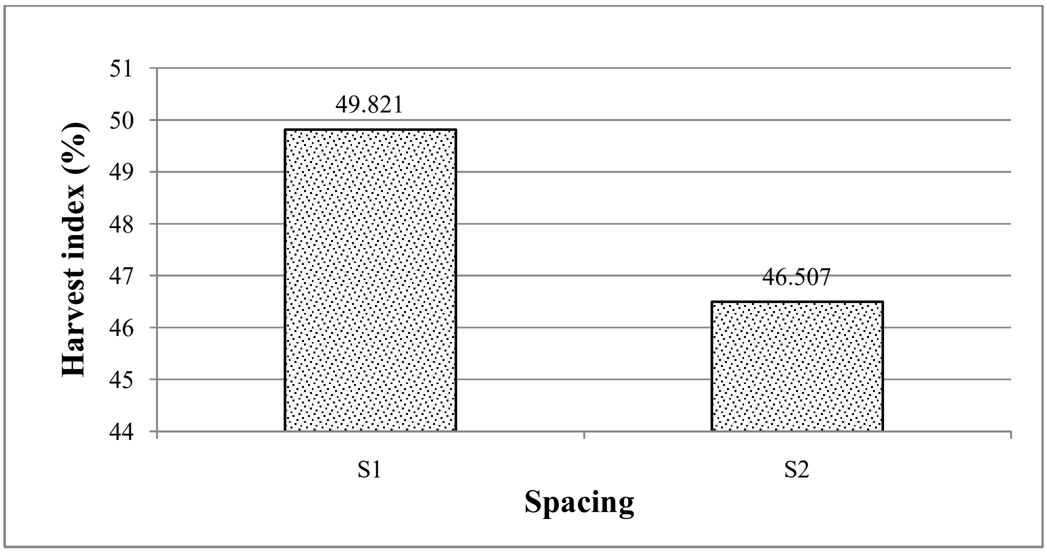
NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

4.2.7 Harvest index

4.2.7.1 Effect of spacing

Different spacing had no significant effect on harvest index (%) of maize (Appendix V). Results represented in Figure 21 indicated that the numerically highest harvest index (49.82 %) was attained with S_1 (60 cm × 20 cm) where the lowest (46.51 %) was with S_2 (40 cm × 20 cm).



S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm

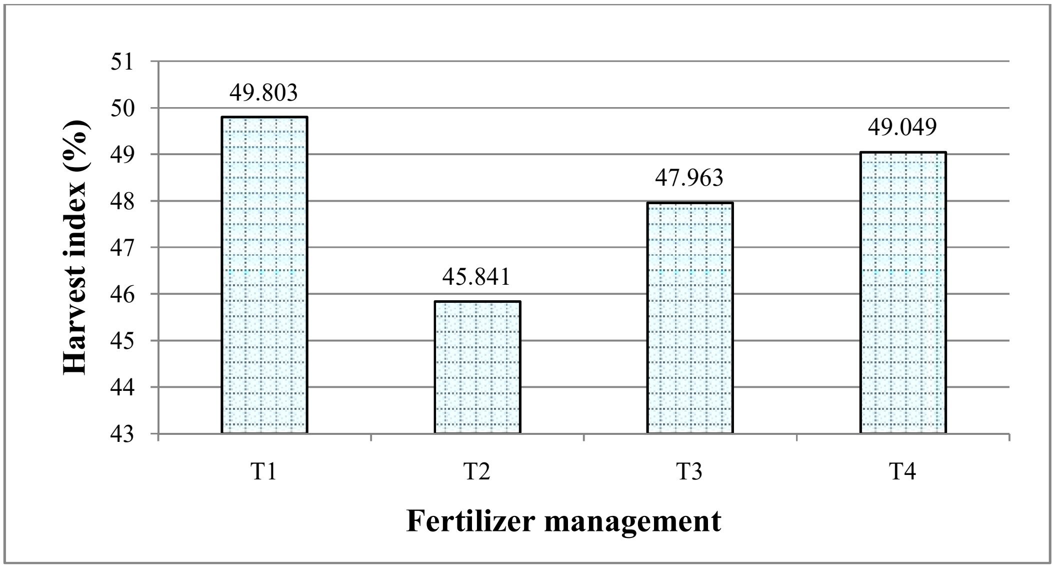
($LSD_{(0.05)}$= NS)

NS= Non Significance

Fig 21. Effect of spacing on harvest index of white maize variety

4.2.7.2 Effect of integrated fertilizer management

Harvest index for different chemical and organic fertilizers, and their combinations treatments showed no significant differences (Appendix V). Numerically, the highest harvest index was recorded from T_1 (49.803 %) and the lowest harvest index was recorded from T_2 (45.84 %) (Figure 22).



T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose

($LSD_{(0.05)}$= NS)

NS= Non Significance

Fig 22. Effect of integrated fertilizer management on harvest index of white maize variety

4.2.7.3 Interaction effect of spacing and integrated fertilizer management

Interaction effect of spacing and integrated fertilizer management on harvest index of maize is presented in Table 11. Results in table 11 showed that the highest harvest index (50.54 %) was recorded from the combined effect of S_1T_4 where the lowest harvest index (42.80%) was observed by S_2T_2.

Table 11. Interaction of spacing and fertilizer management on harvest index of white maize variety

Interaction(spacing x fertilizer management)	Harvest Index (%)
S_1T_1	49.41
S_1T_2	48.89
S_1T_3	50.45
S_1T_4	50.54
S_2T_1	50.19
S_2T_2	42.79
S_2T_3	45.48
S_2T_4	47.56
$LSD_{(0.05)}$	**NS**
CV(%)	**9.63**

NS= Non Significance

S_1= 60 cm X 20 cm and S_2 = 40 cm X 20 cm; T_1: All chemical fertilizer (recommended dose), T_2: maize straw compost +½ of recommended dose, T_3: cowdung+½ of recommended dose, T_4: vermicompost +½ of recommended dose.

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the Agronomy Farm of Sher-e-Bangla Agricultural University, Dhaka to evaluate the performance of white maize variety under different spacings and integrated fertilizer management. The experiment comprised two different factors; (1) two different plant spacings viz. S_1 (60 cm × 20 cm) and S_2 (40 cm × 20 cm) and (2) four levels of integrated fertilizer application viz. T_1: All chemical fertilizer (recommended dose),T_2: maize straw compost +½ of recommended dose,T_3: cowdung+½ of recommended dose,T_4: vermicompost +½ of recommended dose. The experiment was set up in split plot design with three replications. There were 8 treatment combinations. The experimental plot was fertilized as per treatment with chemical and organic fertilizer. Data on different growth and yield parameters were recorded and analyzed statistically.

Data were collected on plant height (cm), number of leaves plant^{-1}, leaf area index, crop growth rate (g m^{-2} d^{-1}), cob length (cm), cob circumference (cm), number of grains cob^{-1}, shelling percentage (%), 100- grains weight (g), grain yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%).

Results under the present study showed that growth, yield and yield contributing characters of maize were influenced by different plant spacings. The higher plant spacing, S_1 (60 cm × 20 cm) showed the highest plant height (37.25, 177.94 and 197.91 cm at 45, 90 DAS and at harvest respectively) where the lower plant spacing S_2 (40 cm × 20 cm) showed the lowest plant height (35.889, 172.81 and 186.70 cm at 45, 90 DAS and at harvest respectively). Like this, the highest number of leaves plant^{-1} at 45, 90 DAS and at harvest were 8.17, 10.26 and 12.31 respectively S_1 (60 cm × 20 cm) where the lowest were 7.8056, 9.194 and 11.567 which was with S_2 (40 cm × 20 cm) at 45, 90 DAS and at harvest, respectively. In terms of other growth parameters; data showed that higher leaf area index and crop growth rate was achieved with lower plant spacing where lower plant spacing showed higher leaf area index and crop growth rate due to higher plant number per area. The highest leaf area index at 90 DAS was 3.14 and highest crop growth rate at 90 DAS and at harvest were 11.94 g m^{-2} d^{-1} and 27.57 g m^{-2} d^{-1} respectively with S_2 (40 cm × 20 cm) where the lowest leaf area index was 2.57 and lowest crop growth rate were 8.62 and 22.64 g m^{-2} d^{-1} (at 90 DAS and at harvest respectively) with S_1 (60 cm × 20 cm).

In case of yield and yield contributing parameters; the highest cob length (15.99cm), cob circumference (16.38 cm), number of grains cob^{-1} (372.19), shelling percentage (76.48%), 100-grains weight (30.75 g) and harvest index (49.82%) were achieved by S_1 (60 cm × 20 cm) where the lowest cob length (14.62 cm), cob circumference (15.57 cm), number of grains cob^{-1} (340.72), shelling percentage (72.89%), 100 grains weight (30.29 g) and harvest index (46.51%) were achieved by S_2 (40cm × 20 cm), but the highest grain yield (8.62 t ha^{-1}), stover yield (9.92 t ha^{-1}) and biological yield (18.54 t ha^{-1}) were obtained from S_2 (40 cm × 20 cm) where the lowest grain yield (7.30 t ha^{-1}), stover yield (7.29 t ha^{-1}) and biological yield (14.59 t ha^{-1}) were from S_1 (60 cm × 20 cm).

Considerable effect was observed on growth, yield and yield contributing characters of maize with different levels of chemical and organic fertilizer application. The growth parameters; plant height (cm), number of leaves $plant^{-1}$, leaf area index and crop growth rate (g m^{-2} d^{-1}) were highest with cowdung and half dose chemical fertilizer as recommended dose, T_3. The highest plant height (40.78 cm, 195.48 cm and 211.52 cm at 45, 90 DAS and harvest respectively), number of leaves $plant^{-1}$ (8.83, 11.01 and 13.75 at 45, 90 DAS and at harvest respectively), leaf area index (3.66 at 90 DAS) and crop growth rate (12.12g m^{-2} d^{-1} and 31.12 g m^{-2} d^{-1} at 90 DAS and at harvest respectively) were with T_3 (cowdung and half dose chemical fertilizer as recommended dose). But the lowest plant height (32.61cm, 164.44cm and 176.57 cm at 45, 60 DAS and at harvest respectively), number of leaves $plant^{-1}$ (7.28, 8.78 and 10.67 at 45, 90 DAS and at harvest respectively), leaf area index (2.16 at 90

DAS) and crop growth rate (8.81g m^{-2} d^{-1} and 17.04 g m^{-2} d^{-1} at 90 DAS and at harvest respectively) were with T_2 (maize straw compost and half dose chemical fertilizer as recommended dose).

Yield and yield contributing parameters were also significantly affected by different levels of integrated fertilizer application. It was evident that the highest cob length (16.75 cm), cob circumference (17.20 cm), number of grains cob^{-1} (413.47), shelling percentage (76.55 %), 100-grains weight (34.17 g), grain yield (9.64 t ha^{-1}), stover yield (10.54 t ha^{-1}) and biological yield (20.19 t ha^{-1}) were achieved by T_3 (cowdung and half dose chemical fertilizer as recommended dose). But the lowest cob length (14.13 cm), cob circumference (14.85 cm), number of grains cob^{-1} (300.57), shelling percentage (70.87 %), 100-grains weight (27.17 g), grain yield (5.48 t ha^{-1}), stover yield (6.71 t ha^{-1}) and biological yield (12.20 t ha^{-1}) were achieved by T_2 (maize straw compost and half dose chemical fertilizer as recommended dose). But in terms of harvest index, the highest result (49.80%) was obtained with T_1 (all chemical fertilizer as recommended dose) where the lowest (45.84 %) was with T_2 (maize straw compost and half dose chemical fertilizer as recommended dose).

The growth, yield and yield contributing parameters of maize were also influenced by different spacing along with integrated fertilizer application. The highest plant height (42.22, 204.19 and 225.03cm at 45, 90 DAS and at harvest respectively) was with S_1T_3 where the lowest (30.44, 161.78 and 174.20 cm at 45, 90 DAS and at harvest respectively) was by S_2T_2. The highest number of leaves $plant^{-1}$ (9.22, 12.02 and 14.89 at 45, 90 DAS and at harvest respectively) but the lowest number of leaves $plant^{-1}$ was 7.22 at 45 days for S_1T_2 and 8.44 and 10.53 at 90 DAS and at harvest respectively were for S_2T_2. The treatment combination S_2T_3 gave the highest leaf area index (4.02) at 90 DAS and lowest (1.92) for S_1T_2. Similarly, S_2T_3 gave the highest crop growth rate;14.28 and 32.75 g m^{-2} d^{-1} at 90 DAS and at harvest respectively where the treatment combination S_1T_2 gave the lowest result at 90 DAS and at harvest (7.46 and 15.55 g m^{-2} d^{-1} respectively).

Yield and yield contributing parameters were regulated by different treatment combinations. It was evident that the highest cob length (17.90 cm), cob circumference (18.03 cm), number of grains cob^{-1} (433.95), shelling percentage (78.76 %) and 100-grains weight (35.33 g) were achieved by S_1T_3. But the lowest cob length (13.60 cm), cob circumference (14.69 cm), number of grains cob^{-1} (282.27) and shelling percentage (67.60 %) were achieved by S_2T_2, however lowest 100-grains weight (26.67 g) was obtained from S_1T_2.

But in terms of grain yield (10.02 t ha^{-1}), stover yield (12 t ha^{-1}) and biological yield (22.02 t ha^{-1}), the highest result was obtained with S_2T_3 where the lowest grain yield (5.27 t ha^{-1}), stover yield (5.55 t ha^{-1}) and biological yield (10.82 t ha^{-1}) were with S_1T_2. In case of harvest index highest result was (50.54%) for S_1T_4 and the lowest result was (42.80%) for S_2T_2.

It may be concluded from the results that plant spacing and integrated fertilizer management is very much promising for higher maize yield. The best plant spacing was 60 cm × 20 cm and cowdung along with half of chemical fertilizer as recommended dose was showed better performance on growth and yield under the present study. Though the combination of S_2T_3 (40cm × 20 cm plant spacing with cowdung + half of recommended dose) performed best in term of producing the highest yield compared to other treatments combination (other plant spacing and different organic fertilizer along with half of recommended dose) under the present study. This is because, lower spacing contained higher number in plant per area. However, interactions of 60 cm × 20 cm plant spacing with cowdung + half of recommended dose showed its superiority in producing the highest grain of maize.

The present research work was carried out at the Sher-e-Bangla Agricultural University and in one season only. Further trial of this work in different locations of the country is needed to justify the present findings and arrive at a definite conclusion.

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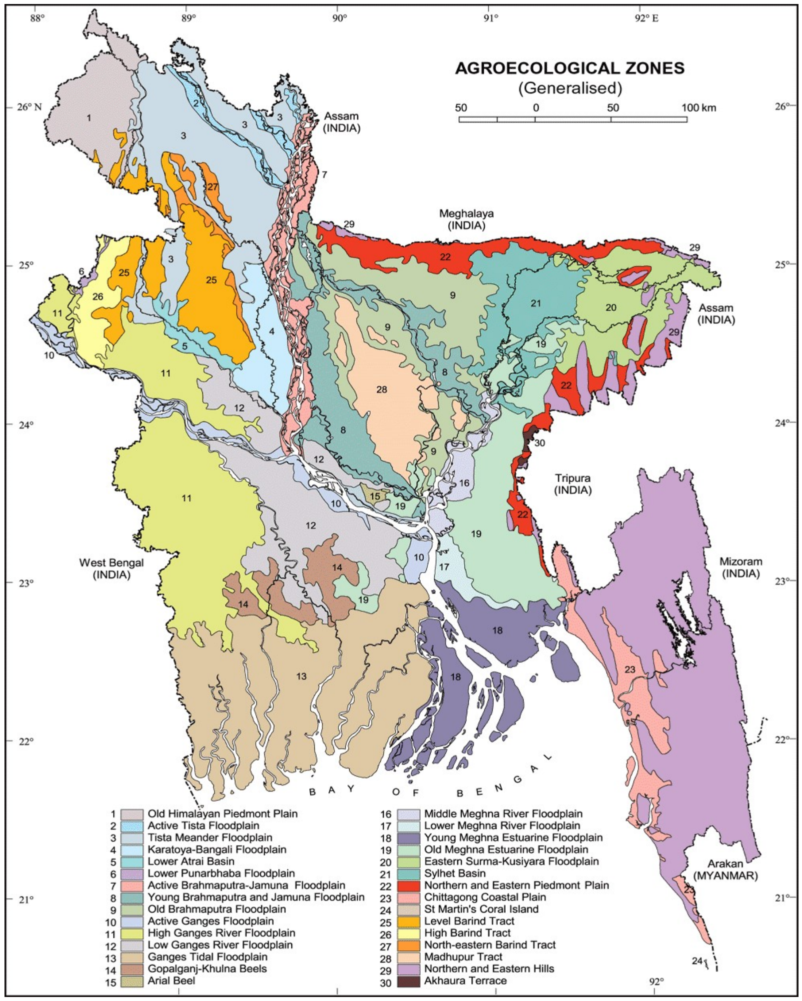
APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II: Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

A. Morphological characteristics of the experimental soil

Morphological features	***Characteristics***
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	***Value***
Partical size analysis	
% Sand	27
%Silt	43
% Clay	30
Textural class	Silty-clay
Ph	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III. Analysis of variance of the data on plant height (cm)

A. Plant height at 45 DAS

Source	DF	SS	MS	F	P
Rep	2	0.954	0.4769		
spacing	1	11.116	11.1157	0.37	0.6050
Error Rep*spacing	2	60.120	30.0602		
treatment	3	205.792	68.5972	6.07	0.0093
spacing*treatment	3	32.088	10.6960	0.95	0.4488
Error Rep*spacing*treatment	12	135.593	11.2994		
Total	23	445.662			
Grand Mean	36.569				
CV(Rep*spacing)	14.99				
CV(Rep*spacing*treatment)	9.1				

B. Plant height at 90 DAS

Source	DF	SS	MS	F	P
Rep	2	1792.22	896.11		
spacing	1	157.88	157.88	1.08	0.4082
Error Rep*spacing	2	292.92	146.46		
treatment	3	3504.14	1168.05	9.67	0.0016
spacing*treatment	3	364.37	121.46	1.01	0.4239
Error Rep*spacing*treatment	12	1449.43	120.79		
Total	23	7560.97			
Grand Mean	175.37				
CV(Rep*spacing)	6.90				
CV(Rep*spacing*treatment)	6.27				

C. Plant height at harvest

Source	DF	SS	MS	F	P
Rep	2	1831.94	915.97		
spacing	1	753.77	753.77	6.08	0.1325
Error Rep*spacing	2	247.77	123.89		
treatment	3	4103.91	1367.97	9.77	0.0015
spacing*treatment	3	518.44	172.81	1.23	0.3400
Error Rep*spacing*treatment	12	1679.60	139.97		
Total	23	9135.42			
Grand Mean	192.30				
CV(Rep*spacing)	5.79				
CV(Rep*spacing*treatment)	6.15				

Appendix IV. Analysis of variance of the data on number of leaves plant $^{-1}$

A. Number of leaves plant^{-1} at 45 DAS

Source	DF	SS	MS	F	P
Rep	2	0.4539	0.22694		
spacing	1	0.7812	0.78120	1.74	0.3177
Error Rep*spacing	2	0.8969	0.44843		
treatment	3	7.6008	2.53361	9.19	0.0020
spacing*treatment	3	0.6051	0.20170	0.73	0.5528
Error Rep*spacing*treatment	12	3.3085	0.27571		
Total	23	13.6464			
Grand Mean	7.9860				
CV(Rep*spacing)	8.39				
CV(Rep*spacing*treatment)	6.58				

B. Number of leaves plant^{-1} at 90 DAS

Source	DF	SS	MS	F	P
Rep	2	4.7744	2.38722		
spacing	1	6.7557	6.75574	18.42	0.0502
Error Rep*spacing	2	0.7337	0.36685		
treatment	3	16.5783	5.52611	9.74	0.0015
spacing*treatment	3	2.0080	0.66932	1.18	0.3583
Error Rep*spacing*treatment	12	6.8059	0.56716		
Total	23	37.6561			
Grand Mean	9.7250				
CV(Rep*spacing)	6.23				
CV(Rep*spacing*treatment)	7.74				

C. Number of leaves plant^{-1} at harvest

Source	DF	SS	MS	F	P
Rep	2	19.7785	9.8893		
spacing	1	3.2856	3.2856	0.68	0.4965
Error Rep*spacing	2	9.6772	4.8386		
treatment	3	32.1288	10.7096	11.23	0.0008
spacing*treatment	3	4.8435	1.6145	1.69	0.2213
Error Rep*spacing*treatment	12	11.4445	0.9537		
Total	23	81.1581			
Grand Mean	11.937				
CV(Rep*spacing)	10.43				
CV(Rep*spacing*treatment)	8.18				

Appendix V. Analysis of variance of the data on leaf area index

Source	DF	SS	MS	F	P
Rep	2	1.7679	0.88393		
spacing	1	1.9592	1.95918	40.41	0.0239
Error Rep*spacing	2	0.0970	0.04849		
treatment	3	7.3163	2.43876	71.69	0.0000
spacing*treatment	3	0.0558	0.01860	0.55	0.6597
Error Rep*spacing*treatment	12	0.4082	0.03402		
Total	23	11.6043			
Grand Mean	2.8535				
CV(Rep*spacing)	7.72				
CV(Rep*spacing*treatment)	6.46				

Appendix VI. Analysis of variance of the data on crop growth rate

A. Crop growth rate at 90 DAS

Source	DF	SS	MS	F	P
Rep	2	0.767	0.3835		
spacing	1	66.019	66.0191	14.21	0.0637
Error Rep*spacing	2	9.293	4.6465		
treatment	3	37.377	12.4591	18.67	0.0001
spacing*treatment	3	2.819	0.9396	1.41	0.2885
Error Rep*spacing*treatment	12	8.008	0.6673		
Total	23	124.283			
Grand Mean	10.276				
CV(Rep*spacing)	8.98				
CV(Rep*spacing*treatment)	7.95				

B. Crop growth rate at harvest

Source	DF	SS	MS	F	P
Rep	2	92.43	46.217		
spacing	1	146.29	146.289	15.09	0.0603
Error Rep*spacing	2	19.39	9.694		
treatment	3	647.86	215.955	19.17	0.0001
spacing*treatment	3	19.83	6.609	0.59	0.6352
Error Rep*spacing*treatment	12	135.16	11.263		
Total	23	1060.96			
Grand Mean	25.104				
CV(Rep*spacing)	12.40				
CV(Rep*spacing*treatment)	13.37				

Appendix VII. Analysis of variance of the data on cob length

Source	DF	SS	MS	F	P
Rep	2	3.5052	1.7526		
spacing	1	11.5509	11.5509	3.94	0.1857
Error Rep*spacing	2	5.8694	2.9347		
treatment	3	21.7670	7.2557	8.20	0.0031
spacing*treatment	3	2.2561	0.7520	0.85	0.4932
Error Rep*spacing*treatment	12	10.6238	0.8853		
Total	23	55.5724			
Grand Mean	15.298				
CV(Rep*spacing)	11.20				
CV(Rep*spacing*treatment)	6.15				

Appendix VIII. Analysis of variance of the data on cob circumference

Source	DF	SS	MS	F	P
Rep	2	3.2957	1.64784		
spacing	1	3.9407	3.94065	47.57	0.0204
Error Rep*spacing	2	0.1657	0.08284		
treatment	3	17.2574	5.75246	8.04	0.0033
spacing*treatment	3	1.6553	0.55176	0.77	0.5320
Error Rep*spacing*treatment	12	8.5841	0.71534		
Total	23	34.8987			
Grand Mean	15.970				
CV(Rep*spacing)	4.80				
CV(Rep*spacing*treatment)	5.30				

Appendix IX. Analysis of variance of the data on number of grains cob^{-1}

Source	DF	SS	MS	F	P
Rep	2	3058.0	1529.0		
spacing	1	5939.0	5939.0	14.04	0.0644
Error Rep*spacing	2	845.9	423.0		
treatment	3	41373.1	13791.0	37.78	0.0000
spacing*treatment	3	338.2	112.7	0.31	0.8186
Error Rep*spacing*treatment	12	4380.6	365.0		
Total	23	55934.8			
Grand Mean	356.46				
CV(Rep*spacing)	5.77				
CV(Rep*spacing*treatment)	5.36				

Appendix X. Analysis of variance of the data on shelling percentage

Source	DF	SS	MS	F	P
Rep	2	25.122	12.5608		
spacing	1	77.366	77.3664	4.18	0.1776
Error Rep*spacing	2	37.010	18.5051		
treatment	3	119.487	39.8289	3.23	0.0608
spacing*treatment	3	28.511	9.5036	0.77	0.5320
Error Rep*spacing*treatment	12	147.867	12.3222		
Total	23	435.362			
Grand Mean	74.687				
CV(Rep*spacing)	5.76				
CV(Rep*spacing*treatment)	4.70				

Appendix XI. Analysis of variance of the data on 100 grains weight

Source	DF	SS	MS	F	P
Rep	2	6.396	3.1979		
spacing	1	1.260	1.2604	0.11	0.7716
Error Rep*spacing	2	22.896	11.4479		
treatment	3	156.698	52.2326	17.97	0.0001
spacing*treatment	3	9.615	3.2049	1.10	0.3859
Error Rep*spacing*treatment	12	34.875	2.9062		
Total	23	231.740			
Grand Mean	30.521				
CV(Rep*spacing)	11.09				
CV(Rep*spacing*treatment)	5.59				

Appendix XII. Analysis of variance of the data on grain yield

Source	DF	SS	MS	F	P
Rep	2	0.1202	0.0601		
spacing	1	10.5303	10.5303	297.33	0.0033
Error Rep*spacing	2	0.0708	0.0354		
traetment	3	57.6844	19.2281	530.01	0.0000
spacing*traetment	3	3.5752	1.1917	32.85	0.0000
Error Rep*spacing*traetment	12	0.4353	0.0363		
Total	23	72.4163			
Grand Mean	7.9605				
CV(Rep*spacing)	2.36				
CV(Rep*spacing*traetment)	2.39				

Appendix XIII. Analysis of variance of the data on stover yield

Source	DF	SS	MS	F	P
Rep	2	16.180	8.0900		
spacing	1	41.480	41.4795	35.56	0.0270
Error Rep*spacing	2	2.333	1.1665		
treatment	3	47.545	15.8482	17.83	0.0001
spacing*treatment	3	0.787	0.2623	0.30	0.8282
Error Rep*spacing*treatment	12	10.666	0.8889		
Total	23	118.990			
Grand Mean	8.6062				
CV(Rep*spacing)	12.55				
CV(Rep*spacing*treatment)	10.95				

Appendix XIV. Analysis of variance of the data on biological yield

Source	DF	SS	MS	F	P
Rep	2	22.054	11.0270		
spacing	1	93.398	93.3982	142.15	0.0070
Error Rep*spacing	2	1.314	0.6570		
treatment	3	205.618	68.5393	35.23	0.0000
spacing*treatment	3	3.968	1.3226	0.68	0.5811
Error Rep*spacing*treatment	12	23.348	1.9457		
Total	23	349.701			
Grand Mean	16.567				
CV(Rep*spacing)	4.89				
CV(Rep*spacing*treatment)	8.42				

Appendix XV. Analysis of variance of the data on harvest index

Source	DF	SS	MS	F	P
Rep	2	102.460	51.2301		
spacing	1	65.904	65.9040	1.02	0.4191
Error Rep*spacing	2	129.369	64.6844		
treatment	3	53.425	17.8082	0.83	0.5033
spacing*treatment	3	40.986	13.6619	0.64	0.6063
Error Rep*spacing*treatment	12	257.946	21.4955		
Total	23	650.089			
Grand Mean	48.164				
CV(Rep*spacing)	16.70				
CV(Rep*spacing*treatment)	9.63				

Plate 1. Photograph showing general view of experimental plot with sign board

Plate 2. Photograph showing general view of experimental plot at vegetative stage

Plate 3. Photograph showing general view of experimental plot at reproductive stage