ALLOMETRY AND YIELD COMPONENTS OF WHITE MAIZE TO VARYING LEVELS OF SPACING AND FERTILIZER APPLICATION

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CERTIFICATE

*This is to certify that the thesis entitled, "**ALLOMETRY AND YIELD COMPONENTS OF WHITE MAIZE TO VARYING LEVELS OF SPACING AND FERTILIZER APPLICATION**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. RAKIBUL HASAN RAKIB**, Registration no. **19-10181** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:

Place: Dhaka, Bangladesh

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Dedicated to

My

Beloved Parents

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ALLOMETRY AND YIELD COMPONENTS OF WHITE MAIZE TO VARYING LEVELS OF SPACING AND FERTILIZER APPLICATION

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm SAU, Dhaka during the period from October- 2020 to February-2021 in *Rabi* season to studying allometry and yield components of white maize to varying levels of spacing and fertilizer application. The experiment was consisted of two factors and followed split plot design with three replications. Factor A: Fertilizer application rate (4) *viz*, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, Factor B: Different spacings (3) *viz*, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm and S_3 = 30 cm × 20 cm. The experimental results revealed that different fertilizer dose, spacings and their combination significantly influenced the growth, yield contributing characteristics and yield of white maize. In case of different dose of fertilizer application, the F_4 treatment recorded the highest grain yield (11.96 t ha^{-1}), stover yield (15.40 t ha^{-1}), biological yield (27.36 t ha^{-1}) and harvest (43.67 %) comparable to other treatments. In case of different spacing the highest grain yield (12.05 t ha^{-1}), stover yield (14.77 t ha^{-1}), biological yield (26.82 t ha^{-1}) and harvest (44.99 %) were observed in S_3 treatment. In case of combined effect, the F_4S_2 treatment combination had the highest grain yield (12.90 t ha^{-1}) followed by F_4S_3 (12.65 t ha^{-1}) treatment combination. Components dry matter (root, stem and leaf) had positive correlations with the total dry matter accumulations. The total dry matter accumulation had strongest correlation with leaf area at 40 DAS. The exponential trend of dry matter accumulation of the treatment combinations with time largely followed that of the spacing treatments.

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ABBREVIATIONS

Full word	**Abbreviations**
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Science	Sci.
Serial	Sl.
Soil Resource Development Institute	SRDI
Technology	Technol.
Triple super phosphate	TSP

CHAPTER I

INTRODUCTION

Maize is the most important cereal crop in Bangladesh after rice and wheat. It has potential nutritional values i.e., 100 grams of mature maize seeds contain 9.42 g of protein, 74.26 g carbohydrates, 0.64 g sugar, 7.3 g dietary fiber, 365 kcal energy (Wikifarmer, 2022). Maize helps to boost kidney function and bone health, regulates the heart rate, prevents constipation and reduces stomach acidity. Besides, maize reduces LDL cholesterol and guards against cardiac diseases, diabetes and hypertension. Thus, maize has numerous health benefits, which help to overcome malnutrition in the country's population.

At present, the annual demand for maize in Bangladesh is around two million tons, but production is 4,700 thousand tonnes (BBS, 2021) which is a big gap between demand and production. To fulfill the demand, huge amount of money drains to import maize seeds and products. The consumption of maize in Bangladesh both as human food, livestock and poultry feed overall in all the segments will be increased in the future. In addition, Maize has a potential prospect in Bangladesh and annual average weather had a positive effect on maize production in Bangladesh. Maize has a wide genetic variability and able to grow successfully in any environment in Bangladesh. It generally grows both in winter and summer time in Bangladesh and shows potential yield.

Recently, the yield of maize has experienced explosive growth in Bangladesh. Maize has now positioned itself as the first among the cereals in terms of yield (6.15 t/ha) as compared to boro rice (3.90 t ha^{-1}) and wheat (2.60 t/ha) (BBS, 2020).

There are two kinds of maize in respect of grain colour; yellow and white. Worldwide, the yellow maize is mainly used as fodder while the white ones are consumed as human food (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). Maize currently grown in Bangladesh is of yellow type and is used in the feed industry. Hybrid maize cultivation area has increased at the rate of about 20-25% per year since nineties as the yield potential of hybrid maize is greater than those of local races (Ullah *et al*., 2017a; Ullah *et al.* 2017b; Fatima *et al.*, 2019; Shompa *et al*., 2020). Now-a-days, there are many government and non government organizations are working for increasing maize production in Bangladesh. Bangladesh Agricultural Research Institute (BARI) has developed seven open pollinated and 11 hybrid varieties whose yield potentials are 5.50–7.00 t ha^{-1} and 7.40–12.00 t ha^{-1}, respectively, which are well above the world average of 3.19 t ha^{-1} (Nasim *et al*., 2012). Different varieties respond differently to input supply, cultivation practices and prevailing environment etc during the growing season (Ullah *et el.,* 2018a; Ullah *et el.*, 2018b; Ullah *et el.,* 2018c; Bithy and Ahamed, 2018). The low productivity of maize is attributed to many factors like decline of soil fertility, poor agronomic practices (such as proper management of planting configuration, irrigation interval, fertilizer managements, weeding, thinning, earthing up etc), and limited use of input, insufficient technology generation, poor seed quality, disease, insect, pest and weeds (Ullah *et al.*, 2017a).

Allometry, in its broadest sense, describes how the characteristics of living creatures change with size. The term originally referred to the scaling relationship between the size of a body part and the size of the body as a whole, as both grow during development. However, more recently the meaning of the term allometry has been modified and expanded to refer to biological scaling relationships in general, be it for morphological traits (e.g., the relationship between brain size and body size among adult humans), physiological traits (e.g., the relationship between metabolic rate and body size among mammal species) or ecological traits (e.g., the relationship between wing size and flight performance in birds) (Shingleton, 2010).

Allometry is a well-known study, particularly in statistical shape analysis for its theoretical developments, as well as in biology for practical applications to the differential growth rates of the parts of a living organism's body. Allometry often studies shape differences in terms of ratios of the objects' dimensions. Two objects of different size, but common shape, will have their dimensions in the same ratio (https://en.wikipedia.org/wiki/Allometry). Allometry is a salient feature of the covariance structures of most complex morphologies. Traits are said to exhibit allometric variation when they do not scale isometrically to some measure of size (Gould, 1966). In plants, Allometry is an empirical expression of the distribution of biomass between aboveground and belowground tissues (https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/allometry). Allometry has been studied in many crops along with that of maize (Akram *et al*. 2010; Vega *et al*., 2000). However, those were made using varieties of maize which may not represent those being cultivated in Bangladesh.

Inadequate and imbalanced use of major nutrients is one of the major bottlenecks in low productivity of maize. It is well known that maize is a heavy feeder for both nutrients and soil moisture due to its high productivity.

Fertilizer recommendations not only contain the recommended rates of fertilizer but also management strategies for getting the most, out of the fertilizer investment while protecting the environment. The fertilizer recommendation addresses commercial yield and quality, the economics of crop production and protection of the environment.

Maize being an exhaustive crop, its requirement for fertilizers especially for nitrogen is very high. Nitrogen is the essential constituent of chlorophyll, protoplasm and enzymes (Kaur *et al*., 2020). Further, it governs utilization of phosphorus and potassium. It is an important factor for better vegetative growth and boosting up the yield of cereals. It is essential to know the optimum level of nitrogen application forgetting a higher crop yield so that maximum benefits could be realized. Inadequate N availability during the first to six weeks after planting can result in reduced yield potentials. Its use and demand is continuously increasing day by day (Kaur *et al*., 2020). Since it is highly mobile, it is subjected to greater loss from the soil plant system. Phosphorus (P) is an essential element in plants which is required for vital structural and metabolic functions. Crop fertilization programmes must ensure adequate P to support critical role of this element in plant metabolism and growth (Li *et al*., 2020). Application of phosphorus fertilizer in balanced proportion with other essential nutrients like nitrogen and potassium produces high crop yield and ensure more profit to farmers. Potassium (K) is an essential element for plant growth and development and is the most abundant cation in plants, making upto 3-5% of a plant's total dry weight.

Along with macronutrients micronutrients are essential elements required for plant growth and development at smaller amounts compared to macronutrients (Hu *et al*., 2017). Iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), molybdenum (Mo), and nickel (Ni) are metal micronutrients that participate in various reactions in plant cells or contribute to protein structure (Moinudden *et al*., 2017). This macro and micro nutrient are essential for many plant processes such as enzyme activation, protein synthesis, photosynthesis, osmo regulation during cell expansion, stomatal movements, solute phloem transport, electrical neutralization, regulation of membrane potential, co-transport of sugars and the maintenance of cation-anion balance in the cytosol as well as in the vacuole thus influences growth, development and yield of the plant (Mohammad and Mahmood, 2011).

Agronomic management, especially spacing which significantly influence on yield, since it is ultimately correlated with plant population, root development, plant growth and fruiting (Davi *et al.,* 1995; Ahmmed *et al.,* 2020; Akbar *et al*. 2016). The relationship between yield and spacing is intricate. Salam *et al.* (2010) reported the highest grain yield of BARI hybrid maize 3 when sown at 75 × 25 cm spacing.

Biswas (2019) tested two hybrid white maize at three different spacings (50 × 25 cm, 60 × 25 cm and 70 × 25 cm) at Dhamrai during rabi 2015-16 and reported the highest grain yields at the closer spacings. Ullah *et al.* (2018c) tested eight different hybrid white maize varieties at two different spacings (60 × 25cm and 75 × 25 cm) at the Sher-e-Bangla Agricultural University Farm during rabi season of 2015-16 and reported the highest grain yield (7.551 t ha^{-1}) at 60 × 25 cm spacing which was significantly higher than that (5.832 t ha^{-1}) of the 75 × 25 cm treatment. In another trial at Dhamrai of Dhaka in the same season, they tested two different hybrid white maize varieties and observed that the comparable grain yield (8.740 t ha^{-1}) was from the closest spacing (50 × 20 cm) as was from the paired rows with 70 cm spacing (8.773 t ha^{-1}) which were significantly higher than that (7.920 t ha^{-1}) from the spacing (60 × 20) cm.

In the same season, they also carried out another separate experiment at Rangpur Sadar with two hybrid white maize varieties planted at three different planting configuration. Results showed that the closer spacing of 50x20 cm produced greatest grain yield (6.670 t ha^{-1}) and compared to the yields of 5.198 and 6.626 t/ha obtained, respectively from the wider spacings of 60 × 20 cm and inter paired rows spacing of 70 cm spacing. They also set another experiment at Rangpur with a hybrid white maize variety PSC-121 at different planting configurations (row to row 50 to 80 cm and plant to plant 20-40 cm) and reported the highest grain yields from the 80 × 20 cm spacing. In another separate trial set at Bandarban with two different hybrid white maize varieties plant at different planting configurations (row to row spacing 50-70 cm and paired rows.

Plant to plant distance within the row 25 cm), it was observed that the planting configuration with the highest population density (80,000/ ha) showed the highest grain yield (10.396 t ha^{-1}) which was comparable to that (10.612 t ha^{-1}) obtained from paired row but significantly higher than those (8.733-9.610 t ha^{-1}) obtained from other planting configurations. From the review of the results from the above trials, it may be concluded that the higher grain yields were mostly obtained from row to row spacing either of 60 cm or below this. The researchers (Biswas *et al*., 2019; Ullah *et al*. 2018c; Ullah *et al*. 2018d) opined that the grain yield of an individual maize plant increases with gradual increase in row spacing and plant to plant spacing within a row. But the grain yield in a community level (per hectare) depends on the plant population density and the plant characters such as plant height, leaf area, leaf orientation and leaf erectness.

Optimum plant population is vital for maintaining to exploit maximum natural resources such as nutrient, sunlight, soil moisture and to ensure maximum economic grain yield per production area. It exerts decisive influence on maize growth and yield, which outcome timely inception of vegetative and reproductive development. Maize differs in its responses to plant density (Luque *et al.,* 2006). Closer spacing leading to overcrowding, enhanced interplant competition for incident photosynthetic photon flux density and soil rhizosphere resource, resulting reduction yield per plant because it's influence hormonally mediated apical dominance, exaggerated barrenness, and finally decreases the number of ears produced per plant and kernels set per ear (Sangoi, 2001).

Wider spacing causes low density of population promotes dense vegetative growth, increased weed density due to more feeding area available and remain nutrient and moisture unutilized thereby decrease in total yield. However, under high population density, cumulative yield is higher per production area, but drops yield per plant. The appropriate spacing outcome optimum plant population per area for optimum yield. The best optimum spacing is one, which enables the plants to make the better use of the conditions at their disposal (Lawson and Topham, 1985).

Keeping all points in minds mentioned above, the proposed research work was undertaken to achieve the following objectives:

Objectives:

i. To find out the suitable fertilizer doses for the production of white maize
ii. To find out suitable spacing for maize crop and
iii. To study the response of maize to different fertilizer levels under different spacing's.

CHAPTER II

REVIEW OF LITERATURE

In this section, an attempt was made to collect and study relevant information available about studying allometry and yield components of white maize to varying levels of spacing and fertilizer application in order to gather knowledge useful in carrying out the current piece of work.

2.1 Effect of different fertilizer dose

Jadhav (2018) reported that higher grain yield (7769 kg ha^{-1}) of maize sown during summer was recorded for 120% RDF (180:90:90 kg NPK ha^{-1}) followed by 100% RDF (150:75:75 kg NPK ha^{-1}) and significantly superior over 80% RDF (120:60:60 kg $NPKha^{-1}$).

Patil *et al.* (2018) revealed that, the growth characters, yield attributes and yield of baby corn during summer season were significantly increased up to 100 kg N, 50 kg P_2O_5 and 50 kg K_2O ha^{-1}. Application of 100 kg N with 50 kg P_2O_5 ha^{-1} recorded significantly higher yield attributes, baby corn yield and green fodder yield over rest of N and P_2O_5 levels.

Raman and Suganya (2018) conducted an experiment at Annamalai University, Tamil Nadu during summer. He concluded that yield components of hybrid maize *viz.,* cob length, cob diameter and number of grains cob^{-1}, 100 grain weight, grain yield, stover yield and harvest index were favorably influenced with 100% RDF + Pressmud compost @ 5 t ha^{-1}. It was followed by 100% RDF + Enriched Farmyard manure @ 750 kg ha^{-1}.

Satyabhan *et al.* (2018) showed that the combined application of 100% RDF + PSB produced significantly more cob and green fodder yields than other treatments. Higher plant growth (plant height and stem girth) and green fodder yield was recorded with the application of 150% RDF + PSB (Phosphate Solubilizing Bacteria) while, yield attributes, green cob yield was maximum with the application of treatment 100% RDF + PSB. Treatment 100% RDF + PSB was recorded higher net returns over rest of the treatments (97466.66 ha^{-1}) and B:C (2.77).

Majid *et al.* (2017) opined that BARI hybrid maize-9 achieved maximum yield (10.99 t ha^{-1}) and it was followed by the BARI hybrid maize-7 (10.37 t ha^{-1}). Results of study revealed that yield traits and final yield significantly increased with increasing nitrogen fertilizer from 0 to 345 kg ha^{-1}. Among various tested N-fertilizer doses, higher grain yield was obtained from the plot treated with N_3 treatment (345 kg ha^{-1}) but it was not statistically differing from the N_2 treatment (230 kg ha^{-1}).

Pal *et al*. (2017) indicated that application of 120 kg N recorded the maximum number of cobs $plant^{-1}$ (1.49), cob length (17.87 cm), cob girth (15.05 cm), dry matter accumulation (153.09 g $plant^{-1}$), number of grains cob^{-1} (283.19), 100 grain weight (26.70 g), grain yield (4905 kg ha^{-1}), stover yield (8478 kg ha^{-1}), biological yield (13382 kg ha^{-1}), net returns (39228 ha^{-1}) and BC ratio(3.14).

Tomar *et al.* (2017) revealed that combination of 100% NPK + 5 t FYM+ *Azotobacter* + PSB recorded higher yield and yield attributing components *viz*., no. of cobs $plants^{-1}$ (1.1), number of grains cob^{-1} (541.2), test weight (245.05 g) and grain yield (53.15 q ha^{-1}), quality parameters *viz*., protein content (8.38%) and protein yield (445.4 kg ha^{-1}), total nutrients uptake in a study conducted in summer 2010 and 2011.

Kaur *et al.* (2017) revealed that application of 150 kg N ha^{-1}produced significantly higher seed yield over higher number of cobs (1.2), cob girth (3.6 cm), number of grains cob^{-1} (274.8) which were comparably higher as compared to other treatments.

Kurne *et al.* (2017) revealed that, an application of 125% RDF (150:75:50 kg NPK ha^{-1}) in summer sweetcorn recorded significantly higher growth and yield attributes, which resulted into higher green cob and fodder yields of sweet corn (10.07 and 26.93 t ha^{-1}, respectively) over rest of fertilizer levels of 75 and 100% RDF.

Jinjala *et al.* (2016) reported that significantly highest grain weight cob^{-1} was observed with application of 125% RDN from chemical fertilizer with bio-fertilizer.

Thakur *et al*. (2015) conducted a field experiment at the S G College of Agriculture and Research Station, Jagdalpur (Chhattisgarh) during Rabi season of 2014 to study the effect of different plant geometry and nitrogen levels, in relation to growth characters, yield and economics of maize. They reported that 125 kg N ha^{-1} was recorded significantly tallest plant height (178cm), days to 50 % flowering (51 DAS), No. of cobs ha^{-1} (84860) and LAI (5.35).

Rana *et al*. (2014) conducted field trail at Ludhiana. Nitrogen levels tried were 75, 100,125 and 150 % of recommended N and the RDF was 120:60:30 kg NPK ha^{-1}. Maximum grain yield was observed with 150 % RDF, which was significantly more than the lower levels of fertilizers inmaize.

An experiment was conducted at Maharana Pratap University of Agriculture and Technology, Udaipur in clay loam soil by Chaudhary *et al*. (2013) on maize. They reported that the application of 175 kg Nha^{-1} recorded significantly higher grains per cob (339), grains weight per plant (73.6 g), test weight (196.9 g), shelling percentage (80.2 %), grain yield (4.85 tha^{-1}) and stover yield (7.53 tha^{-1}) over 150 kg N ha^{-1} and 125 kg Nha^{-1}.

Ravi *et al.* (2012) opined that application of 10 t FYM + 100 % RDF ha^{-1} (T_1) recorded significantly higher grain yield (71.79 q ha^{-1}) over rest of the treatments but it was on par with T_{10}, T_8, T_6 and T_4 (70.75, 68.84, 68.00 and 67.25 q ha^{-1}, respectively).

Spandana (2012) conducted a field experiment at Agricultural Research Institute, Hyderabad during kharif season, 2009 to study the response of maize hybrid to varying plant densities and nitrogen levels. The data revealed that the growth characters like plant height, leaf area index (LAI) and dry matter accumulation increased due to increased level of nitrogen application from 120 to 240 kg ha^{-1}.

Singh *et al*. (2012) conducted a field experiment during rainy seasons of 2007 and 2008 at Wadura, Jammu and Kashmir to study the effect of crop geometry and nitrogen levels (0, 30, 60, 90, 120 and 150 Kg N ha^{-1}) on growth of maize. They observed that an application of 120 kg N ha^{-1} recorded significantly the highest plant height, leaf area and number of leaves plant^{-1} as compared to 0, 30, 60, 90 and 150 kg N ha^{-1}.

Verma (2011) carried out a field trial during two rabi seasons at Hamirpur, Uttar Pradesh to study the effects of integrated nutrient management on the growth, yield and quality of maize. The results revealed that the leaf area, dry weight plant^{-1} and grain yield were significantly higher under 150 kg N ha^{-1} as compared to 50 and 100 kg N ha^{-1}.

Gozubenli and Kinuskan (2010) carried out a field experiment during kharif seasons of 2002 and 2003 at Hatay in Turkey to study the nitrogen and spacing requirement of maize. The results revealed that increased nitrogen doses recorded significantly taller plants and maximum plant height was obtained under 240 kg N ha^{-1}, while shortest tasseling period was observed at the highest N dose of 240 kg ha^{-1}. They also found that the nitrogen levels of 180 and 240 kg N ha^{-1} were at par and recorded significantly higher grain yield of maize over control and 120 kg N ha^{-1}.

Lingaraju *et al*. (2010) conducted field experiment to study the effects of organics on the productivity in maize-Bengal gram cropping system at Dharwad on medium black soil. The results revealed that an application of 100% RDF (100:50:25 kg NPK ha^{-1}) produced significantly higher maize grain yield of 5578 kg ha^{-1} as compared to 75 % RDF (75 :37.5:18.7 kg NPK ha^{-1}) and 50 % RDF (50:25:12.5 kg NPK ha^{-1}), which gave 5281 and 4917 kg ha^{-1} grain yields, respectively.

Thakur *et al.* (2010) conducted a field experiment on fertilizer requirement of maize during kharif season of 2008-09 at Latur. The results indicated that an application of 100:50: 50 kg NPK ha^{-1} recorded significantly more cob length, cob diameter, number of grains cob^{-1}, grain and straw yields of maize over FYM alone and FYM + Azospirillum application. Application of 120:60:60 kg NPK ha^{-1} (100 % RDF) was on par with 100:50:50 kg NPK ha^{-1}.

Ashok (2009) conducted a field experiment during two kharif seasons on nitrogen and spacing requirement of maize at New Delhi and observed significantly taller plants with more dry weight $plant^{-1}$ with 120 kg N ha^{-1} over 40 and 80 kg N ha^{-1}.

Kunjir *et al*. (2009) carried out a field experiment during rabi season of 2003-04 at Dapoli on maize. They found that application of 150 and 225 kg N ha^{-1} recorded significantly higher values for all growth parameters viz., plant height, leaf area and number of leaves over 75 kg N ha^{-1} and control.

Singh and Choudhary (2008) carried out a field experiment during rainy (kharif) seasons of 2005 and 2006 at Udaipur (Rajasthan) to study effect of plant population and fertilizer levels (90+45, 60+30 kg N and P_2O_5 ha^{-1}) on the yield and economics of maize. The results revealed that amongst fertilizer levels, application of 90+45 kg N and P_2O_5 ha^{-1} significantly improved yield attributes, grain and stover yield over 60+30 kg N and P_2O_5 ha^{-1}.

Thakur and Sharma (2009) found that the length of the cob increased progressively with the successive increase in N application upto 200 kg ha^{-1}.

Nimje and Seth (2008) conducted a field experiment at IARI, New Delhi during *rabi* on clay loam soil with maize variety Ganga 5 and reported that number of cobs $plant^{-1}$, number of grains cob^{-1}, grain yield cob^{-1}, 1000 grain weight and maize yield responded to N application significantly from 0 to 120 kg N ha^{-1}. Stover yield, harvest index and shelling percentage were also increased.

Rafiq *et al*. (2008) at Faisalabad (Pakistan) conducted a field experiment during summer 2006 and 2007 and observed that the higher grain yield was recorded from those maize plots which were fertilized with 250 kg N ha^{-1}. Increasing fertilizer levels linearly increased plant height and grain yield. However, the application of nitrogen had no significant effect on tasseling and silking.

Sidhu and Thind (2008), while assessing the nitrogen, phosphorus and potassium requirement of winter maize at Ludhiana, on sandy loam soil during 2002-03 observed that an application of 175:60:30 kg NPK ha^{-1} recorded significantly the highest grain yield of maize over 150:60:30 and 200:60:30 kg NPK ha^{-1}.

Suryavanshi *et al*. (2008) reported an increase in cob length, total grains cob^{-1}, 100 grain weight, grain yield and stover yield of maize with 150 kg N ha^{-1} over 100 and 50 kg N ha^{-1} on Vertisols of MAU, Parbhani.

Channabasavanna *et al*. (2007) carried out a field experiment to study the effects of integrated nutrient management on maize at Siruguppa, Karnataka during four kharif seasons on deep black clay loam soil. They obtained significantly the highest grain yield under 100% RDF (150:75:37.5 kg NPK ha^{-1}) over 75% RDF (112.5:56.25:28.12 kg NPK ha^{-1}) and 50% RDF (75:37.5:18.75 kg NPK ha^{-1}).

Kumar *et al*. (2007) carried out a field experiment during kharif season of 2005 on medium black clay loam soil at Raichur, Karnataka to study the integrated nutrient management in maize. They reported that an application of 100 % RDF (150:75:37.5 kg NPK ha^{-1}) recorded significantly higher dry matter accumulation in plant parts of maize as compared to 50 % RDF (75:37.5:18.75 kg NPK ha^{-1}).

Mushtaq *et al.* (2007) carried out a field experiment at NWFP Agricultural University Peshawar in 2002 to study response of maize to phosphorous levels and plant density. The results showed that the maximum cobs $plant^{-1}$ (1.41), 1000 grains weight (276 g) and grain yield (6515 kg ha^{-1}) were observed at the highest phosphorus level of 120 kg ha^{-1}. They concluded that the phosphorus at the rate of 120 kg ha^{-1} in monsanto-707 showed the best performance.

Sahoo and Mahapatra (2007) conducted a field experiment on plant population and fertilizer requirement of maize during two rabi seasons at Jashipur, Orissa. They observed that significantly maximum number of cobs ha^{-1} was recorded under the fertilizer level of 120:26.2:50 kg NPK ha^{-1} over 80:17.5:33.3, 40:8.7:16.7 kg NPK ha^{-1} and control.

Bhagat *et al.* (2006) conducted a field experiment during rabi season of 2004-05 at Dapoli on clay loam soil to find out the productivity of groundnut + maize intercropping at different fertility levels and row proportions. It was found that an application of 125 % RDF (187.5:62.5:62.5 kg NPK ha^{-1}) produced significantly higher weight of cob, maximum length and girth of cob than 75 % RDF (112.5:37.5:37.5 kg NPK ha^{-1}) and 100 % RDF (150:50:50 kg NPK ha^{-1}).

Kar *et al*. (2006) conducted a field experiment on effects of plant geometry and nitrogen on the yield of maize during kharif seasons of 2002 and 2003 at Bhubaneshwar, Orissa. The results indicated that an application of 80 kg N ha^{-1} produced significantly the highest number of prime cobs (62,328 ha^{-1}), cob length (17.5 cm) and cob diameter (16.7 cm) of maize as compared to 0, 20, 40 and 60 kg N ha^{-1}.

Kumar *et al.* (2006) conducted a field experiment during winter seasons of 2001-02 and 2002-03 at New Delhi to study the nutrient requirement of winter maize (*zea mays*) based intercropping systems. The results indicated that significantly the tallest plants and maximum dry matter content were recorded under 100 % RDF (160:26.2:33.2 kg NPK ha^{-1}) over 50 % RDF (80:13.1:16.6 kg NPK ha^{-1}) and 75 % RDF (120:19.65:24.9 kg NPK ha^{-1}).

Massey and Gaur (2006) conducted an experiment at Udaipur, Rajasthan during kharif seasons of 2001 and 2002 on maize to study the effect of plant population and fertilizer levels and reported that the fertilizer application of 120 kg N and 60 kg P_20_5 ha^{-1} resulted in significantly higher plant height, number of leaves $plant^{-1}$ and leaf area at harvest as compared to 90 kg N and 45 kg P_2O_5 ha^{-1}.

Meena *et al.* (2006) conducted a field experiment to study the effect of row ratio and fertility levels on the productivity of maize + soybean intercropping system during two rainy seasons at Udaipur. The pooled results revealed that the maize grain yield significantly increased with the application of 100 % RDF (90 kg N + 40 kg P_2O_5 ha^{-1}) as compared to 50 % RDF (45 kg N + 20 kg P_2O_5 ha^{-1}) and 75 % RDF (67.5 kg N + 30 kg P_2O_5 ha^{-1}).

Verma *et al.* (2006) conducted a field experiment during rainy seasons of 2000-01 and 2001-02 on sandy clay loam soil at Udaipur, Rajasthan to evaluate the effects of integrated nutrient management on the productivity of maize-wheat cropping system. The results revealed that significantly higher plant height at harvest was achieved by 150 % NPK (135:45:22.5 kg NPK ha^{-1}), which was at par with 100 % NPK (90:30:15 kg NPK ha^{-1}) + FYM 10 tonnes ha^{-1}. However, the treatments of 150 % NPK and 100 % NPK + FYM 10 tonnes ha^{-1} achieved significantly higher leaf area index at 60 days after sowing.

Kumar *et al.* (2005) studied integrated nutrient management in maize-cauliflower-mustard cropping system under rainfed conditions and observed that the maize yield was significantly higher under 150 % of recommended NPK (180:90:60 kg NPK ha^{-1}) followed by 150% NPK (180:90:60 kg NPK ha^{-1}) + 10 tonnes FYM ha^{-1} and 100 % NPK (120:60:40 kg NPK ha^{-1}) +10 tonnes FYM ha^{-1}. The higher yield at higher fertility level was due to higher number of cobs ha^{-1} and no. of grains cob^{-1}.

Kumar *et al*. (2005) conducted a study on nutrient management in maize-wheat cropping system at New Delhi. They observed that the fertilizer level of 100 % RDF

(120:26.2:33.2 kg NPK ha^{-1}) + 10 tonnes FYM ha^{-1} recorded significantly the highest number of cobs per plant and grain yield of maize over 50 % RDF (60:13.1:16.6 kg NPK ha^{-1}) + 10 tonnes FYM ha^{-1} and 50 % RDF (60:13.1:16.6 kg NPK ha^{-1}) + 5 tonnes.

Mehta *et al*. (2005) conducted a field experiment during rainy seasons of 1999 and 2000 on clay loam soil at Udaipur, Rajasthan to study the effects of single super phosphate and FYM on the yield attributes and yield of maize and found that an application of 40 kg P_20_5 ha^{-1} increased significantly the yield attributes viz., number of cobs per plot, grain weight per cob and grain and stover yields of maize over 20 kg P_2O_5 ha^{-1}.

Sutaliya and Singh (2005) carried out a field experiment during winters of 2000-01 and 2001-02 to find out the effects of planting time, fertility levels and phosphorus solubilzing bacteria on maize after rice at Varanasi on sandy loam soils. They reported that the plant height, leaf area $plant^{-1}$ and dry matter accumulation $plant^{-1}$ increased significantly with the highest level of 180:90:60 kg N, P_20_5 and K_20 ha^{-1} followed by 120:60:40 and 60:30:20 kg N, P_20_5 and K_20 ha^{-1}.

Arun (2004) conducted a field experiment during kharif 2002 at Dharwad, Karnataka to study the fertilizer requirement of maize grown on vertisols. The results indicated that significantly the highest total dry matter production of maize was recorded under 150+75+50 kg NPK ha^{-1} at 30 and 60 DAS and at harvest.

Banerjee *et al*. (2004) carried out a field experiment to study the effects of nitrogen (50, 100, 150 kg ha^{-1}) and plant population on the yield and quality of different maize varieties (*Zea mays* L.) at New Delhi. They reported that increasing levels of nitrogen up to 150 kg ha^{-1} significantly increased the grain yield.

Ramachandrappa *et al.* (2004) carried out a field experiment at the Main Research Station of the University of Agricultural Sciences, Bangalore, India during 2001 and 2002 to study yield and quality of maize (*Zea mays* L.) as influenced by spacing and fertilization levels. The data revealed that the application of 150 : 75 : 40 kg NPK ha^{-1} + 10 t farmyard manure (FYM) was found to be optimal for obtaining high grain and fodder yields.

Banerjee *et al*. (2003) conducted a field experiment during kharif at Mohanpur (West Bengal) to study the effect of various spacing and nitrogen levels (50, 100, 150 kg N ha^{-1})

on two maize varieties and reported that an application of 150 kg N ha^{-1} was significantly superior over 50 and 100 kg N ha^{-1} in respect of leaf area at all the crop growth stages.

Grazia *et al*. (2003), while studying the effects of N and P fertilization on the yield of hybrid maize at turkey observed that the ear diameter increased significantly with both levels of N application (100 and 200 kg N ha^{-1}) and ear diameter was maximum for 40 kg P_2O_5 ha^{-1} and minimum at 80 kg P2O5 ha^{-1}. Further, significantly the highest yield was obtained under treatment 200 kg N and 80 kg P_20_5 ha^{-1} as compared to their lower levels.

Gokmen *et al*. (2001) carried out a field experiment to find out nitrogen and spacing requirement of maize during kharif seasons (1995 and 1996) at Kazova Plain in Turkey. The results revealed that the plant height significantly increased with increase in the nitrogen levels and maximum plant height was recorded under 250 kg N ha^{-1}. The tasseling period was reduced as the nitrogen levels increased during both years and in the pooled data.

Singh and Singh (2001) reported that the cob girth and number of grains cob^{-1} increased with increasing nutrient level up to 180:90:60 kg ha^{-1} N, P_2O_5 and K_2O compared to control.

Surendra and Sharanappa (2000) conducted a field experiment on sandy loam soil at Bangalore, Karnataka to study the integrated management of nitrogen and phosphorus in maize and their residual effect on cowpea. They found that significantly the highest dry matter accumulation $plant^{-1}$ was obtained under 150 kg N and 75 kg P_2O_5 ha^{-1} as compared to 75 kg N, 37.50 kg P_2O_5 and 16 tonnes FYM ha^{-1}, which was at par with 112.5 kg N, 56.25 kg P_2O_5 and 12 tonnes FYM ha^{-1}.

Yogananda *et al*. (2000) conducted a field experiment during kharif season of 1997 at Bangalore, Karnataka to study the effect of plant population, phosphorus (0 and 75 kg P ha-1) and potassium (0, 50 and 100 kg K ha^{-1}) levels on the yield and quality of maize. They observed that, an application of 75 kg P ha^{-1} significantly increased the grain yield (2979 kg ha^{-1}) as compared to control. The treatment of 100 kg K_2O ha^{-1} recorded significantly the highest grain yield (3097 kg ha^{-1}) as compared to control.

Effect of different spacing

Ahmmed *et al.* (2020) reported that in maize plant height increased with increased spacing . They also reported that the wider spacing showed the highest number of grain per cob compared to other spacings.

Gaire *et al*. (2020) reported that the variation in biological yield due to each increment in nitrogen level and spacing was significant ($p<0.01$). The highest biological yield (12.37 mt/ha) produced under 60×15 cm spacing and the lowest biological yield (9.24 mt/ha) produced under 60×25 cm spacing.

Koirala *et al*. (2020) founded that the highest grain yield was found in Rampur Composite and Arun-2 while they were planted with row spacing of 60 cm with plant to plant spacing of 25 cm. The highest cob length was reported when maize was planted in the row spacing 60×25 cm.

Worku and Derebe (2020) reviled that stover and grain yields were significantly increased with increasing PD from 53,333 to 90,900 plants ha^{-1}. Eyasu *et al.* (2018) reported that number of kernels per rows was significantly influenced by the interaction effect of row spacing and varieties.

Hasan *et al*. (2018) reported that variety and plant spacing had significant effect on the studied crop characters and yield. Maximum diameter of cob and 1000-grain weight were observed in the spacing of 75 cm × 25 cm.

Azam (2017) showed that intra-row spacing had statistically significant effect on yield and yield components of Maize. Highest number of rows per cob (14.31), cm), was recorded where 12 inches plant spacing was kept.

Heisnam and Gautam (2017) conducted a field experiment at the Crop Research Farm, Department of Agronomy, SHUATS, Allahabad during (kharif) season of 2016 to study the effect of planting geometry, nitrogen levels and zinc application on growth and yield of hybrid maize (*Zea mays* L.). They found that the 60×15 cm^2 spacing with nitrogen level of 150 kg ha^{-1} and zinc 15 kg ha^{-1} is suitable to get higher maize yield.

Revathi *et al.* (2017) carried out a field experiment at Agricultural College Farm, Bapatla during rabi season 2014-15 at to study the growth and yield of rabi maize (*Zea mays* L.) at different planting densities and nitrogen levels. The results showed that planting density of 1,00,000 plants ha^{-1} recorded highest growth, yield attributes and yield as compared to plant density of 83,333 plants ha^{-1} and 66,6666 plants ha^{-1} respectively.

A field investigation conducted by Selila *et al*. (2017) at the experimental research farm of School of Agricultural Sciences and Rural Development, Nagaland University, Medziphema campus during the kharif season of 2014 to optimize N doses and planting densities for enhanced growth and yield performance of maize under rainfed conditions of Nagaland. The data revealed that the planting density of 55,555 plants ha^{-1} at a spacing of 60 cm × 30 cm was found to provide optimum crop stand in maize resulting in favourable growth consequently recording better yield attributes and maximum grain yield of 2941.66 kg ha^{-1}.

Sunita *et al.* (2017) carried out a field experimentat Instructional Farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) during kharif 2016 to study the effect of super absorbent polymer and plant geometry on growth and productivity of maize (*Zea mays* L.). The data revealed that the plant geometry 60 cm × 25 cm recorded higher growth and yield attributes as compared to 60 cm × 20 cm and 45 cm × 30 cm. However, the highest grain yield of 3978 kg ha^{-1} was recorded under 60 cm × 20 cm plant geometry.

Getaneh *et al*. (2016) reported that the highest above ground dry biomass yields per plant was occurred at the widest inter and intra-row spacing might be due to high stem diameter and high leaf area because there is more availability of growth factors and better penetration of light at wider row spacing.

Rahman *et al*. (2016) found that nitrogen levels and plant spacing had significant effect on yield attributes and yield of Khai bhutta. The highest number of, grain per row and grains weight cob^{-1} were recorded at 75 cm × 25 cm spacing.

Ukonze *et al.* (2016) reported that the 70 × 30 and 60 × 40 cm spacing gave higher values of the morphological parameters than 80 × 20 cm. With regard to yield, 80 × 20 cm gave the highest average cob weight of 0.74 kg and 1000-grain weight (yield) of 0.27t/ha.

Dutta *et al.* (2015) conducted a field experiment at Gayeshpur, Nadia, West Bengal during 2010 to 2012 (three years) to investigate the effect of irrigation schedules and planting geometry on growth, yield and water-use efficiency of summer maize (*Zea mays* L.). The results showed that the planting geometry of 45 × 20 cm^2 exhibited significantly higher grain yield, but on a par with 60 × 15 cm^2 plant geometry.

Mechi (2015) indicated that, the highest harvest index (53.16 %) was recorded from inter row spacing of 85 cm and the lowest harvest index (42.91 %) was obtained from inter row spacing of 55 cm

Thakur *et al*. (2015) carried out a field experiment at the S G College of Agriculture and Research Station, Jagdalpur, Chhattisgarh during Rabi season of 2014 to study the effect of different plant geometry and nitrogen levels, in relation to growth characters, yield and economics of maize. They reported that the plant population, plant height and LAI was recorded significantly higher in 30 × 30 cm^2 spacing followed by 50 × 30 cm^2 spacing as compared to 50 × 50 cm^2 spacing plant geometry. They also reported that the weight of cob with and without cover and weight of cobs ha^{-1} was recorded significantly highest in 50 × 50 cm^2 spacing.

Jula *et al*. (2013) reported that, the highest number of leaves $plant^{-1}$ (12.33) was recorded from maize intercrop planted at 75 cm × 75 cm and the lowest number of leaves $plant^{-1}$ (8.00) was reported from sole maize crop treatment at 75 cm × 25 cm spacing.

Mukhtar *et al*. (2012) founded that plant spacing had significant effect on shelling percentage while hybrids and hybrid x spacing interaction showed non-significant effect. In case of plant spacings, maximum shelling percentage 86.63% was observed in maximum plant spacing that was 17.50 cm which was statistically at par with 15.00 and 12.50 cm spacings.

Neupane *et al*. (2011) carried out a field experiment at Agricultural Research Farm, Institute of Agricultural sciences, Banaras Hindu University, Varanasi studied on sandy loam soil during pre- kharif seasons of 2008 and 2009 to evaluate the quality and yield performance of maize (*Zea mays* L.) as influenced by N sources and spacing. The results showed that the spacing of 40 cm × 15 cm were found to be best source of nitrogen and spacing and their combination 75% N through urea + 25% N through FYM + 40 cm × 15 cm spacing showed superior.

Abuzar *et al.* (2011) conducted a field experiment at the Agricultural Research Institute, Dera Ismail Khan, in mid July 2009 to determine the effect of plant population densities on yield of maize. The results showed that the plant population of 40000 ha^{-1} produced maximum number of grains per row and grains per ear. However, 60000 plants ha^{-1} produced the maximum number of ears per plant, number of grain rows per ear, biomass yield and grain yield.

Salam *et al.* (2010) showed that significantly higher number of grains cob^{-1} (300.33) was found in 75cm × 25cm spacing. Paygonde *et al.* (2008) carried out a field experiment during kharif season of 2004 at Pune to study the effects of weed control method and planting pattern on the growth characters of maize. They observed that, the spacing of 60 × 20 cm^2 produced significantly maximum number of functional leaves, dry matter, higher leaf area per plant and leaf area index as compared to 45-75 × 20 cm^2 spacing level.

Mushtaq *et al*. (2007) carried out a field experiment at NWFP Agricultural University, Peshawar to study response of maize to phosphorous levels and plant density. The results showed that the plant density significantly affected cobs $plant^{-1}$, grains cob^{-1}, 1000 grain weight and grain yield. Maximum cob $plant^{-1}$ and 1000 grain weight was noticed in plant density of 70000 plants ha^{-1}, while grain yield was highest at plant density of 90000 plant ha^{-1}. It is concluded that plant density of 90000 plant ha^{-1} in monsanto-707 showed the best performance.

Kar *et al.* (2006) conducted a field experiment during two rainy seasons at Bhubaneshwar, Orissa to study the effect of plant geometry and nitrogen on the yield, economics and nitrogen uptake of maize. The results revealed that the planting geometry of 60 × 20 cm^2 significantly increased the number of prime cobs ha^{-1} as compared with 60 × 30, 45 × 20 and 45 × 30 cm^2. The plant geometry of 60 × 30 cm^2 recorded significantly the highest length and girth of cob over remaining plant geometry of 60 × 20, 45 × 20 and 45 × 30 cm^2.

Thavaprakash *et al.* (2005) studied the impact of varied crop geometry, short duration intercrops and integrated nutrient management practices on production of maize based intercropping systems during late rabi 2002 and late rabi 2002-03 seasons at Eastern Block farm, Tamil Nadu Agricultural University, Coimbatore. The data revealed that the growth characters such as plant height, LAI and DMP; yield attributes for length of cob and corn, diameter of cob and corn and weight of cob and corn; green cob yield and fodder yield were significantly higher at 60 cm wider row spacing than 45 cm spacing level.

Chougale (2003) conducted a field experiment on maize at Pune and found significantly higher length, girth and weight of cobs with wider spacing of 60 × 20 cm^2 as compared to 60 × 15, 45 × 20 and 45 × 15 cm^2 spacing levels.

Gozubenli *et al.* (2003) on the basis of pooled results revealed that significantly the highest ear diameter, ear length, grain weight per ear were obtained from the lowest plant density of 50,000 plants ha^{-1} as compared to 60,000, 70,000, 80,000, 90,000 and 1,00,000 plants ha^{-1}.

Gokmen *et al.* (2001) conducted the field experiment on nitrogen rates and plant density in maize during two kharif seasons (1995-96) at Turkey and observed that the lower plant densities (57,000 plants ha^{-1}) significantly recorded maximum ear length and number of kernels per ear as compared to remaining plant populations. However, significantly the highest grain yield was obtained from 70,000 plants ha^{-1} over 57,000, 95,000 and 1,40,000 plants ha^{-1}.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Experimental period

The experiment was conducted during the period from October- 2020 to February-2021 in Rabi season.

3.2 Site description

3.2.1 Geographical location

The experiment was directed at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar Agargong Dhaka, Bangladesh. The experimental site is topographically situated at 23°77′ N scope and 90°33′ E longitude at an elevation of 8.6 meter above ocean level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I. (Banglapedia, 2014)

3.3 Climate and weather

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

3.4 Soil

The soil of the experimental pots belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon soil series. Soil pH ranges from 5.4–5.6. The land was above flood level and sufficient sunshine was available during the experimental period. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix-III. (Banglapedia, 2014 and Biswas *et al*., 2019).

3.5 Planting materials

In this research work, " SAU white maize " genotype variety of white maize seed was used as planting materials, which was collected from Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.6 Description of the variety

"SAU white maize" genotype of white maize used as planting material for the present study. These variety was recommended for Rabi and Kharif season. The feature of this variety was presented below:

SAU white maize	
Identifying character : Bold grain quality and drought tolerant	Suitable area : All over Bangladesh
Type : Medium duration, Open pollinated	Number of cobs plant-^{1} : Mainly one
Height : 180–200 cm	Cob colour : White colour.
Crop duration : 110–120 days	Grain colour : White
Leaf colour at Maturity : Light Green color at maturity	Yield : 9-9.50 t ha^{-1}

Source : Personal Communication: Prof. Dr. Md. Jafar Ullah, Dept. Of Agronomy, SAU, Dhaka.

3.7 Experimental details

Land preparation Date:	19 October 2020
Seed Sowing Date:	20 October 2020
Spacing:	According to the treatment requirement
Fertilizer application	According to the treatment requirement all the fertilizers were applied at 19 October 2020 during final land preparation except total urea
Flowering date:	24 December 2020
Silking Date:	2 January 2021
Harvesting Date:	20 February 2021

3.8 Experimental treatment

There were two sets of treatments in the experiment. The treatments were fertilizer application rate and spacing. Those are shown below:

Factor A: Fertilizer application rate viz (4);

F_1 = 50 % recommended dose of fertilizer

F_2 = 75 % recommended dose of fertilizer

F_3 = 100 % recommended dose of fertilizer

F_4 = 125 % recommended dose of fertilizer

Factor B: Different spacing viz (3);

S_1 = 50 cm × 20 cm,

S_2 = 40 cm × 20 cm and

S_3 = 30 cm × 20 cm.

3.9 Experimental design

The experiment was laid out in the Split plot design with three replications. The field was divided into 3 blocks to represent 3 replications. Total 36 unit plots were made for the experiment with 12 treatments. The size of each unit plot was 3.89 m^2 (3.17 m × 1.23 m). Distance maintained between replication and plots were 1.0 m and 0.50 m, respectively.

3.10 Detail of experimental preparation

3.10.1 Preparation of experimental land

The land was opened with the help of a tractor drawn disc harrow on (19 October 2019) and then ploughed with rotary plough twice followed by laddering to achieve a medium tilth required for the crop under consideration. All weeds and other plant residues of previous crop were removed from the field. Immediately after final land preparation, the field layout was made on (19 October 2019) according to experimental specification. Individual plots were cleaned and finally the plot were prepared.

3.10.2 Fertilizer application

Cow dung 5 t ha^{-1} was used before final land preparation. The field was fertilized with nitrogen, phosphate, potash, sulphur, zinc and boron at the rate of 500-250-200-250-15-5 kg ha^{-1} of urea, triple super phosphate, muriate of potash, gypsum, zinc sulphate and boric acid, respectively (BARI, 2014). The whole amounts of fertilizers were applied as basal doses except Urea. Only one third Urea was applied as basal doses and the rest amount was applied at 15 DAS interval for three installments. Fertilizer were applied according with par treatment requirement.

3.10.3 Seed sowing and maintaining spacing

The white maize seeds were sown in lines maintaining sapcing as per treatments requirement having 2 seeds $hole^{-1}$ under direct sowing in the well prepared plot on 20 October 2020.

3.11 Intercultural operations

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

3.11.1 Gap filling and thinning

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

3.11.2 Weed management

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

3.11.3 Water management

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

3.11.4 Earthing up

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

3.11.5 Plant protection measure

Plant protection measures was adopted where ever they found necessary during the crop growth period. Chloropyriphos spray 2.5ml lt^{-1} was sprayed against the control of stem borer.

3.11.6 Harvesting

The crop was harvested after attaining the physiological maturity at 90 days after sowing from all the plots. The cobs were picked up when ears were of full size, had tight husk and somewhat dried silks. At this stage, kernels were fully developed and exuded a milky liquid when punctured. The crop was harvested at milky stage by removing the cobs from the plot in the net plot area. The green fodder is obtained after harvest of the produce and the fresh cob yield, green fodder is worked out for t ha^{-1}. Harvesting was done on 20 February 2020.

3.12 Crop sampling

During 20, 40, 60 , 60 days and at harvesting period 5 plants was cutting from the soil base which was selected for crop sampling for taking various parameters data of the plant.

3.13 Data collection

The data were recorded on the following parameters

A. Crop growth characters

i. Plant height (cm)
ii. Leaf area index
iii. Root dry matter weight $plant^{-1}$
iv. Stem dry matter weight $plant^{-1}$ at 120 DAS (g)
v. Lamina dry matter weight $plant^{-1}$ at 120 DAS (g)
vi. Correlation studies
vii. Total dry matter $plant^{-1}$ (g)
viii. Dry matter weight $plant^{-1}$
ix. Net assimilation rate ($gm^{-2}day^{-1}$)
x. Crop growth rate ($gm^{-2}day^{-1}$)
xi. Relative crop growth rate, RGR ($gm^{-2}day^{-1}$)
xii. Trend of total dry matter accumulation under phenomena of varying spacing and fertilizer application

B. Yield contributing characters

xiii. Cob length $plant^{-1}$ (cm)
xiv. Cob circumference $plant^{-1}$ (cm)
xv. Number of grains cob^{-1}(no)
xvi. 1000 grains weight cob^{-1}(g)
xvii. Chaff weight $plant^{-1}$ (g)

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

xix. Grain weight cob^{-1} (g)

xx. Cob weight plant^{-1} (g)

C. Yield characters

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

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

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

xxiv. Harvest index (%)

3.14 Procedure of recording data

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

i. Plant height

The plant height was measured at 20, 40, 60, 80 days after sowing (DAS) and at maturity stage from the base to the base of the youngest fully opened top leaf until tassel emergence, afterwards plant height was measured from the base of the plant to the collar of flag leaf and expressed in centimeter (cm).

ii. Leaf area index

Leaf area index was calculated using the following formula given by Watson (1956). Leaf area index is defined as leaf area (assimilatory source) per unit land area (spacing). It was calculated by dividing the leaf area per plant by land area occupied by single plant

$$\text{Leaf Area Index} = \frac{\text{Leaf area per plant (cm}^2\text{)} \times 0.70}{\text{Unit ground area per plant (cm}^2\text{)}}$$

iii. Root dry matter weight plant^{-1}

At harvest five plants roots were selected randomly from the gross plot areas. Plant samples were separated into root, stem and lamina. These were then dried in oven at 65^0 - 70^0 C in hot air oven until it attained constant weight and the oven dry weight was recorded. Dry weight was recorded separately at each stage to assess total root dry matter production was expressed in gram per plant (g plant^{-1}).

iv. Stem dry matter weight plant^{-1} at 120 DAS (g)

At 120 DAS five plants stem were selected randomly from the gross plot areas. These were then dried in oven at 65^0 - 70^0 C in hot air oven until it attained constant weight and the oven dry weight was recorded. Dry weight was recorded separately at each stage to assess total stem dry matter production was expressed in gram per plant (g plant^{-1}).

v. Lamina dry matter weight plant^{-1} at 120 DAS (g)

At 120 DAS five plants stem were selected randomly from the gross plot areas. These were then dried in oven at 65^0 - 70^0 C in hot air oven until it attained constant weight and the oven dry weight was recorded. Dry weight was recorded separately at each stage to assess total lamina dry matter production was expressed in gram per plant (g plant^{-1}).

vi. Dry matter weight plant $^{-1}$

Five plants were selected randomly from the gross plot areas and they were cut at ground level and separated into leaves, stem (including sheath) and cobs with husk. Plant samples were separated into root, stem and lamina. These were then dried in oven at 65^0 - 70^0 C in hot air oven until it attained constant weight and the oven dry weight was recorded. Dry weight was recorded separately at each stage to assess total dry matter accumulation and total dry matter production was expressed in gram per plant (g plant^{-1}).

vii. Correlation studies

Regression analysis of total dry matter and time was made both under the environment of spacing and fertilizer application using MS Excel packages. Correlation among root, stem and lamina were also made.

viii) Crop growth rate (CGR) (g m^{-2} day^{-1})

The average daily increment in plant stand is an important characteristic. The CGR is an increase in dry matter production per unit ground area per unit time. In the present investigation the crop growth rate was calculated at different DAS with the help of following formula given by Watson (1956).

Crop growth rate (CGR) = $\frac{W2-W1}{P(t2-t1)}$ g m^{-2} day^{-1}

Where,

P = ground area (m^{-2})

W_1 = dry weight per unit area at t_1

W_2 = dry weight per unit area at t_2

t_1 = time of first sampling

t_2 = time of second sampling

ix) Relative growth rate (mg g^{-1} day^{-1})

The relative growth rate expresses the increase in dry weight at time intervals concerning the initial weight. In practical situations, the mean relative growth rate was calculated from measurements on dry weight at the time intervals (Between 60 to 90 DAT) with the help of the following equation suggested by Beadle (1985).

Relative growth rate = $\frac{Ln\,(W2)-\mathrm{Ln}\,(W1)}{(t2-t1)}$

Where,

Ln = natural log values

W_1 = dry weight per unit area at t_1

W_2 = dry weight per unit area at t_2

t_1 = time of first sampling

t_2 = time of second sampling

x. Net assimilation rate (NAR) (g m^{-2} day^{-1})

It is an increase in dry weight of plant per unit leaf area per unit time. The net assimilation rate was calculated from the following equation given by Gregory (1926).

Net assimilation rate =$\frac{(W2-W1)(\ \mathrm{LnLA}\ 2-\mathrm{LnLA}\ 1)}{(t2-t1)(\ \mathrm{LnLA}\ 2-\mathrm{LnLA}\ 1)}$g m^{-2} day^{-1}

Where,

LA_1 = leaf area of first sampling

LA_2 = leaf area of second sampling

W_1 = dry weight per unit area at t1

W_2 = dry weight per unit area at t2

t_1 = time of first sampling

t_2 = time of second sampling

Ln = natural log values

xi. Cob length plant^{-1}

At harvest, length of the cob of selected plants was taken from the base to tip of the cob with the help of meter scale. Thereafter mean cob length was worked out and represented in centimeter (cm).

xii. Cob circumference plant^{-1}

Five cobs were randomly selected per plot and the circumference was taken from each cob. Then average result was recorded in cm.

xiii. Number of grains cob^{-1}

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

xiv. 1000-grain weight

After removing the grain from each cob from each plot grains are stored in a specific grain stock or pot. From the seed stock of each plot 1000 seeds were counted and the weight was measured by an electrical balance. It was recorded in gram.

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

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

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

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

xvii. Grain weight cob^{-1}(g)

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

xviii. Cob weight plant^{-1} (g)

Cob weight (includes chaff, shell and total grain weight of a cob) of five randomly selected cobs from the five selected plants in each plot was taken in an electrical balance and the average weight was recorded in gram.

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

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

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

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

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

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

Biological yield = Seed yield + Stover yield.

xxi. Harvest Index (%)

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

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

3.15 Statistical data analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistix 10 software .The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

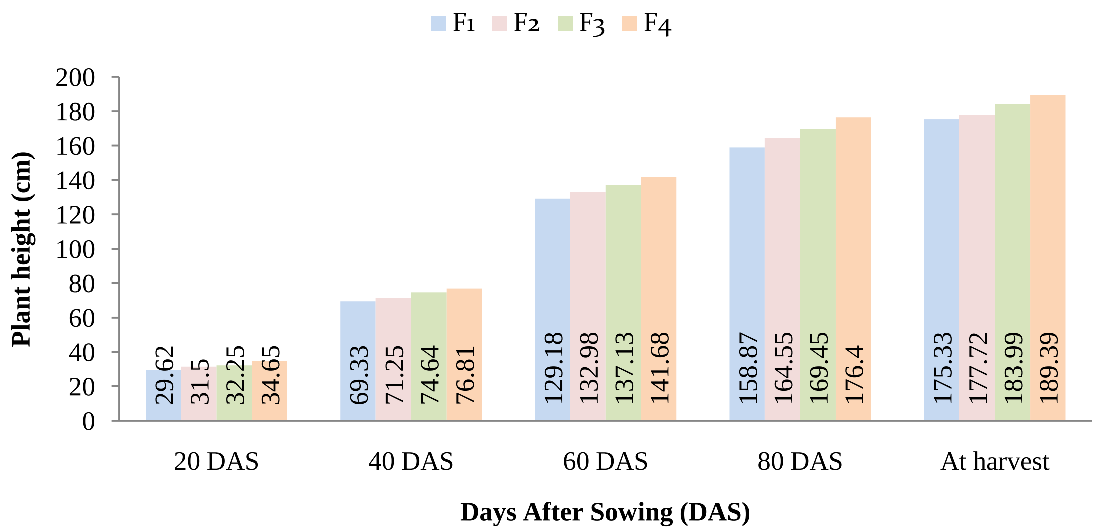
Results obtained from the present study have been presented and discussed in this chapter with a view to studying allometry and yield components of white maize to varying levels of spacing and fertilizer application. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height

Effect of fertilizer dose

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants. Different rate of fertilizer application significantly influenced on plant height of white maize at different days after sowing (DAS). It was seen that height increased more and more with the age of the crop up to harvest. The plant height reached the highest value at maturity (Figure 1). Experimental result revealed that the highest plant height (34.65, 76.81, 141.68, 176.40 and 189.39 cm) at 20, 40, 60, 80 DAS and at harvest respectively was observed in F_4 treatment (125 % recommended dose of fertilize) which was statistically similar with F_3 treatment (74.64, 137.13, 169.45 and 183.99 cm) at 40, 60, 80 DAS and at harvest respectively. Whereas the lowest plant height (29.62, 69.33, 129.18, 158.87 and 175.33 cm) at 20, 40, 60, 80 DAS and at harvest respectively was observed in F_1 (50 % recommended dose of fertilize) treatment which was statistically similar with F_2 treatment (71.25, 132.98, 164.55 and 177.72 cm) at 40, 60, 80 DAS and at harvest respectively. The more fertilizer a crop receives, the faster it grows. If a crop is provided with too little fertilizer, plant growth response is poor; but if fertilizer rates are excessive, plant growth slows and there is a potential for root damage or death from high fertilizer salts. If fertilizer application rates are maintained between these extremes, then plant growth can be manipulated based on the fertilizer application rate. The result was similar with the findings of Satyabhan *et al.* (2018) who reported that the highest plant growth (plant height and stem girth) and green fodder yield was recorded with the application of 150% RDF + PSB (Phosphate Solubilizing Bacteria).

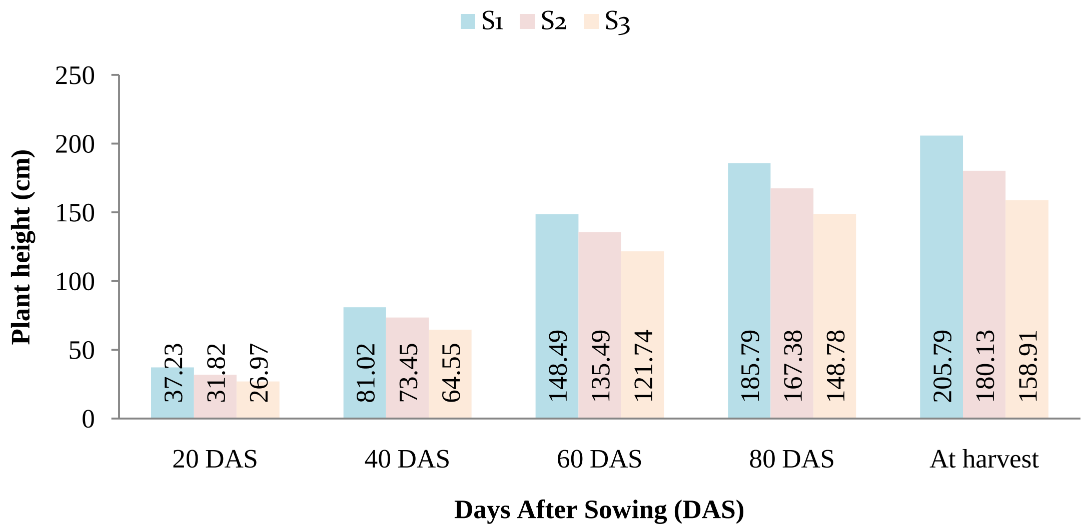


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 1. Effect of fertilizer dose on plant height of white maize at different DAS ($LSD_{(0.05)}$ = 1.42, 3.46, 6.87, 10.29 and 6.89 cm at 20, 40, 60, 80 DAS and at harvest respectively)

Effect of spacing

Different spacing showed significant effect on plant height of white maize at different days after sowing (Figure 2). Experimental result showed that the highest plant height (37.23, 81.02, 148.49, 185.79 and 205.79 cm) at 20, 40, 60, 80 DAS and at harvest respectively was observed in S_1 (50 cm × 20 cm) treatment. While the lowest plant height (26.97, 64.55, 121.74, 148.78 and 158.91 cm) at 20, 40, 60, 80 DAS and at harvest respectively was observed in S_3 (30 cm × 20 cm) treatment. In general, height was increased as the plant spacing was increased indicating tendency of plant to grow tall under adequate space which might be due to less competition for light and CO_2 between plants. The result obtained from the present study was similar with the findings of Thavaprakash *et al.* (2005) reported that the growth characters such as plant height, was significantly higher at 60 cm wider row spacing than 45 cm spacing level.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 2. Effect of different spacings on plant height of white maize at different DAS ($LSD_{(0.05)}$ = 1.07, 2.52, 2.66, 7.51 and 5.31cm at 20, 40, 60, 80 DAS and at harvest respectively)

Combined effect of fertilizer dose and spacing

Different rate of fertilizer application along with spacing, significantly influenced plant height of white maize at different DAS (Table 1). Experimental result revealed that the highest plant height (40.27, 85.87, 156.37, 196.71 and 212.67 cm) was observed in F_4S_1 treatment combination at 20, 40, 60, 80 DAS and at harvest respectively that was statistically similar with F_3S_1 (82.03 and 149.89 cm) at 40 and 60 DAS; with F_2S_1 (184.73 cm) and F_3S_1 (82.03 cm) at 80 DAS and with F_2S_1 (202.00 cm) and F_3S_1 (207.83 cm) at harvest respectively. While the lowest plant height (24.83, 61.43,116.49, 141.39 and 151.33 cm) at 20, 40, 60, 80 DAS and at harvest respectively was observed in F_1S_3 treatment combination, which was statistically similar with F_2S_3 (25.27, 62.07, 117.57, 142.91 and 155.00 cm) at 20, 40, 60, 80 DAS and at harvest respectively and with F_3S_3 (26.87, 123.93, 150.87 and 161.97 cm) at 20, 60, 80 DAS and at harvest respectively.

Table 1. Combined effect of fertilizer doses and different spacing on plant height of white maize at different DAS

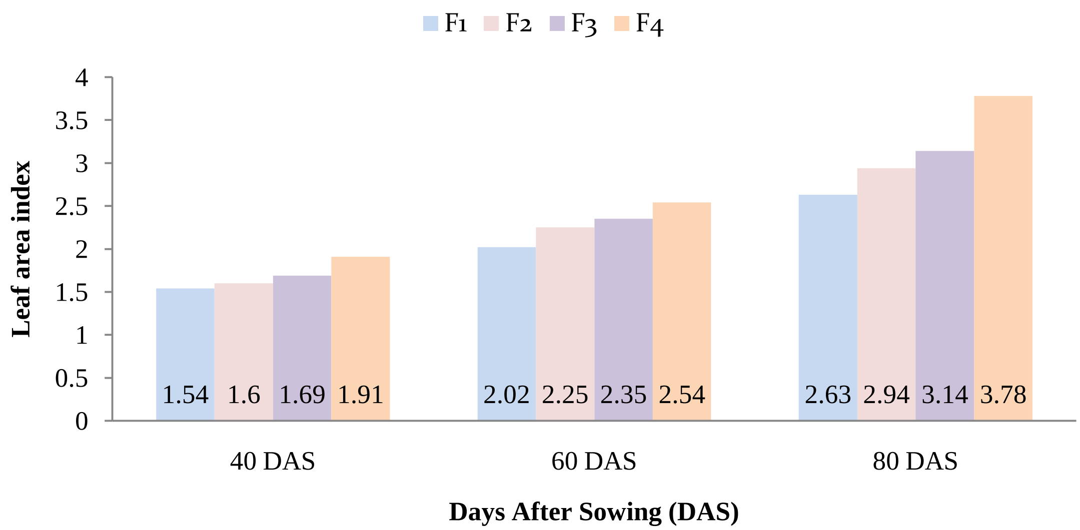
Treatment combinations	Plant height (cm) at				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
F_1S_1	33.40 c	77.03 b-d	140.66 cd	174.13 b-d	200.67 b
F_1S_2	30.63 d	69.53 ef	130.39 e-g	161.09 de	174.00 de
F_1S_3	24.83 e	61.43 h	116.49 h	141.39 f	151.33 g
F_2S_1	37.63 b	79.17 bc	147.03 bc	184.73 a-c	202.00 ab
F_2S_2	31.60 cd	72.50 de	134.33 d-f	166.00 de	176.17 de
F_2S_3	25.27 e	62.07 gh	117.57 h	142.91 f	155.00 g
F_3S_1	37.63 b	82.03 ab	149.89 ab	187.59 ab	207.83 ab
F_3S_2	32.26 cd	75.07 cd	137.56 de	169.89 cd	182.17 cd
F_3S_3	26.87 e	66.83 fg	123.93 gh	150.87 ef	161.97 fg
F_4S_1	40.27 a	85.87 a	156.37 a	196.71 a	212.67 a
F_4S_2	32.77 cd	76.70 b-d	139.70 cd	172.54 b-d	188.17 c
F_4S_3	30.90 d	67.85 ef	128.98 fg	159.95 de	167.33 ef
$LSD_{(0.05)}$	2.24	5.37	8.12	15.98	11.06
CV (%)	3.86	3.99	4.41	5.33	3.38

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

4.1.2 Leaf area index

Effect of fertilizer dose

The leaf area index of white maize considerably changed at different DAS due to various dose of fertilizer application treatments (Figure 3). The results of the experiment indicated that the F_4 treatment (125% recommended dose of fertilizer) had the highest leaf area index (1.91, 2.54 and 3.78) at 40, 60 and 80 DAS respectively. While the F_1 treatment (using 50% of the recommended dose fertilizer dose) had the lowest leaf area index (1.54, 2.02 and 2.63) at 40, 60 and 80 DAS respectively which was statistically comparable to F_2 treatment (1.60) at 40 DAS. The LAI of maize reduced under lower level of fertilizer and the lowest LAI was found in plants grown without fertilizer. The increase in LAI with the increase in fertilizer might be due to increase in availability of plant nutrients. Spandana (2012) reported that the growth characters like leaf area index (LAI) increased due to increased level of nitrogen application from 120 to 240 kg ha^{-1}.

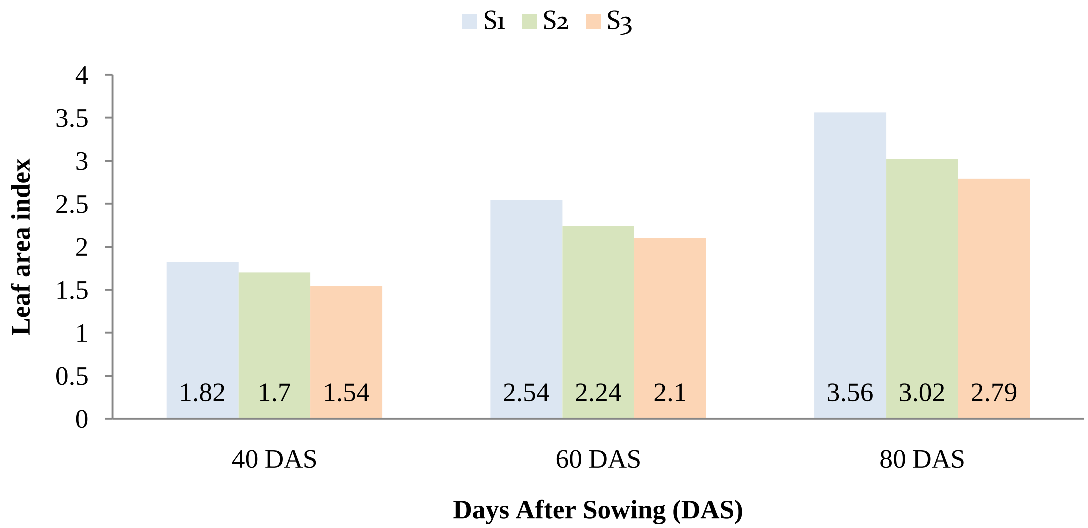


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 3. Effect of fertilizer dose on leaf area index of white maize at different DAS ($LSD_{(0.05)}$ = 0.10, 0.12 and 0.04 at 40, 60 and 80 DAS)

Effect of spacing

At various days after sowing, different spacing had a significant effect on the leaf area index of white maize (Figure 4). The results of the experiment revealed that the S_1 treatment had the highest leaf area index (1.82, 2.54 and 3.56) at 40, 60 and 80 DAS respectively. While at 40, 60 and 80 DAS respectively, the S_3 treatment exhibited the lowest leaf area index (1.54, 2.10 and 2.79). Lower plant spacing increases of plant density which decreased the number of leaves $plant^{-1}$ due to plants at higher densities accumulate less carbon which is not sufficient to support more leaves result in lower leaf area index $plant^{-1}$. Paygonde *et al.* (2008) reported that, the spacing of 60 × 20 cm^2 produced significantly maximum number of functional leaves, total dry matter, higher leaf area per plant and leaf area index as compared to 45× 20 cm^2 spacing level.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 4. Effect of different spacings on leaf area index of white maize at different DAS ($LSD_{(0.05)}$ = 0.07, 0.08 and 0.13 at 40, 60 and 80 DAS)

Combined effect of fertilizer dose and spacing

Applying different dose of fertilizer and maintaining different spacings together had shown significant effect on the leaf area index of white maize at various DAS (Table 2). According to experimental findings, the F_4S_1 treatment combination had the highest leaf area index (2.14, 2.87 and 4.63) at 40, 60 and 80 DAS respectively. However the F_1S_3 treatment combination had the lowest leaf area index (1.35, 1.80 and 2.35) at 40, 60 and 80 DAS respectively.

Table 2. Combined effect of fertilizer doses and different spacing on leaf area index of white maize at different DAS

Treatment combinations	Leaf area index at		
	40 DAS	60 DAS	80 DAS
F_1S_1	1.68 cd	2.28 c	2.87 d
F_1S_2	1.59 de	1.99 d	2.66 d
F_1S_3	1.35 f	1.80 e	2.35 e
F_2S_1	1.67 cd	2.48 b	3.22 c
F_2S_2	1.65 cd	2.28 c	2.80 d
F_2S_3	1.48 ef	1.99 d	2.79 d
F_3S_1	1.77 bc	2.51 b	3.50 b
F_3S_2	1.65 cd	2.29 c	3.27 bc
F_3S_3	1.65 cd	2.24 c	2.65 d
F_4S_1	2.14 a	2.87 a	4.63 a
F_4S_2	1.90 b	2.40 bc	3.35 bc
F_4S_3	1.69 cd	2.36 bc	3.35 bc
$LSD_{(0.05)}$	0.16	0.18	0.22
CV (%)	5.28	4.47	4.93

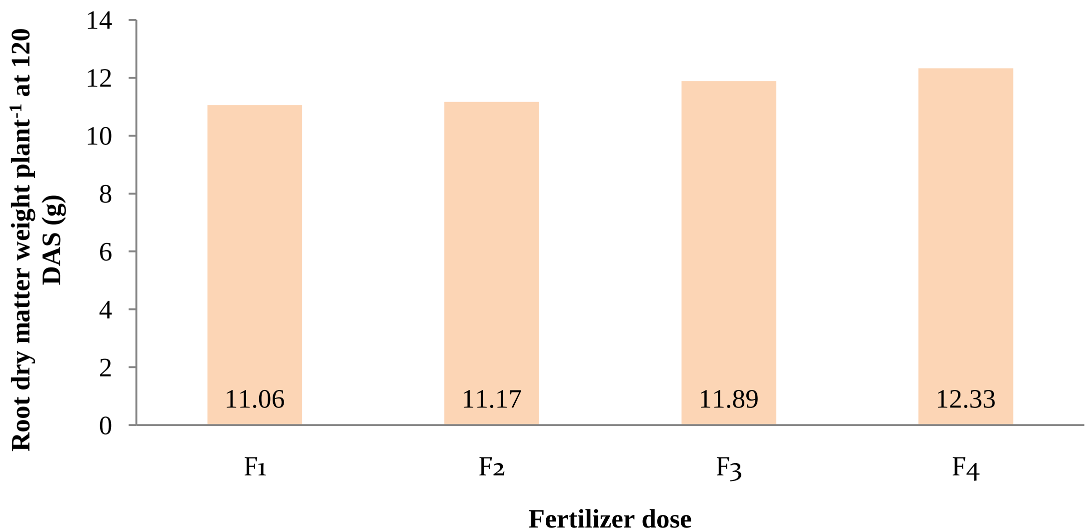
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

4.2 Plant components dry matter

4.2.1 Root dry matter weight plant^{-1} at 120 DAS

Effect of fertilizer dose

The experimental findings demonstrated that different rate of fertilizer application had a significant effect on root dry matter weight plant^{-1} of white maize at 120 DAS (Figure 5). Experimental result revealed that the F_4 treatment had the highest root dry matter weight plant^{-1} (12.33 g) at 120 DAS. While F_1 treatment showed the lowest root dry matter weight plant^{-1} (11.06 g) at 120 DAS which was statistically similar with F_2 treatment (11.17 g). The effect of different rate of fertilizers on plant growth is due to the increased availability of nutrients, especially nitrogen and phosphorus. Rahman *et al.* (2000) reported that as the rate of N fertilizer application increases the total dry weight also increases. Nitrogen application creates a significant increase on leaf photosynthesis, leaf area index, crop growth rate and biomass production of plant.



Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 5. Effect of fertilizer dose on root dry matter weight plant^{-1} of white maize at 120 DAS ($LSD_{(0.05)}$ = 0.44 g)

Effect of spacing

Depending on the various spacing, the root dry matter weight plant^{-1} of white maize at 120 DAS varied significantly (Figure 6). The experimental findings showed that the S_1 treatment had the highest root dry matter weight plant^{-1} (13.88 g) at 120 DAS. While at 120 DAS, the S_3 treatment demonstrated the lowest root dry matter weight plant^{-1} (9.46 g). The variation of root dry matter weight plant^{-1} of white maize among different treatment due to availability of more space for plant spread, getting more sunlight and CO_2 for better growth and development of the plant.

Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 6. Effect of different spacings on root dry matter weight plant^{-1} of white maize at 120 DAS ($LSD_{(0.05)}$ = 0.32 g)

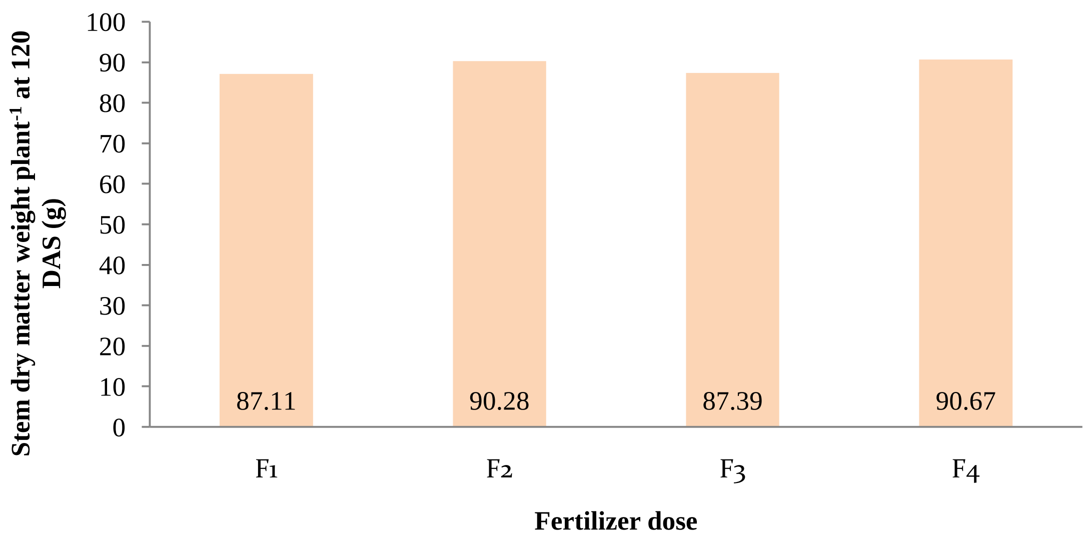
Combined effect of fertilizer dose and spacing

Different fertilizer doses combined with different spacings had a significant effect on the root dry matter weight plant^{-1} of white maize at 120 DAS (Table 3). According to experimental results, the F_4S_1 treatment combination had the highest root dry matter weight plant^{-1} (14.50 g) at 120 DAS. This combination was statistically similar with F_2S_1 (14.00 g) treatment combination at 120 DAS. However the lowest root dry matter weight plant^{-1} (8.67 g) at 120 DAS was found in F_1S_3 treatment combination and it was statistically comparable to F_2S_3 (8.67 g) at 120 DAS.

4.2.2 Stem dry matter weight plant^{-1} at 120 DAS

Effect of fertilizer dose

The experimental results showed that different fertilizer application rates had a significant effect on the stem dry matter weight plant^{-1} of white maize at 120 DAS (Figure 7). According to the experimental results the F_4 treatment had the highest stem dry matter weight plant^{-1} (90.67 g) at 120 DAS which was statistically similar with F_2 (90.28 g) treatment. While at 120 DAS, the F_1 treatment had the lowest stem dry matter weight plant^{-1} (87.11 g), which was statistically similar to the F_3 treatment (87.39 g). The effect of fertilizer rates on plant growth was might be due to increased nutrient availability, particularly nitrogen and phosphorus.



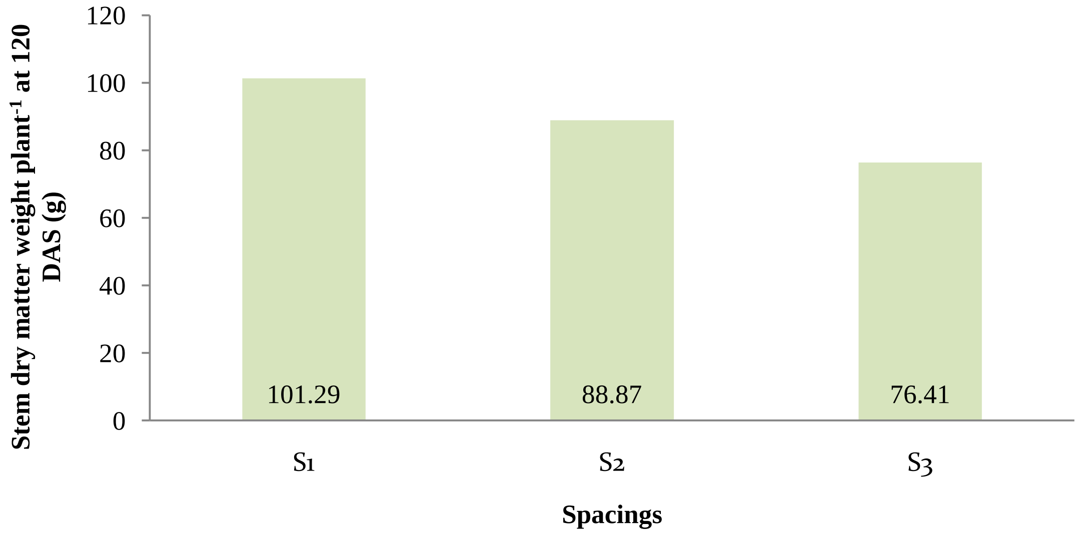
Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 7. Effect of fertilizer dose on stem dry matter weight plant^{-1} of white maize at 120 DAS ($LSD_{(0.05)}$ = 1.69 g)

Effect of spacing

Depending on the various spacing, the stem dry matter weight plant^{-1} of white maize at 120 DAS varied significantly (Figure 8). The experimental findings showed that the S_1 treatment had the highest stem dry matter weight plant^{-1} (101.29 g) at 120 DAS. While at 120 DAS, the S_3 treatment demonstrated the lowest stem dry matter weight plant^{-1} (76.41

g). The variation of stem dry matter weight plant^{-1} of white maize among different treatment might be due to availability of more space for plant spread, getting more sunlight and CO_2 for better growth and development of the plant.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 8. Effect of different spacings on stem dry matter weight plant^{-1} of white maize at 120 DAS ($LSD_{(0.05)}$ = 0.63 g)

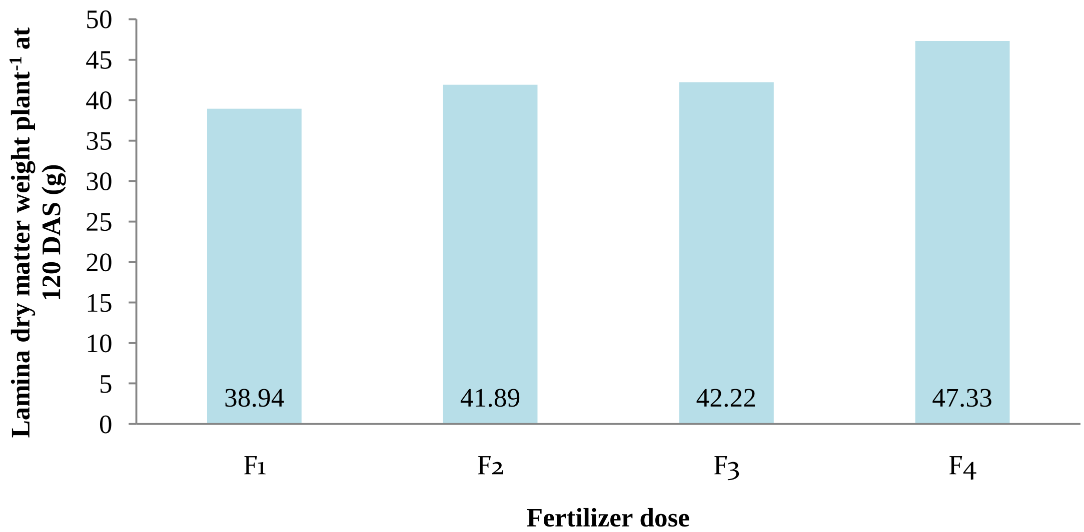
Combined effect of fertilizer dose and spacing

Different fertilizer doses combined with different spacings had a significant effect on the stem dry matter weight plant^{-1} of white maize at 120 DAS (Table 3). According to experimental results, the F_2S_1 treatment combination had the highest stem dry matter weight plant^{-1} (106.17 g) at 120 DAS. However the lowest stem dry matter weight plant^{-1} (71.33 g) at 120 DAS was found in F_2S_3 treatment combination.

4.2.3 Lamina dry matter weight plant^{-1} at 120 DAS

Effect of fertilizer dose

The experimental results showed that different fertilizer application rates had a significant effect on the lamina dry matter weight plant^{-1} of white maize at 120 DAS (Figure 9). According to the experimental results the F_4 treatment had the highest lamina dry matter weight plant^{-1} (47.33 g) at 120 DAS. While at 120 DAS, the F_1 treatment had the lowest lamina dry matter weight plant^{-1} (38.94 g). The effect of fertilizer rates on plant growth was might be due to increased nutrient availability, particularly nitrogen and phosphorus.



Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 9. Effect of fertilizer dose on lamina dry matter weight plant^{-1} of white maize at 120 DAS ($LSD_{(0.05)}$ = 1.66 g)

Effect of spacing

Depending on the various spacing, the lamina dry matter weight plant^{-1} of white maize at 120 DAS varied significantly (Figure 10). The experimental findings showed that the S_1 treatment had the highest lamina dry matter weight plant^{-1} (52.25 g) at 120 DAS. While at 120 DAS, the S_3 treatment demonstrated the lowest lamina dry matter weight plant^{-1} (32.71 g). The variation of lamina dry matter weight plant^{-1} of white maize among different treatment might be due to availability of more space for plant spread, getting more sunlight and CO_2 for better growth and development of the plant.

Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 10. Effect of different spacings on lamina dry matter weight plant^{-1} of white maize at 120 DAS ($LSD_{(0.05)}$ = 0.90 g)

Combined effect of fertilizer dose and spacing

Different fertilizer doses combined with different spacings had a significant effect on the lamina dry matter weight plant^{-1} of white maize at 120 DAS (Table 3). According to experimental results, the F_4S_1 treatment combination had the highest lamina dry matter weight plant^{-1} (57.83 g) at 120 DAS. However the lowest lamina dry matter weight plant^{-1} (29.50 g) at 120 DAS was found in F_1S_3 treatment combination which was statistically similar with F_2S_3 (29.50 g) treatment combination.

Table 3. Combined effect of fertilizer doses and different spacing on root, stem and lamina dry matter weight plant^{-1} at of white maize at 120 DAS

Treatment combinations	Root dry matter weight plant^{-1} at 120 DAS (g)	Stem dry matter weight plant^{-1} at 120 DAS (g)	Lamina dry matter weight plant^{-1} at 120 DAS (g)
F_1S_1	13.67 b	96.17 c	48.83 c
F_1S_2	10.83 d	88.00 e	38.50 f
F_1S_3	8.67 f	77.17 g	29.50 h
F_2S_1	14.00 ab	106.17 a	50.83 bc
F_2S_2	10.83 d	93.33 d	44.17 de
F_2S_3	8.67 f	71.33 h	30.67 gh
F_3S_1	13.33 b	102.00 b	51.50 b
F_3S_2	12.33 c	81.50 f	42.83 e
F_3S_3	10.00 e	78.67 g	32.33 g
F_4S_1	14.50 a	100.83 b	57.83 a
F_4S_2	12.00 c	92.67 d	45.83 d
F_4S_3	10.50 de	78.47 g	38.33 f
$LSD_{(0.05)}$	0.68	1.98	2.21
CV (%)	3.20	4.83	3.39

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm.

4.3 Correlation studies

Correlation between leaf dry matter and total dry matter

From the Table 4 it was noticed that dry matter (Dm) was both positively and negatively correlated with leaf area at different fertilizer levels. According to the correlation study, dry matter was positively and negatively correlated with leaf area at different fertilizer levels.

On an average, it was observed that the total dry matter accumulation largely dependent on the leaf area at 40 days after sowing of white maize (average value of 0.1724). On an average, the dry matter accumulation mostly followed that of the leaf area at 40 DAS showing the maximum coefficient value of 0.1724.

Table 4 Correlation coefficient values between total dry matter and leaf area of white maize at different days after sowing (using the data of individual spacings)

Using the data of varying Fertilization levels						
Dm /Days after sowing	Dm/plant at 40 DAS (g)	Dm/plant at 60 DAS (g)	Dm/plant at 80 DAS (g)	Dm/plant at 100 DAS (g)	Dm/plant at 120 DAS (g)	Average
Leaf area at 40 DAS	0.874	0.601	0.646	-0.979	-0.280	0.1724
Leaf area at 60 DAS	-0.989	-0.673	-0.389	0.922	0.589	-0.108
Leaf area at 80 DAS	-0.822	-0.231	-0.179	0.933	0.601	0.0604
Leaf area at 100 DAS	0.616	-0.053	0.092	-0.848	-0.482	-0.135
Leaf area at 120 DAS	-0.015	-0.702	-0.502	-0.231	-0.379	-0.3658

From the (Table 5) it was noticed that at different spacings, dry matter was positively correlated with leaf area. From the correlation study, it appears that at different spacings dry matter increase with increasing leaf area. On an average, the dry matter accumulation under the phenomenal change of varied fertilizer application was in the range of 0.98725-0.99825. That is, under fertilizer application phenomenon, the average correlation did not change appreciably due to the varied leaf area under different growth stages, although fertilizer application had very strong relations of leaf area with the total dry matter accumulation.

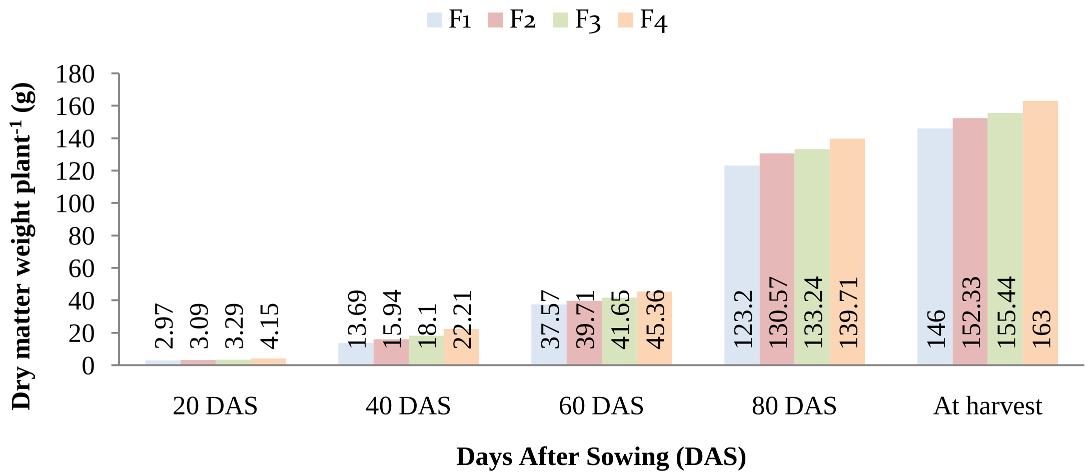
Table 5. Correlation coefficient between leaf dry matter and total dry matter at different days after sowing (using the data of individual fertilizer doses)

Using the data of varying Spacings						
Parameters	Dm/plant at 40 DAS (g)	Dm/plant at 60 DAS (g)	Dm/plant at 80 DAS (g)	Dm/plant at 100 DAS (g)	Dm/plant at 120 DAS (g)	Average
Leaf area at 40 DAS	0.994	1.000	0.994	0.997	0.998	0.99625
Leaf area at 60 DAS	0.998	0.979	0.983	0.995	0.993	0.98875
Leaf area at 80 DAS	0.979	0.998	0.986	0.986	0.989	0.98725
Leaf area at 100 DAS	0.998	0.997	0.998	1.000	1.000	0.99825
Leaf area at 120 DAS	0.997	0.998	0.999	0.999	1.000	0.99825

4.4 Dry matter weight plant^{-1}

Effect of fertilizer dose

The experimental findings demonstrated that different rate of fertilizer application had a significant effect on dry weight plant^{-1} of maize at various DAS (Figure 11). Experimental result revealed that the F_4 treatment had the highest dry matter weight plant^{-1} (4.15, 22.21, 45.36, 139.71 and 163.00 g) at 20, 40, 60, 80 DAS and at harvest respectively. While F_1 treatment showed the lowest dry matter weight plant^{-1} (2.97, 13.69, 37.57, 123.20 and 146.00 g) at 20, 40, 60, 80 DAS and at harvest respectively which was statistically similar with F_2 treatment (3.09 g) at 20 DAS. The effect of different rate of fertilizers on plant growth was due to the increased availability of nutrients, especially nitrogen and phosphorus. Nitrogen increased the growth of aerial organs, phosphorus increased the energy transfer for the growth of plant vegetative organs, in general, it improves photosynthesis and thus increased dry matter weight plant^{-1}. Sutaliya and Singh (2005) reported that the dry matter accumulation plant^{-1} increased significantly with the highest level of 180:90:60 kg N, P_20_5 and K_20 ha^{-1} followed by 120:60:40 and 60:30:20 kg N, P_20_5 and K_20 ha^{-1}. Arun (2004) indicated that, significantly the highest total dry matter production of maize was recorded under 150+75+50 kg NPK ha^{-1} at 30 and 60 DAS and at harvest.

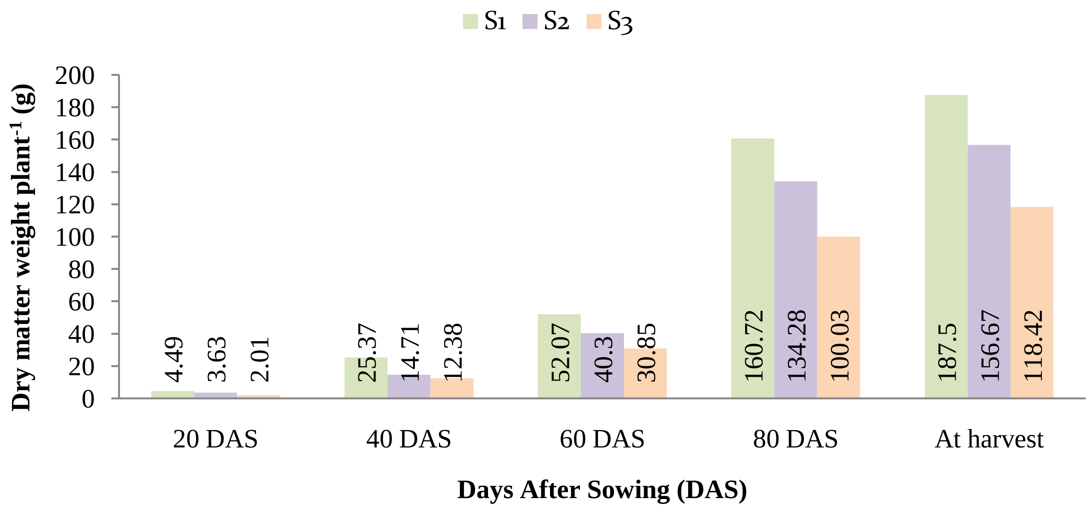


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 11. Effect of fertilizer dose on dry matter weight plant^{-1} of white maize at different DAS ($LSD_{(0.05)}$ = 0.15, 0.86, 2.14, 3.66 and 5.26 g at 20, 40, 60, 80 DAS and at harvest respectively)

Effect of spacing

Depending on the various spacing, the dry weight plant^{-1} of maize at different days after sowing varied significantly (Figure 12). The experimental findings showed that the S_1 treatment had the highest dry weight plant^{-1} (4.49, 25.37, 52.07, 160.72 and 187.50 g) at 20, 40, 60, 80 DAS and at harvest respectively. While at 20, 40, 60, 80 DAS and at harvest respectively, the S_3 treatment demonstrated the lowest dry weight plant^{-1} of (2.01, 12.38, 30.85, 100.03 and 118.42 g respectively). The variation of dry matter weight plant^{-1} of white maize among different treatment was might be due to availability of more space for plant spread, getting more sunlight and CO_2 for better growth and development of the plant. Getaneh *et al*. (2016) reported that the highest above ground dry biomass yields per plant was occurred at the widest inter and intra-row spacing might be due to high stem diameter and high leaf area because there was more availability of growth factors and better penetration of light at wider row spacing.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 12. Effect of different spacings on dry matter weight plant^{-1} of white maize at different DAS ($LSD_{(0.05)}$ = 0.12, 0.62, 1.64, 3.08 and 5.75 g at 20, 40, 60, 80 DAS and at harvest respectively)

Combined effect of fertilizer dose and spacing

Different fertilizer doses combined with different spacings had a significant effect on the dry weight plant^{-1} of white maize at various DAS (Table 6). According to experimental results, the F_4S_1 treatment combination had the highest dry weight plant^{-1} (5.48, 28.68, 55.60, 166.00 and 193.67 g) at 20, 40, 60, 80 DAS and at harvest respectively. This combination was statistically similar with F_3S_1 (52.53, 165.15 and 192.67 g) at 60, 80 DAS and at harvest respectively and with F_2S_1 (184.67 g) treatment combination at harvest respectively. However the lowest dry weight plant^{-1} (1.46, 8.58, 28.58, 90.44 and 112.33 g) at 20, 40, 60, 80 DAS and at harvest respectively was found in F_1S_3 treatment combination and it was statistically comparable to F_2S_3 (1.65, 29.72 and 114.00g) at 20, 60 DAS and at harvest respectively and with F_3S_3 (30.95 and 115.33 g) treatment combination at 60 DAS and at harvest respectively.

Table 6. Combined effect of fertilizer doses and different spacing on dry matter weight plant^{-1} white maize at different DAS

Treatment combinations	Dry matter weight plant^{-1} (g) at				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
F_1S_1	4.06 b	21.87 c	48.27 c	153.44 b	179.00 b
F_1S_2	3.40 d	10.61 h	35.85 e	125.72 d	146.67 d
F_1S_3	1.46 g	8.58 i	28.58 g	90.44 g	112.33 f
F_2S_1	4.19 b	25.28 b	51.88 b	158.29 b	184.67 ab
F_2S_2	3.42 d	11.88 gh	37.53 e	135.71 c	158.33 c
F_2S_3	1.65 g	10.65 h	29.72 g	97.71 f	114.00 f
F_3S_1	4.23 b	25.65 b	52.53 ab	165.15 a	192.67 a
F_3S_2	3.70 c	15.83 f	41.48 d	135.71 c	158.33 c
F_3S_3	1.94 f	12.83 g	30.95 fg	98.85 f	115.33 f
F_4S_1	5.48 a	28.68 a	55.60 a	166.00 a	193.67 a
F_4S_2	3.98 b	20.52 d	46.34 c	139.99 c	163.33 c
F_4S_3	2.98 e	17.44 e	34.15 ef	113.14 e	132.00 e
$LSD_{(0.05)}$	0.25	1.33	3.42	6.21	10.75
CV (%)	4.32	4.12	4.63	2.71	4.31

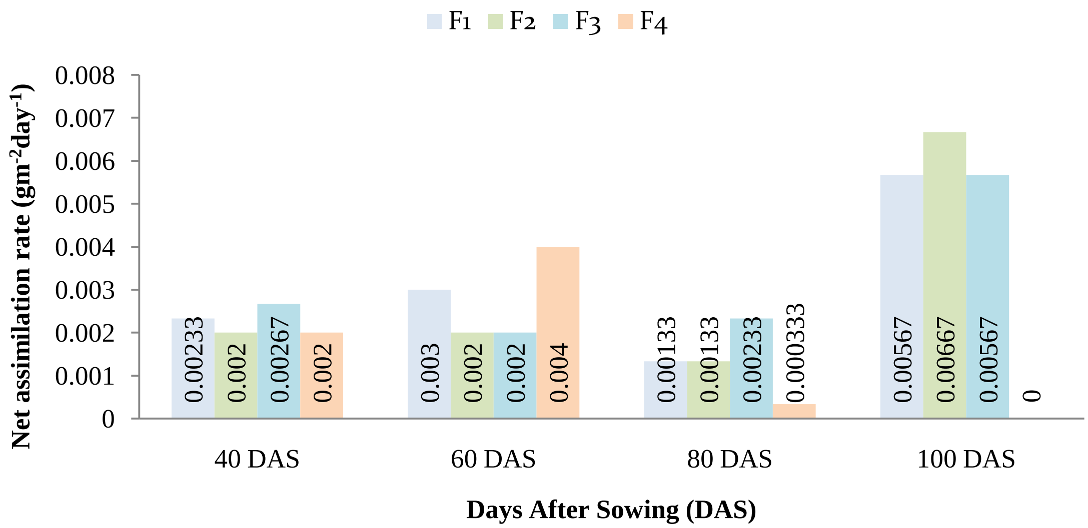
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

4.5 Derived dry matter analysis

4.5.1 Net assimilation rate

Effect of fertilizer dose

Net assimilation rate describes the net-production efficiency of the assimilatory apparatus. Different rate of fertilizer application significantly influenced on net assimilation rate of white maize at different days after sowing (Figure 13). Experimental result revealed that at 40 DAS the highest net assimilation rate (0.00267 $gm^{-2}day^{-1}$) was found in F_3 treatment. At 60 DAS the highest net assimilation rate (0.004 $gm^{-2}day^{-1}$) was found in F_4 treatment. At 80 DAS the highest net assimilation rate (0.00233 $gm^{-2}day^{-1}$) was found in F_3 treatment and at 100 DAS the highest net assimilation rate (0.00667 $gm^{-2}day^{-1}$) was found in F_2 treatment. While at 40 DAS the lowest net assimilation rate (0.00200 $gm^{-2}day^{-1}$) was found in F_4 treatment which was statistically similar with F_2 treatment (0.00200 $gm^{-2}day^{-1}$). At 60 DAS the lowest net assimilation rate (0.002 $gm^{-2}day^{-1}$) was found in F_2 treatment which was statistically similar with F_3 treatment (0.002 $gm^{-2}day^{-1}$). At 80 DAS the lowest net assimilation rate (0.000333 $gm^{-2}day^{-1}$) was found in F_4 treatment and at 100 DAS the lowest net assimilation rate (0.00567 $gm^{-2}day^{-1}$) was found in F_1 treatment which was statistically similar with F_3 treatment (0.00567 $gm^{-2}day^{-1}$). Increase in net assimilation rate enhances photosynthetic capacity of leaves with improved nutrition of the plants thereby increasing dry matter accumulation at final harvest. It might be due to the maximum leaf area index and crop growth rate with the same treatment, which enhanced the rate of accumulation of assimilates. Similar result also observed by Shukla and Warsi (2000) who reported that the highest net assimilation rate with the application of Zn along with NPK.

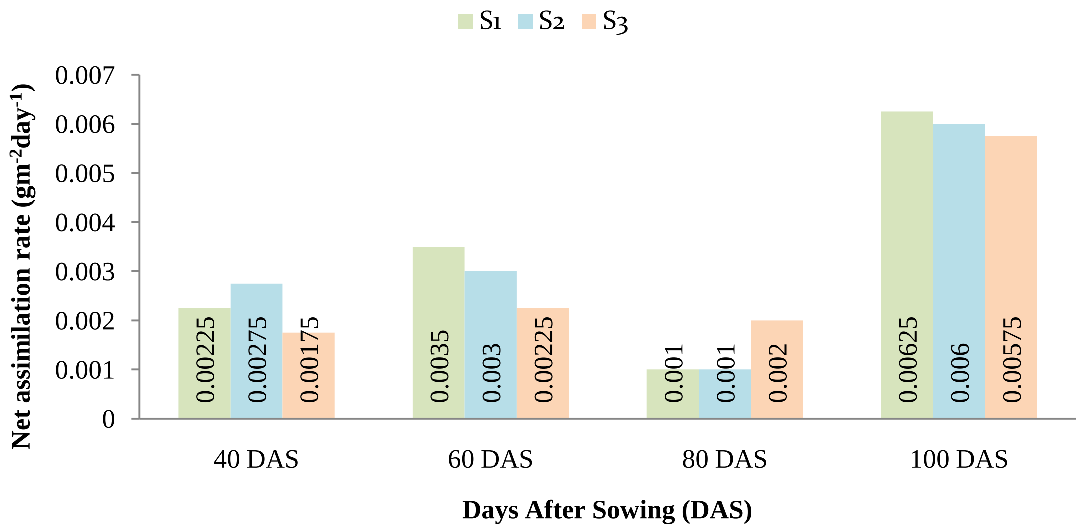


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 13. Effect of fertilizer dose on net assimilation rate of white maize at different DAS (LSD$_{(0.05)}$ = 0.00006, 0.0000001, 0.00009 and 0.00007 gm^{-2} day^{-1}at 40, 60, 80 and 100 DAS)

Effect of spacing

Different spacing significantly influenced on net assimilation rate of white maize at different days after sowing (Figure 14). Experimental result revealed that at 40 DAS the highest net assimilation rate (0.00275 gm^{-2}day^{-1}) was found in S_2 treatment. At 60 DAS the highest net assimilation rate (0.00350 gm^{-2}day^{-1}) was found in S_1 treatment. At 80 DAS the highest net assimilation rate (0.002 gm^{-2}day^{-1}) was found in S_3 treatment and at 100 DAS the highest net assimilation rate (0.00625 gm^{-2}day^{-1}) was found in S_1 treatment. While at 40 and 60 DAS the lowest net assimilation rate (0.00175 AND 0.00225 gm^{-2}day^{-1}) was found in S_3 treatment. At 80 DAS the lowest net assimilation rate (0.001 gm^{-2}day^{-1}) was found in S_1 treatment which was statistically similar with S_2 treatment (0.001 gm^{-2}day^{-1}) and at 100 DAS the lowest net assimilation rate (0.00575 gm^{-2}day^{-1}) was found in S_3 treatment. The result obtained from the present study was similar with the findings of Sridevi and Chellamuthu (2015) and they reported that in general, the rectangular planting with closer spacing recorded lesser NAR than square planting with wider spacing at all the growth stages. Reduction in NAR could be attributed to less leaf area and shortage of other growth factors (nutrient, space, water etc).



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 14. Effect of different spacings on net assimilation rate of white maize at different DAS ($LSD_{(0.05)}$ = 0.00004, 0.00008, 0.00007 and 0.00007 gm^{-2} day^{-1}at 40, 60, 80 and 100 DAS)

Combined effect of fertilizer dose and spacing

Different rate of fertilizer application along with spacing, significantly influenced net assimilation rate of white maize at different days after sowing (Table 7). Experimental result revealed that at 40 DAS the highest net assimilation rate (0.003 gm^{-2}day^{-1}) was found in F_1S_1 treatment combination, which was statistically similar with F_1S_2 (0.003 gm^{-2}day^{-1}), F_2S_2 (0.003 gm^{-2}day^{-1}), F_3S_2 (0.003 gm^{-2}day^{-1}) and F_3S_3 (0.003 gm^{-2}day^{-1}) treatment combination. At 60 DAS the highest net assimilation rate (0.005 gm^{-2}day^{-1}) was found in F_4S_2 treatment combination. At 80 DAS the highest net assimilation rate (0.003 gm^{-2}day^{-1}) was found in F_3S_3 treatment combination and at 100 DAS the highest net assimilation rate (0.007 gm^{-2}day^{-1}) was found in F_2S_1 treatment combination which was statistically similar with F_2S_2 (0.007 gm^{-2}day^{-1}) and F_4S_1 (0.007 gm^{-2}day^{-1}) treatment combination. However at 40 DAS the lowest net assimilation rate (0.001 gm^{-2}day^{-1}) was found in F_1S_3 treatment combination which was statistically similar with F_2S_3 (0.001 gm^{-2}day^{-1}). At 60 DAS the lowest net assimilation rate (0.002 gm^{-2}day^{-1}) was found in F_1S_3 treatment combination which was statistically similar with F_2S_2 (0.001 gm^{-2}day^{-1}), F_2S_3 (0.001 gm^{-2}day^{-1}), F_3S_2 (0.001 gm^{-2}day^{-1}) and F_3S_3 (0.001 gm^{-2}day^{-1}) treatment combination. At 80 DAS the lowest net assimilation rate (0.00 $gm^{-2}day^{-1}$) was found in F_4S_1 treatment combination which was statistically similar with F_4S_2 (0.001 $gm^{-2}day^{-1}$) treatment combination and at 100 DAS the lowest net assimilation rate (0.005 $gm^{-2}day^{-1}$) was found in F_1S_2 treatment combination which was statistically similar with F_3S_1 (0.005 $gm^{-2}day^{-1}$) and F_4S_3 (0.005 $gm^{-2}day^{-1}$) treatment combination.

Table 7. Combined effect of fertilizer doses and different spacing on net assimilation rate (NAR) of white maize at different DAS

Treatment combinations	Net assimilation rate (g $m^{-2}day^{-1}$)			
	40 DAS	60 DAS	80 DAS	100 DAS
F_1S_1	0.003 a	0.004 b	0.001 c	0.006 b
F_1S_2	0.003 a	0.003 c	0.001 c	0.005 c
F_1S_3	0.001 c	0.002 d	0.002 b	0.006 b
F_2S_1	0.002 b	0.003 c	0.001 c	0.007 a
F_2S_2	0.003 a	0.002 d	0.001 c	0.007 a
F_2S_3	0.001 c	0.002 d	0.002 b	0.006 b
F_3S_1	0.002 b	0.003 c	0.002 b	0.005 c
F_3S_2	0.003 a	0.002 d	0.002 b	0.006 b
F_3S_3	0.003 a	0.002 d	0.003 a	0.006 b
F_4S_1	0.002 b	0.004 b	0.00 d	0.007 a
F_4S_2	0.002 b	0.005 a	0.00 d	0.006 b
F_4S_3	0.002 b	0.003 c	0.001 c	0.005 c
$LSD_{(0.05)}$	0.0001	0.0001	0.0001	0.0001
CV (%)	2.57	3.43	6.50	3.36

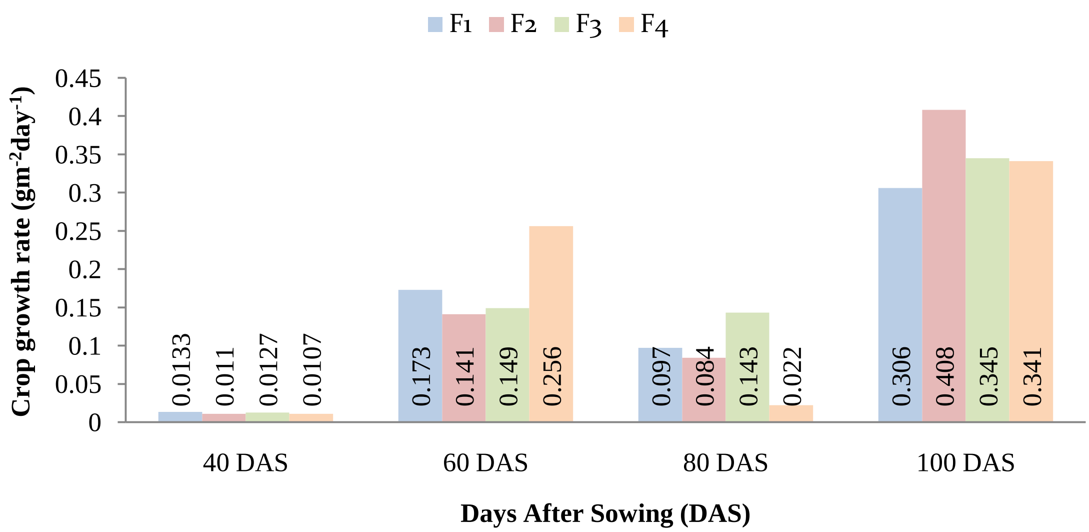
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm.

4.5.2 Crop growth rate

Effect of fertilizer dose

Different rate of fertilizer application significantly influenced on crop growth rate of white maize at different days after sowing (Figure 15). Experimental result revealed that at 40 DAS the highest crop growth rate (0.0133 $gm^{-2}day^{-1}$) was found in F_1 treatment. At 60 DAS the highest crop growth rate (0.256 $gm^{-2}day^{-1}$) was found in F_4 treatment. At 80 DAS the highest crop growth rate (0.143 $gm^{-2}day^{-1}$) was found in F_3 treatment and at 100 DAS the highest crop growth rate (0.408 $gm^{-2}day^{-1}$) was found in F_2 treatment. While at

40 DAS the lowest crop growth rate (0.0107 $gm^{-2}day^{-1}$) was found in F_4 treatment. At 60 DAS the lowest crop growth rate (0.141 $gm^{-2}day^{-1}$) was found in F_2 treatment. At 80 DAS the lowest crop growth rate (0.022 $gm^{-2}day^{-1}$) was found in F_4 treatment and at 100 DAS the lowest crop growth rate (0.306 $gm^{-2}day^{-1}$) was found in F_1 treatment. The increase in CGR ultimately increased total dry matter at the end of growing season. Rahman *et al*., (2000) reported that the increase in CGR at higher N levels was mainly due to larger LAI, since CGR is a product of the LAI and Net Assimilation Rate (NAR). Nitrogen application created a significant impact on leaf photosynthesis, leaf area index, and crop growth rate and biomass production of wheat. Gulser, (2005) reported that high nitrogen levels increased leaf area, leaf number and vegetative growth of plants thus increasing the photosynthetic capacity; consequently the higher dry matter produced increasing crop growth rate (CGR).

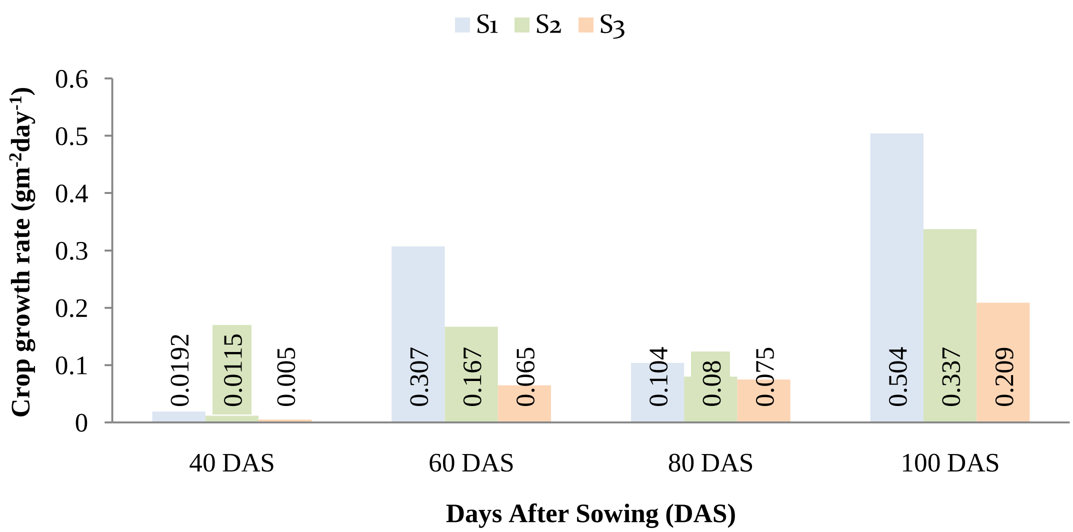


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 15. Effect of fertilizer dose on crop growth rate of white maize at different DAS ($LSD_{(0.05)}$ = 0.003, 0.009, 0.004 and 0.007$gm^{-2}day^{-1}$at 40, 60, 80 and 100 DAS)

Effect of spacing

Different spacing significantly influenced on crop growth rate of white maize at different days after sowing (Figure 16). Experimental result revealed that the highest crop growth rate (0.0192, 0.307, 0.104 and 0.504 $gm^{-2}day^{-1}$) at 40, 60, 80 and 100 DAS respectively were found in S_1 treatment. While at the lowest crop growth rate (0.0050, 0.065,0.075 and 0.209 $gm^{-2}day^{-1}$) at 40, 60, 80 and 100 DAS were found in S_3 treatment. Ashraf *et al.* (2014) reported that the maximum CGR was attained in widest plant spacing while closest spacing resulted in minimum growth rate of crop under both conditions weedy and weed free. Lowest CGR was found in the closest spacing which might be to due maximum intra plant competition for acquisition of resources and ultimately crop growth rate declined.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 16. Effect of different spacings on crop growth rate of white maize at different DAS ($LSD_{(0.05)}$ = 0.003, 0.004, 0.002 and 0.004$gm^{-2}day^{-1}$ at 40, 60, 80 and 100 DAS)

Combined effect of fertilizer dose and spacing

Different rate of fertilizer application along with spacing, significantly influenced crop growth rate of white maize at different days after sowing (Table 8). Experimental result revealed that at 40 DAS the highest crop growth rate (0.024 $gm^{-2}day^{-1}$) was found in F_1S_1

treatment combination. At 60 DAS the highest crop growth rate (0.392 $gm^{-2}day^{-1}$) was found in F_4S_1 treatment combination. At 80 DAS the highest crop growth rate (0.175 $gm^{-2}day^{-1}$) was found in F_3S_1 treatment combination and at 100 DAS the highest crop growth rate (0.585 $gm^{-2}day^{-1}$) was found in F_2S_1 treatment combination. However at 40 DAS the lowest crop growth rate (0.004 $gm^{-2}day^{-1}$) was found in F_2S_3 treatment combination. At 60 DAS the lowest crop growth rate (0.046 $gm^{-2}day^{-1}$) was found in F_2S_3 treatment combination. At 80 DAS the lowest crop growth rate (0.001 $gm^{-2}day^{-1}$) was found in F_4S_2 treatment combination and at 100 DAS the lowest crop growth rate (0.178 $gm^{-2}day^{-1}$) was found in F_4S_3 treatment combination.

Table 8. Combined effect of fertilizer doses and different spacing on crop growth rate of white maize at different DAS

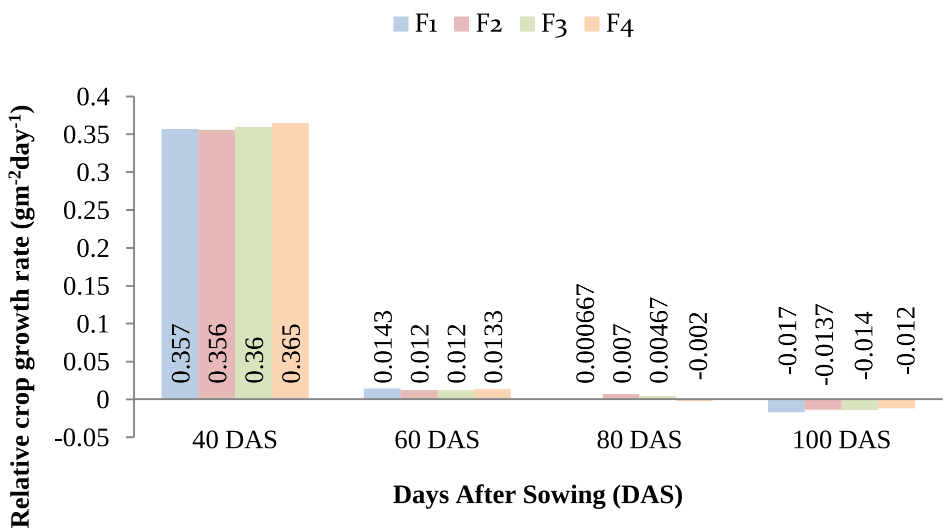
Treatment combinations	Crop growth rate (g $m^{-2}day^{-1}$) at			
	40 DAS	60 DAS	80 DAS	100 DAS
F_1S_1	0.024 a	0.303 b	0.120 c	0.444 d
F_1S_2	0.013 d	0.163 f	0.082 f	0.274 h
F_1S_3	0.003 j	0.053 j	0.090 e	0.199 k
F_2S_1	0.017 c	0.259 e	0.098 d	0.585 a
F_2S_2	0.012 e	0.119 h	0.086 ef	0.416 e
F_2S_3	0.004 i	0.046 l	0.067 g	0.224 j
F_3S_1	0.018 b	0.273 c	0.175 a	0.455 c
F_3S_2	0.012 e	0.124 g	0.151 b	0.345 f
F_3S_3	0.008 g	0.050 k	0.102 d	0.235 i
F_4S_1	0.018 b	0.392 a	0.024 i	0.532 b
F_4S_2	0.009 f	0.263 d	0.001 j	0.312 g
F_4S_3	0.005 h	0.112 i	0.040 h	0.178 l
$LSD_{(0.05)}$	0.007	0.001	0.005	0.009
CV (%)	3.83	4.28	4.01	3.61

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm.

4.5.3 Relative growth rate, RGR

Effect of fertilizer dose

Different rate of fertilizer application significantly influenced on relative crop growth rate of white maize at different days after sowing (Figure 17). Experimental result revealed that at 40 DAS the highest crop growth rate (0.365 $gm^{-2}day^{-1}$) was found in F_4 treatment which was statistically similar with F_3 (0.360 $gm^{-2}day^{-1}$) treatment. At 60 DAS the highest relative crop growth rate (0.0143 $gm^{-2}day^{-1}$) was found in F_1 treatment. At 80 DAS the highest relative crop growth rate (0.00700 $gm^{-2}day^{-1}$) was found in F_2 treatment and at 100 DAS the highest relative crop growth rate (-0.0120 $gm^{-2}day^{-1}$) was found in F_1 treatment. While at 40 DAS the lowest relative crop growth rate (0.356 $gm^{-2}day^{-1}$) was found in F_2 treatment which was statistically similar with F_1 (0.357 $gm^{-2}day^{-1}$) treatment. At 60 DAS the lowest relative crop growth rate (0.0120 $gm^{-2}day^{-1}$) was found in F_2 treatment which was statistically similar with F_3 (0.0120 $gm^{-2}day^{-1}$) treatment. At 80 DAS the lowest relative crop growth rate (-0.00200 $gm^{-2}day^{-1}$) was found in F_4 treatment and at 100 DAS the lowest relative crop growth rate (-0.0170 $gm^{-2}day^{-1}$) was found in F_1 treatment.



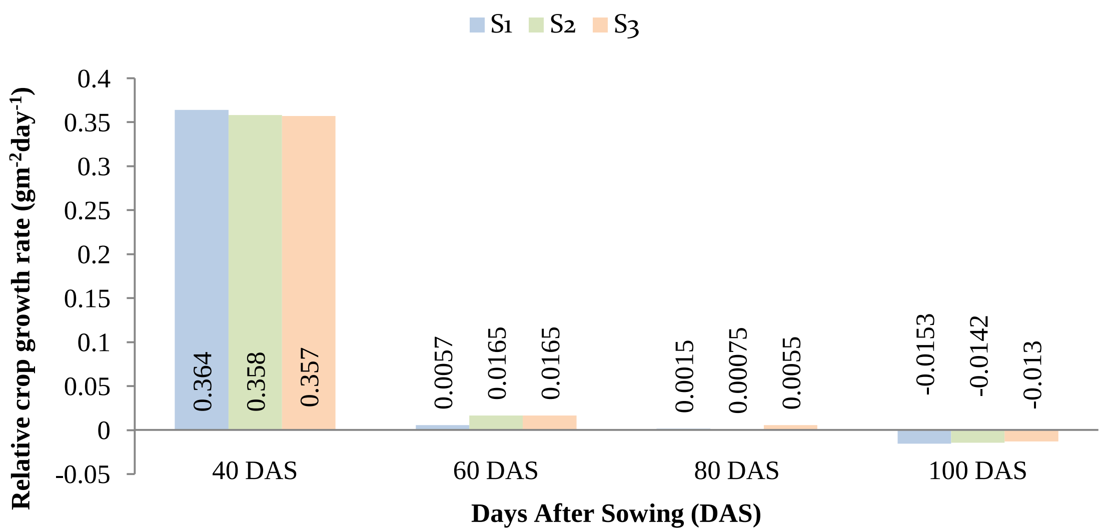
Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 17. Effect of fertilizer dose on relative crop growth rate of white maize at different DAS ($LSD_{(0.05)}$ = 0.006, 0.0006, 0.00006 and 0.0006 $gm^{-2}day^{-1}$at 40, 60, 80 and 100 DAS)

Effect of spacing

Different spacing significantly influenced on relative crop growth rate of white maize at different days after sowing (Figure 18). Experimental result revealed that the highest relative crop growth rate (0.364 $gm^{-2}day^{-1}$) at 40 DAS were found in S_1 treatment. At 60, 80 and 100 DAS the highest relative crop growth rate (0.0165, 0.00550 and -0.0130 $gm^{-2}day^{-1}$ respectively) was found in S_3 treatment. While the lowest crop growth rate (0.357 $gm^{-2}day^{-1}$) at 40 DAS was found in S_3 treatment which was statistically similar with S_2

(0.358 gm^{-2} day^{-1}) treatment. At 60 DAS the lowest relative crop growth rate (0.0057 $gm^{-2}day^{-1}$) was found in S_1 treatment. At 80 DAS the lowest relative crop growth rate (0.000750 gm^{-2} day^{-1}) was found in S_2 treatment. and at 100 DAS the lowest relative crop growth rate (-0.0153 $gm^{-2}day^{-1}$) was found in S_1 treatment.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 18. Effect of different spacings on relative crop growth rate of white maize at different DAS ($LSD_{(0.05)}$ = 0.004, 0.0005, 0.00004 and 0.0005 $gm^{-2}day^{-1}$ at 40, 60, 80 and 100 DAS)

Combined effect of fertilizer dose and spacing

Different rate of fertilizer application along with spacing, significantly influenced relative crop growth rate of white maize at different days after sowing (Table 9). Experimental result revealed that at 40 DAS the highest relative crop growth rate (0.368 $gm^{-2}day^{-1}$) was found in F_4S_1 treatment combination which was statistically similar with F_1S_1 (0.362 $gm^{-2}day^{-1}$), F_2S_1 (0.361 $gm^{-2}day^{-1}$), F_3S_1 (0.363 $gm^{-2}day^{-1}$), F_3S_3 (0.360 $gm^{-2}day^{-1}$), F_4S_2 (0.366 $gm^{-2}day^{-1}$) and F_4S_3 (0.361 $gm^{-2}day^{-1}$) treatment combination. At 60 DAS the highest relative crop growth rate (0.022 $gm^{-2}day^{-1}$) was found in F_4S_3 treatment combination which was statistically similar with F_1S_3 (0.021 $gm^{-2}day^{-1}$) and F_2S_2 (0.021 $gm^{-2}day^{-1}$) treatment combination. At 80 DAS the highest relative crop growth rate (0.013 $gm^{-2}day^{-1}$) was found in F_2S_3 treatment combination and at 100 DAS the highest relative crop growth rate (-0.010 $gm^{-2}day^{-1}$) was found in F_3S_3 treatment combination which was statistically similar with F_4S_1 (-0.011 $gm^{-2}day^{-1}$) and F_4S_2 (-0.011 $gm^{-2}day^{-1}$). However at 40 DAS the lowest relative crop growth rate (0.352 $gm^{-2}day^{-1}$) was found in F_1S_3 treatment combination which was statistically similar with F_1S_2 (0.357 $gm^{-2}day^{-1}$), F_2S_2 (0.353 $gm^{-2}day^{-1}$), F_2S_3 (0.353 $gm^{-2}day^{-1}$) and F_3S_2 (0.357 $gm^{-2}day^{-1}$) treatment combination. At 60 DAS the lowest relative crop growth rate (0.005 $gm^{-2}day^{-1}$) was found in F_1S_1 treatment combination which was statistically similar with F_2S_1 (0.005 $gm^{-2}day^{-1}$) and F_4S_1 (0.006 $gm^{-2}day^{-1}$) treatment combination. At 80 DAS the lowest relative crop growth rate (-0.00400 $gm^{-2}day^{-1}$) was found in F_4S_2 treatment combination and at 100 DAS the lowest net assimilation rate (-0.021 $gm^{-2}day^{-1}$) was found in F_1S_2 treatment combination.

Table 9. Combined effect of fertilizer doses and different spacing on relative crop growth rate of white maize at different DAS

Treatment combinations	Relative growth rate, RGR (g $m^{-2}day^{-1}$) at			
	40 DAS	60 DAS	80 DAS	100 DAS
F_1S_1	0.362 a-c	0.005 f	-0.00100 f	-0.016 f
F_1S_2	0.357 b-d	0.017 b	0.0000 e	-0.021 h
F_1S_3	0.352 d	0.021 a	0.00300 d	-0.014 de
F_2S_1	0.361 a-d	0.005 f	0.00400 c	-0.015 ef
F_2S_2	0.353 cd	0.021 a	0.00400 c	-0.012 bc
F_2S_3	0.353 cd	0.010 d	0.013 a	-0.014 de
F_3S_1	0.363 a-c	0.007 e	0.00400 c	-0.019 g
F_3S_2	0.357 b-d	0.016 b	0.0030 d	-0.013 cd
F_3S_3	0.360 a-d	0.013 c	0.00700 b	-0.010 a
F_4S_1	0.368 a	0.006 ef	-0.00100 f	-0.011 ab
F_4S_2	0.366 ab	0.012 c	-0.00400 g	-0.011 ab
F_4S_3	0.361 a-d	0.022 a	-0.00100 f	-0.014 de
$LSD_{(0.05)}$	0.10	0.001	0.0001	0.001
CV (%)	1.61	5.00	2.33	4.56

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm.

4.6. Trend of total dry matter accumulation under phenomena of varying spacing and fertilizer application

The trend of the dry matter accumulation over the ages of the crop plants can be explained fitting data in the regression analysis. In this study, total dry matter weight was fitted to time (DAS) and it was observed that data were best fitted taking the form 'exponential growth'. Exponential growth is a process that increases quantity of the data over time. It occurs when the instantaneous rate of change (that is, the derivative) of a quantity with respect to time is proportional to the quantity itself. Described as a function, a quantity undergoing exponential growth is an exponential function of time, that is, the variable representing time is the exponent (in contrast to other types of growth, such as quadratic growth) (https://en.wikipedia.org/wiki/Exponential_growth). The general form of exponential functions is $y = ab^x$, where '*a'* is the '*y'*-intercept and '*b'* is the growth factor. The exponential functions have the form $y=ab^x$ or $y=A0\ e^{kx}$, where A0 is equal to the value at time zero, e is Euler's constant, and k is a positive constant that determines the rate (percentage) of growth (https://pivot.utsa.edu/mathmatters/wp-content/uploads/sites/5 /2017/08/College_Algebra-OP-Sec-6-7.pdf). In the case of exponential function, $a > 0$) (https://courses.lumenlearning.com/way maker collegea lgebra/chapter/exp onential-and-logarithmic-regression/).'*x'* represents time. Exponential growth functions increase as '*x'* gets larger, while decay functions (Exponential decay) decrease as '*x'* gets larger *(https://study.com/learn/lesson/expone ntial-function-pro perties-formula. html).*

In this study, the total dry matter data at different growth stages were fitted to different days after sowing (DAS) using regression analysis. It was observed that data were best fitted in exponential growth of the dry matter with the increase of the plant's age (DAS). The trend of change of the total dry matter accumulation was similar. However, the value of 'a' (starting value of Y at the time zero) or A0, that of 'e' (Euler's constant), and k (positive constant that determines the rate [percentage] of growth) differed due to the effect of spacing, fertilizer and their interaction. In this experiment, Y represents dry matter accumulation, while 'x' denotes 'time or DAS'. In the exponential growth nature, in the initial growth phage, the curve lies on the 'x' axis almost horizontally and thereafter in the advanced ages, it increases rapidly with a steep at the end. These phenomena are described below:

Under the phenomenon of varying spacings in the field

Change of dry matter of the whole plants over the time increased exponentially. That is at the initial days (up to 40 DAS), the rate of dry matter increase was very slow (Figure 19). But the rate increased gradually with the increase of time or age of the plants following the model y = A0 e^{kx}. The exponential ('expon.' in the legend) curve below (Fig.) with the phenomenon of varying spacings (using data with the spacing, S_1, S_2 and S_3) had the starting value of Y at the time zero ('a' or 'A0') was 0.180; the value of the positive constant (k) was 1.461 and that of the regression coefficient was 0.916.

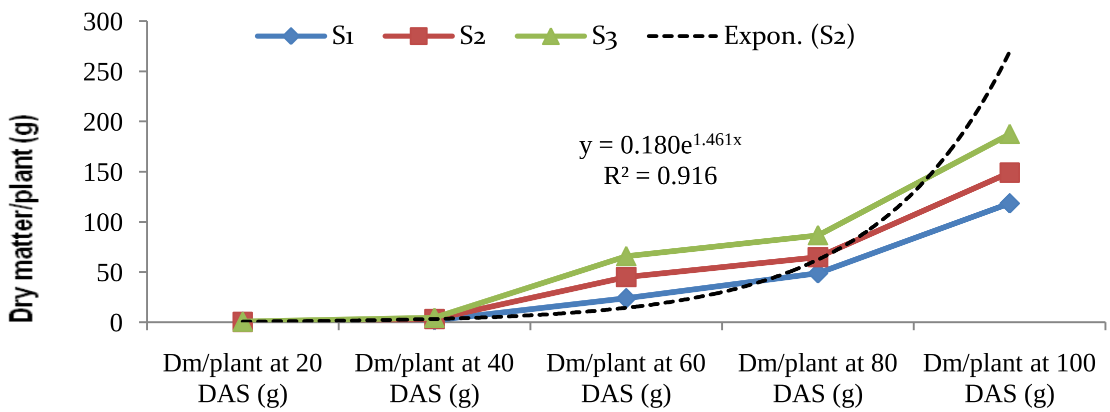


Figure 19. Effect of varying various spacings on the change of dry matter of the whole plants over the time increased exponentially

Under the phenomenon of varying fertilizer doses in the field

Like in the phenomenon of varying spacings, the change of dry matter of the whole plants over the time (DAS) increased exponentially (Figure 20). That is, at the initial days (up to 60 DAS), the rate of dry matter increase was very slow which was found to be lying up to the growth 40 DAS stage with the phenomenon of varying spacing. Similar to that of the spacing, under this varied fertilizer phenomeno, the rate of dry matter also increased gradually with the increase of time or age of the plants following the model $y = A0\ e^{kx}$. The exponential ('expon.' in the legend) curve below (Figure 19) with the phenomenon of varying spacing (using data with the fertilizer treatments, F_1, F_2, f_3 and S_4) had the starting value of Y at the time zero ('a' or 'A0') was 0.057 (very smaller than that with the varied spacing which was 0.180); the value of the positive constant (k) was 1.45 (almost same with the varied spacing which was 1.461) and that of the regression coefficient was 0.93 (higher compared to that with the varied spacing which was 0.916).

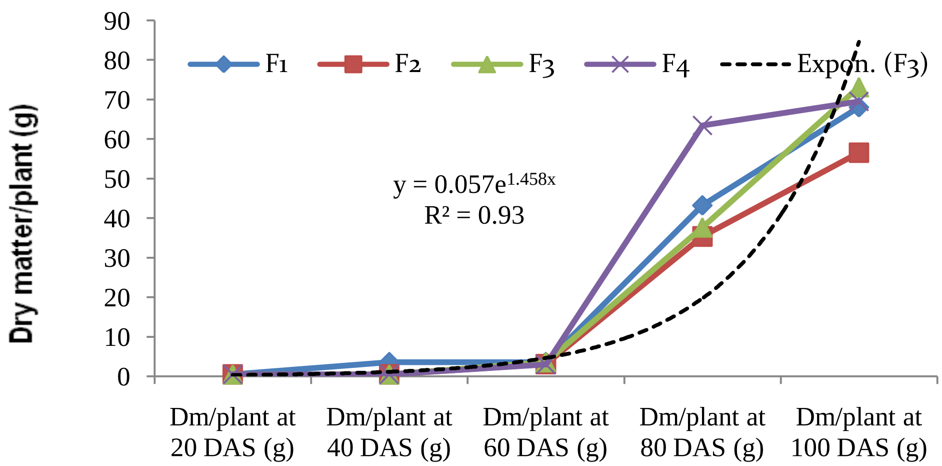


Figure 20. Effect of varying fertilizer application on the change of dry matter of the whole plants over the time (DAS) increased exponentially

Under the interactive phenomenon of varying fertilizer doses in the field

Like in the phenomenon of varying spacing and fertilizer application, the change of dry matter of the whole plants over the time (DAS) increased exponentially (Figure 21). That is, at the initial days (up to 60 DAS), the rate of dry matter increase was very slow which was found to be lying up to the growth 40 DAS stage with the phenomenon of varying spacing. That is, the trend of total dry matter accumulation mostly followed that of the Similar to that both of the spacing and fertilizer application, under this varied interactive effect of spacing and fertilizer phenomenon, the rate of dry matter also increased gradually with the increase of time or age of the plants following the model $y = A0\ e^{kx}$. The exponential (‘expon.’ in the legend) curve below (Fig.) with the phenomenon of varying spacing (using interaction data with the spacing and fertilizer) had the starting value of Y at the time zero (‘a’ or ‘A0’) was 0.169 (comparable to that with the varied spacing which was 0.180); the value of the positive constant (k) was 1.47 (almost comparable with that of the varied spacing which was 1.461) and that of the regression coefficient was 0.94 (higher compared to that with the varied spacing which was 0.916 and fertilizer application, 0.93).

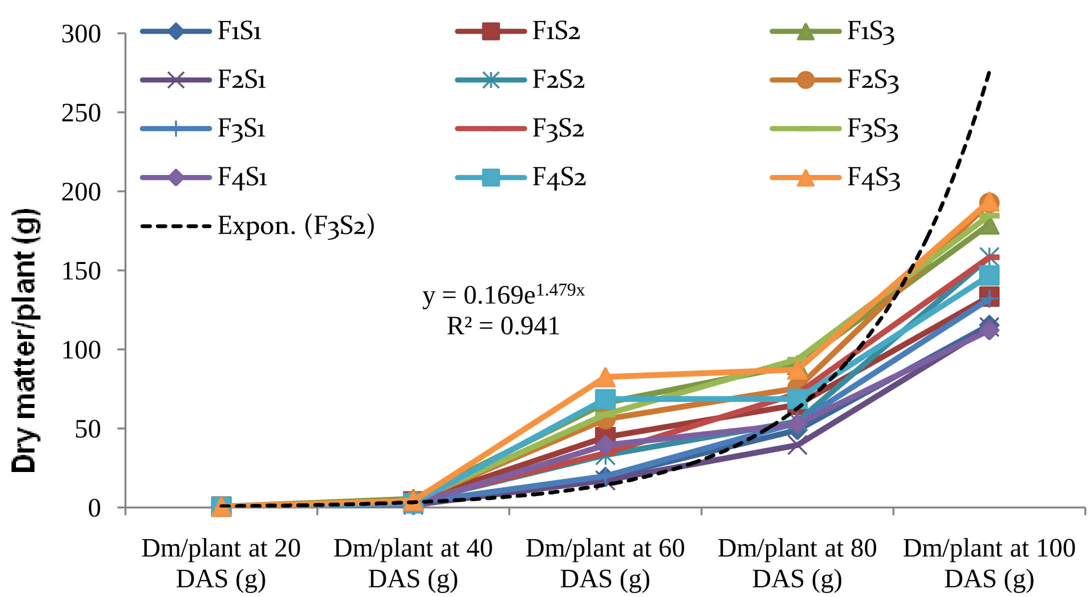


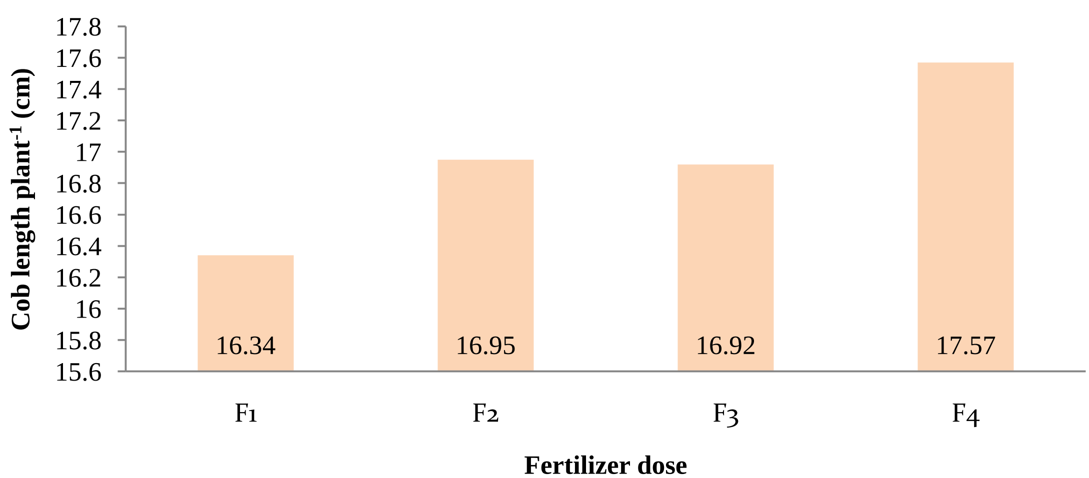
Figure 21. Combined effect of varying fertilizer application and spacingon, the change of dry matter of the whole plants over the time (DAS) increased exponentially

4.7 Yield contributing characters

4.7.1 Cob length plant^{-1}

Effect of fertilizer dose

The different rate of application significantly affected the cob length plant^{-1} of white maize (Figure 22). Experimental result revealed that the highest cob length plant^{-1} (17.57 cm) was found in F_4 treatment which was comparable to F_3 (16.92 cm) and F_2 (16.95 cm) treatment. Whereas the lowest cob length plant^{-1} (16.34) was found in F_1 treatment. This might be due to an increase in cell elongation and more vegetative growth attributed to crop requirements of the additional fertilizer nutrients (*i.e*. NPK) for its normal physiological growth. On the other hand, the shortest cob length in the lower fertilized plots might have been due to the low level of those essential nutrients in the soil for crop requirements. Suryavanshi *et al*. (2008) reported an increase in cob length, of maize with application of 150 kg N ha^{-1} over 100 and 50 kg N ha^{-1} on Vertisols of MAU, Parbhani. Kar *et al*. (2006) reported that incresed fertilizer application significantly influenced cob length of maize.

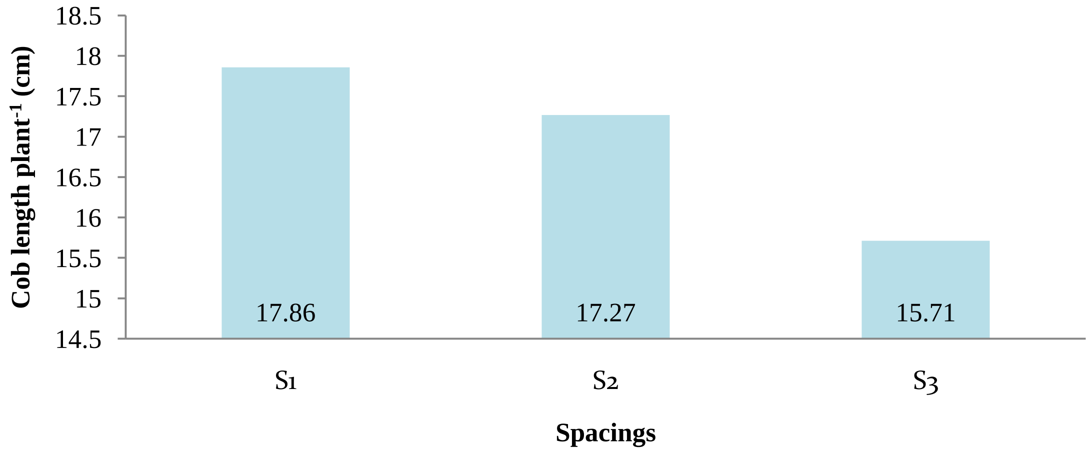


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 22. Effect of fertilizer dose on cob length plant^{-1} of white maize ($LSD_{(0.05)}$ = 0.68 cm)

Effect of spacing

The different spacing had shown significant effect on the cob length plant^{-1} of white maize (Figure 23). Experimental result revealed that the highest cob length plant^{-1} (17.86 cm) was found in S_1 treatment. Whereas the lowest cob length plant^{-1} (15.71 cm) was found in S_3 treatment. Increase in cob length plant^{-1} might due to less competition between plant at optimum spacing and also availability of nutrient in adequate amount resulted in formation of photosynthesis, which promote metabolic activity, increase the cell division, ultimately increase the cob length plant^{-1}. Koirala *et al*. (2020) founded that the highest cob length was reported when maize was planted in the row spacing 60×25 cm.



Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 23. Effect of different sapcings on cob length plant^{-1} of white maize ($LSD_{(0.05)}$ = 0.51 cm)

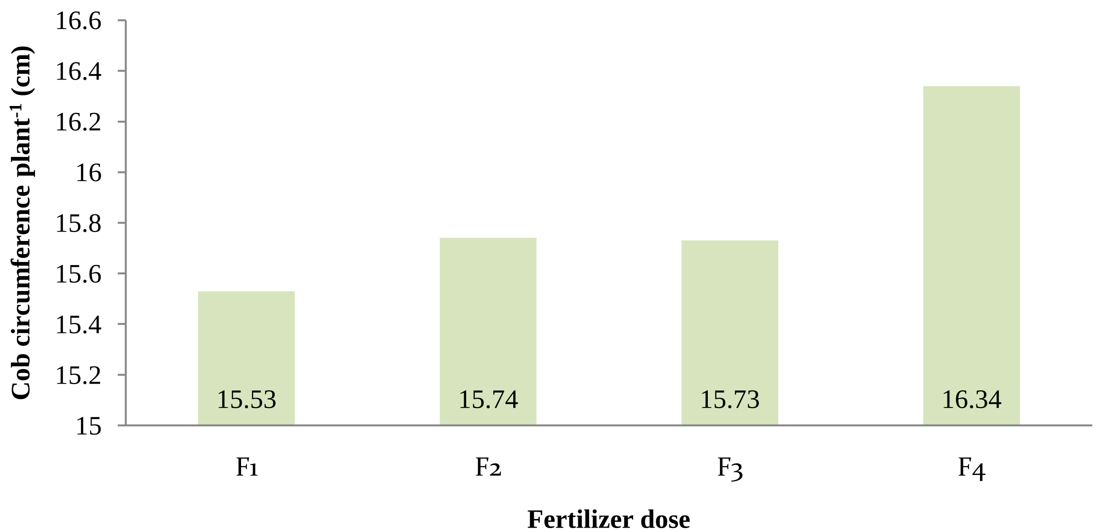
Combined effect of fertilizer dose and spacing

Combined effect of fertilizer application doses and spacing had shown significant effect on the cob length plant^{-1} of white maize (Table 10). Experimental result showed that the highest cob length plant^{-1} (18.57 cm) was found in F_4S_1 treatment combination which was statistically similar with F_3S_1 (17.92 cm), F_2S_1 (17.67 cm) and F_4S_2 (17.67 cm) treatment combination. While the lowest cob length plant^{-1} (14.80 cm) was found in F_1S_3 treatment combination which was statistically similar with F_2S_3 (15.85 cm) and F_3S_3 (15.70 cm) treatment combination.

4.7.2 Cob circumference plant^{-1}

Effect of fertilizer dose

The cob circumference plant^{-1} of white maize was significantly influenced by the various rate of fertilizer application (Figure 24). The results of the experiment showed that the F_4 treatment had the highest cob circumference plant^{-1} (16.34 cm). However the F_1 treatment had the lowest cob circumference plant^{-1} (15.53 cm) which was comparable to F_3 (15.74 cm) and F_2 (15.74 cm) treatment. The result was similar with the findings of Thakur *et al.* (2010) who reported that the application of 100:50:50 kg NPK ha^{-1} recorded significantly more cob diameter of maize over FYM alone and FYM + Azospirillum application.

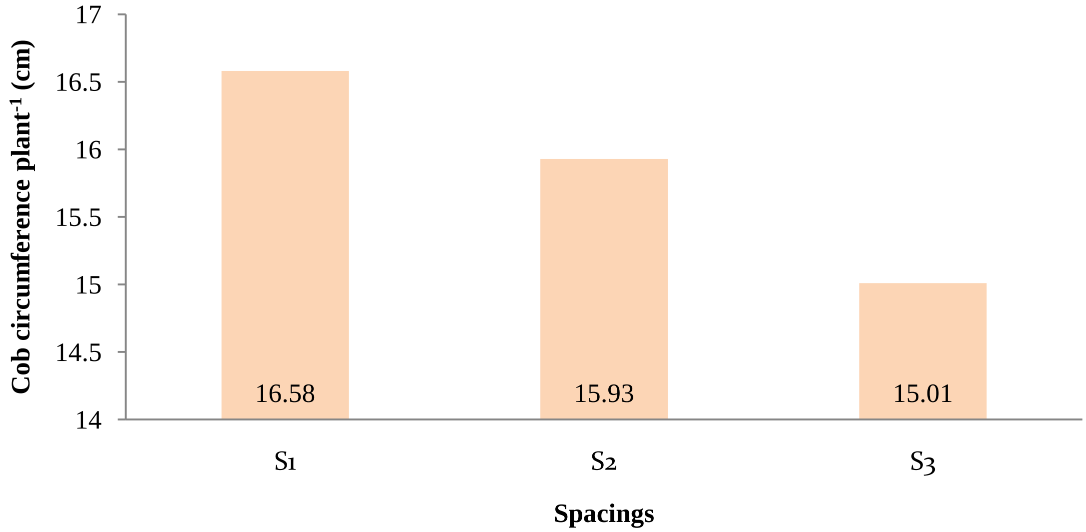


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 24. Effect of fertilizer dose on cob circumference plant^{-1} of white maize ($LSD_{(0.05)}$ = 0.33 cm)

Effect of spacing

The cob circumference plant^{-1} of white maize significantly influenced by the various spacing (Figure 25). According to the results of the experiment, the highest cob circumference plant^{-1} (16.58 cm) was exposed to the S_1 treatment. While the S_3 treatment had the lowest cob circumference plant^{-1} (15.01 cm).



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 25. Effect of different spacings on cob circumference plant^{-1} of white maize ($LSD_{(0.05)}$ = 0.24 cm)

Combined effect of fertilizer dose and spacing

The cob circumference plant^{-1} of white maize has significantly changed as a result of the combined effects of fertilizer treatment and spacing (Table 10). The experimental results revealed that F_4S_1 treatment combination had the maximum cob circumference plant^{-1} (17.07 cm), which was statistically similar to F_1S_1 (16.57 cm) treatment combination. While F_1S_3 treatment combination, which was statistically similar to F_2S_3 (14.83 cm) and F_3S_3 (14.82 cm) treatment combination, had the lowest cob circumference plant^{-1} (14.77 cm).

Table 10. Combined effect of fertilizer doses and different spacing on cob length and cob circumference of white maize

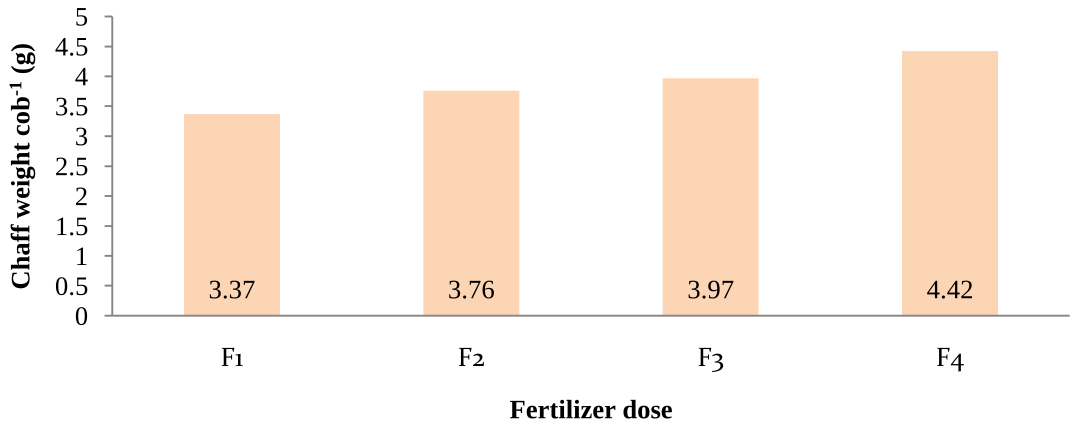
Treatment combinations	Cob length (cm)	Cob circumference (cm)
F_1S_1	17.28 bc	16.57 ab
F_1S_2	16.95 bc	15.83 de
F_1S_3	14.80 e	14.77 f
F_2S_1	17.67 ab	16.23 b-d
F_2S_2	17.32 bc	15.58 e
F_2S_3	15.85 de	14.83 f
F_3S_1	17.92 ab	16.43 bc
F_3S_2	17.15 bc	15.95 c-e
F_3S_3	15.70 de	14.82 f
F_4S_1	18.57 a	17.07 a
F_4S_2	17.67 ab	16.35 bc
F_4S_3	16.48 cd	15.60 e
$LSD_{(0.05)}$	1.08	0.51
CV (%)	3.52	1.78

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

4.7.3 Chaff weight cob^{-1}

Effect of fertilizer dose

The different rates of fertilizer treatment had a substantial impact on the chaff weight cob^{-1} of white maize (Figure 26). The results of the experiment showed that the F_4 treatment had the highest chaff weight cob^{-1} (4.42 g). However, the lowest chaff weight cob^{-1} (3.37 g) was found in the F_1 treatment.

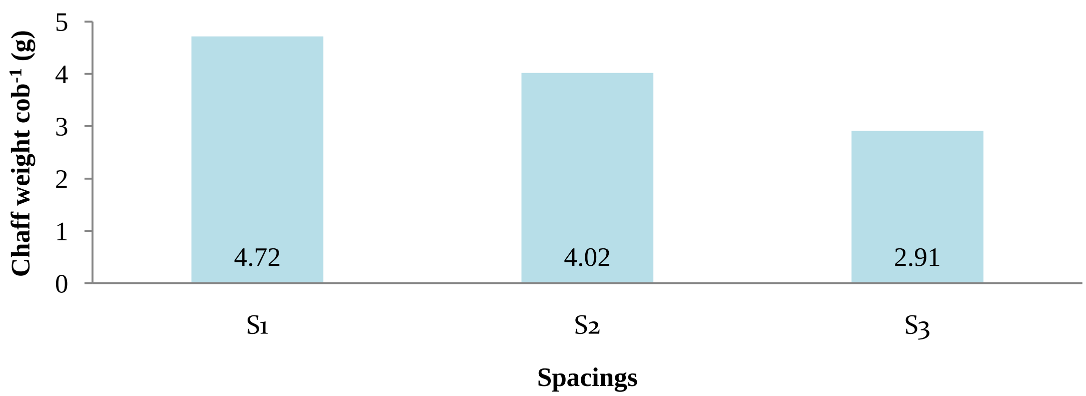


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 26. Effect of fertilizer dose on chaff weight cob^{-1} of white maize (LSD$_{(0.05)}$ = 0.18 g)

Effect of spacing

The various spacing had shown significant effect on the chaff weight cob^{-1} of white maize (Figure 27). The experiment's findings revealed that the S_1 treatment had the highest cob^{-1} chaff weight (4.72 g). However, the chaff weight cob^{-1} was lowest in the S_3 treatment (2.91 g).



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 27. Effect of different spacings on chaff weight cob^{-1} of white maize (LSD$_{(0.05)}$ = 0.13 g)

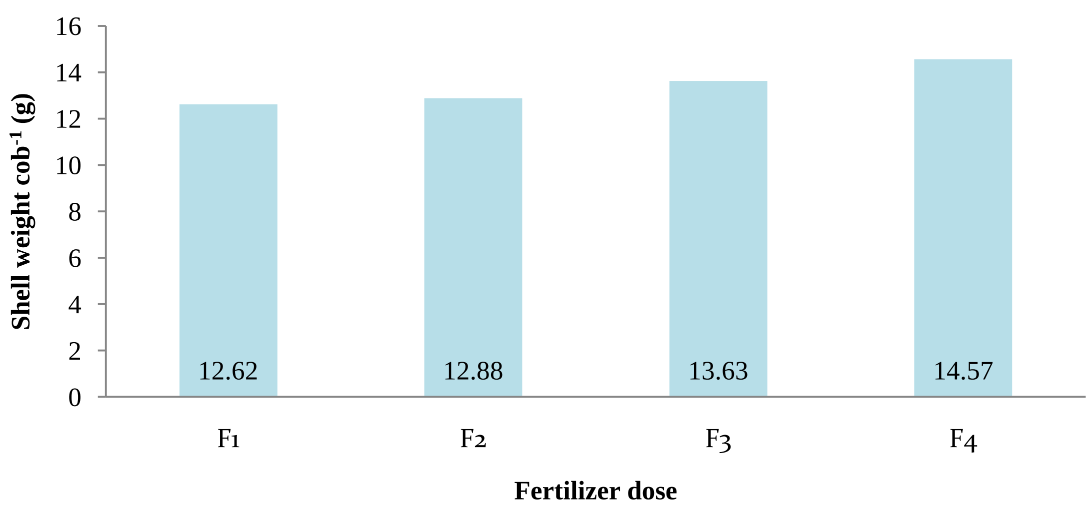
Combined effect of fertilizer dose and spacing

The chaff weight cob^{-1} of white maize had significantly changed as a result of the combined effects of fertilizer treatment and spacing (Table 11). The experimental results revealed that F_4S_1 treatment combination had the highest chaff weight cob^{-1} (5.07 g), which was statistically similar to F_2S_1 (4.80 g) treatment combination. While F_1E_0 treatment combination, which was statistically similar to F_1S_3 treatment combination, had the lowest chaff weight cob^{-1} (2.00 g).

4.7.4 Shell weight cob^{-1}

Effect of fertilizer dose

The shell weight cob^{-1} of white maize was significantly influenced by the various fertilizer application rates (Figure 28). The experiment's findings revealed that the F_4 treatment had the highest shell weight cob^{-1} (14.57 g). However, the F_1 treatment had the lowest shell weight cob^{-1} (12.62 g) which was statistically similar to F_2 (12.88 g) treatment.

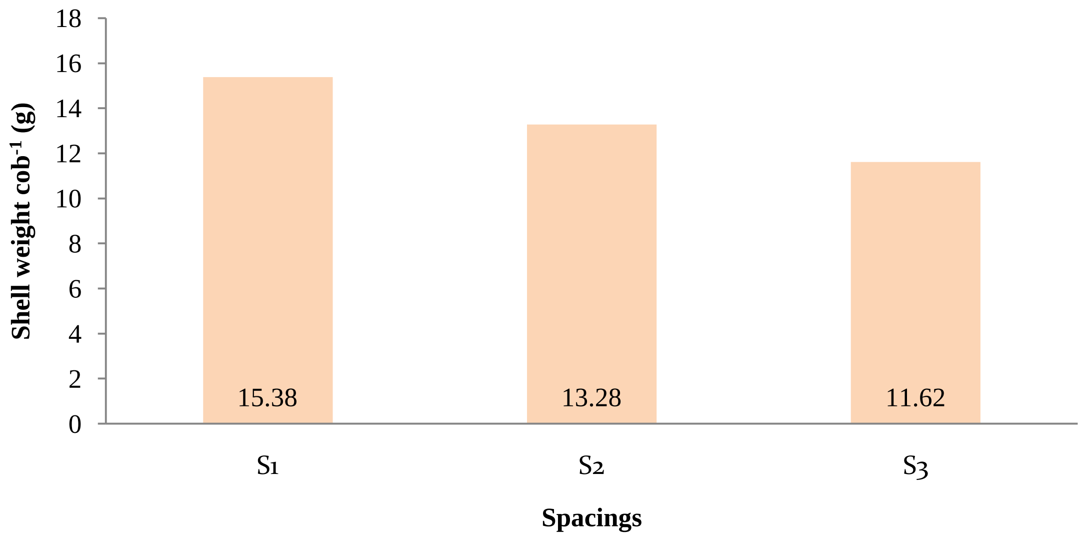


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 28. Effect of fertilizer dose on shell weight cob^{-1} of white maize ($LSD_{(0.05)}$ = 0.69 g)

Effect of spacing

The various spacing had shown significant effect on the shell weight cob^{-1} of white maize (Figure 29). The results of the investigation showed that the S_3 treatment had the highest shell weight cob^{-1} (15.38 g). However, the S_3 treatment had the lowest shell weight cob^{-1} (11.62 g).



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 29. Effect of different spacings on shell weight cob^{-1} of white maize ($LSD_{(0.05)}$ = 0.50 g)

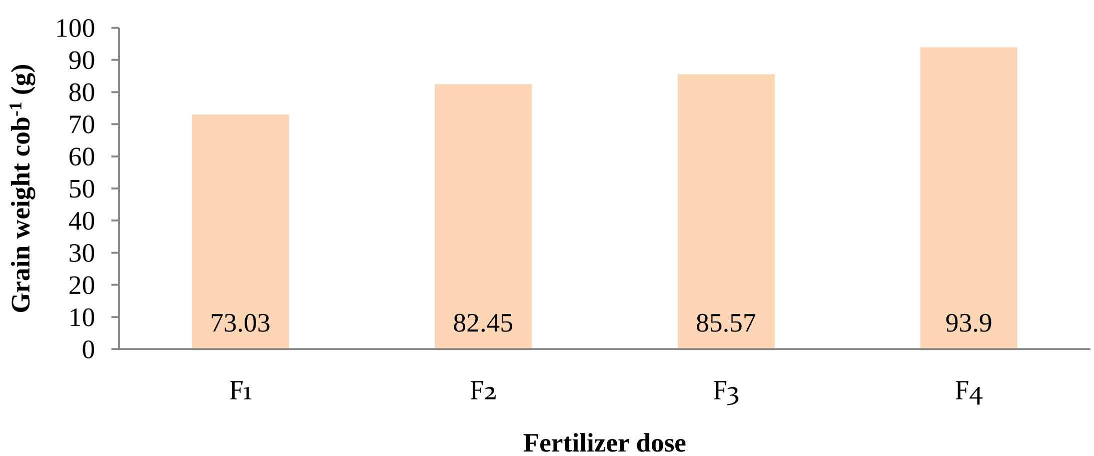
Combined effect of fertilizer dose and spacing

The shell weight cob^{-1} of white maize had significantly changed as a result of the combined effects of fertilizer treatment and spacing (Table 11). The experimental results revealed that the F_4S_1 treatment combination had the highest shell weight cob^{-1} (15.85 g), which was statistically similar to F_4S_2 (15.60 g), F_3S_1 (15.53 g), F_2S_1 (15.18 g) and F_1S_1 (14.95 g). While the F_1S_3 treatment combination, which was statistically similar to F_2S_3 (11.35 g) treatment combination, had the lowest shell weight cob^{-1} (10.58 g).

4.7.5 Grain weight cob^{-1}

Effect of fertilizer dose

The various fertilizer application rates had shown significant effect on the grain weight cob^{-1} of white maize (Figure 30). According to the experimental results, the F_4 treatment had the highest grain weight cob^{-1} (93.90 g). However, the grain weight cob^{-1} for the F_1 treatment was the lowest (73.03 g). The plants grown with less fertilizer produced the lowest grain weight cob^{-1} and it increased with the increase of fertilizer levels. In general, higher the level of fertilizer, greater was the grain weight cob^{-1} production of the crops at all the growth stages. The increased level of added fertilizer might be due to increased photosynthetic rate resulting in higher leaf area and thereby increased grain weight cob^{-1}. It indicate that a greater amount of fertilizer was needed to sustain growth and development of the crop. Jinjala *et al.* (2016) reported that significantly highest grain weight cob^{-1} was observed with application of 125% RDN from chemical fertilizer with bio-fertilizer. Mehta *et al*. (2005) reported that an application of 40 kg P_20_5 ha^{-1} increased significantly the yield attributes viz., grain weight per cob and grain of maize over 20 kg P_2O_5 ha^{-1}.



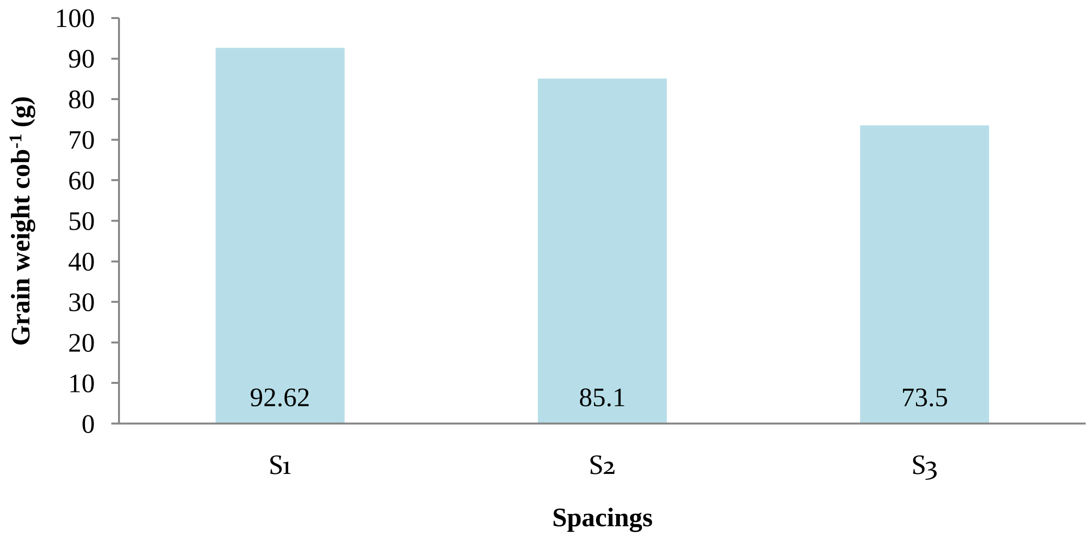
Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 30. Effect of fertilizer dose on grain weight cob^{-1} of white maize ($LSD_{(0.05)}$ = 1.14 g)

Effect of spacing

Effect of spacing

In grain weight cob^{-1} of white maize, had significantly influenced as a result of the various spacing (Figure 31). The investigation's findings revealed that the S_1 treatment had the highest grain weight cob^{-1} (92.62 g). However, the grain weight cob^{-1} of the E_0 treatment was the lowest (73.50 g). Rahman *et al*. (2016) found that nitrogen levels and plant spacing had significant effect on yield attributes and yield of Khai bhutta. The highest grains weight cob^{-1} were recorded at 75 cm × 25 cm spacing.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 31. Effect of different spacings on grain weight cob^{-1} of white maize ($LSD_{(0.05)}$ = 1.20 g)

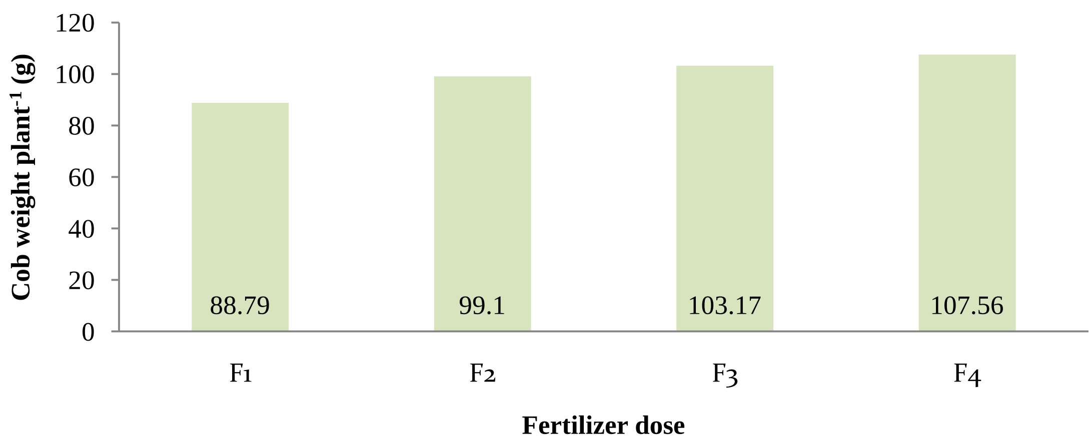
Combined effect of fertilizer dose and spacing

The grain weight cob^{-1} of white maize had significantly changed as a result of the combined effects of fertilizer treatment and spacing (Table 11). The experimental results revealed that F_4S_1 treatment combination had the highest grain weight cob^{-1} (103.35 g), which was statistically similar to F_4S_2 (102.43 g) treatment combination. While F_1S_3 treatment combination, which was statistically similar to F_2S_2 (70.85 g) and F_2S_3 (74.18 g) treatment combination, had the lowest grain weight cob^{-1} (69.04 g).

4.7.6 Cob weight plant^{-1}

Effect of fertilizer dose

The cob weight plant^{-1} of white maize was significantly influenced by the various fertilizer application rates (Figure 32). The experimental findings revealed that the F_4 treatment had the highest cob weight plant^{-1} (107.56 g). However, the F_1 treatment had the lowest cob weight plant^{-1} (88.79 g). The differences of cob weight plant^{-1} might be due to sufficient supply of nitrogen to the crop because nitrogen being an essential constituent of plant tissue is involved in cell division and cell elongation. Singh and Choudhary (2008) reported that amongst fertilizer levels, application of 90+45 kg N and P_2O_5 ha^{-1} significantly improved yield attributes of maize, *viz* cob weight plant^{-1} over 60+30 kg N and P_2O_5 ha^{-1}.

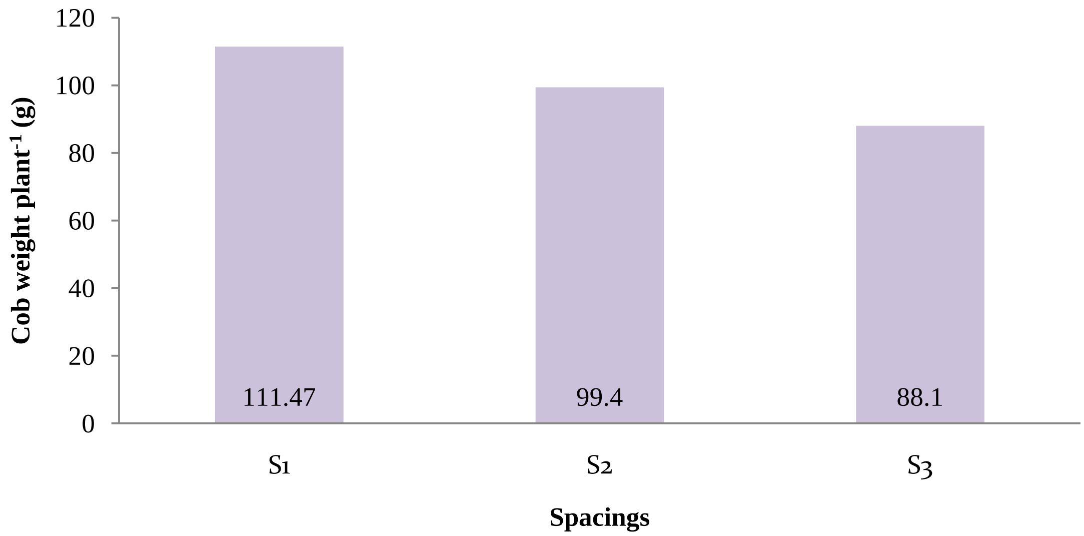


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 32. Effect of fertilizer dose on cob weight plant^{-1} of white maize ($LSD_{(0.05)}$ = 1.83 g)

Effect of spacing

Different spacing had shown significant effect on cob weight plant^{-1} of white maize (Figure 33). The results of the experiment showed that cob weight plant^{-1} was highest in the S_1 treatment (111.47 g). However, the S_3 treatment's had the was the lowest (88.10 g) cob weight plant^{-1}. Ukonze *et al.* (2016) reported that the 70 × 30 and 60 × 40 cm spacing gave higher values of the morphological parameters than 80 × 20 cm. With regard to yield, 80 × 20 cm gave the highest average cob weight of 0.74 kg and 1000-grain weight (yield) of 0.27t/ha.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 33. Effect of different spacings on cob weight plant^{-1} of white maize ($LSD_{(0.05)}$ = 1.14 g)

Combined effect of fertilizer dose and spacing

The cob weight plant^{-1}of white maize had significantly changed as a result of the combined effects of fertilizer treatment and spacing (Table 11). The experimental results revealed that F_4S_1 treatment combination had the highest cob weight plant^{-1} (119.27 g). While F_1S_3 treatment combination had the lowest cob weight plant^{-1} (80.95 g).

Table 11. Combined effect of fertilizer doses and different spacing on chaff weight cob^{-1}, shell weight cob^{-1}, grain weight cob^{-1} and cob weight $plant^{-1}$ of white maize at harvest

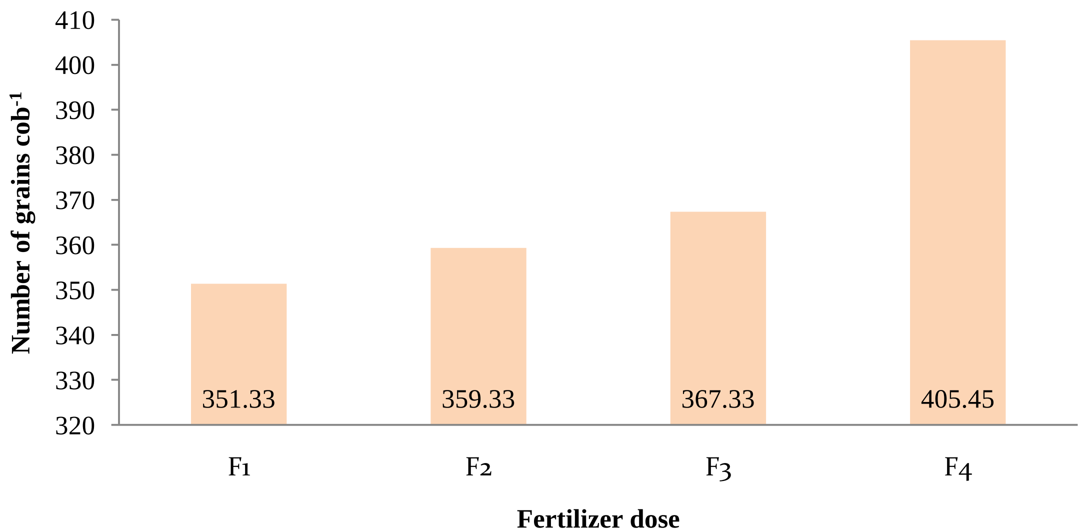
Treatment combinations	Chaff weight cob^{-1} (g)	Shell weight cob^{-1} (g)	Grain weight cob^{-1} (g)	Cob weight $plant^{-1}$ (g)
F_1S_1	4.55 bc	14.95 a	79.20 d	98.70 e
F_1S_2	3.55 ef	12.33 bc	70.85 ef	86.73 h
F_1S_3	2.00 h	10.58 d	69.04 f	80.95 i
F_2S_1	4.80 ab	15.18 a	92.83 b	112.81 bc
F_2S_2	3.75 e	12.12 bc	80.35 d	96.22 e
F_2S_3	2.73 g	11.35 cd	74.18 d-f	88.26 gh
F_3S_1	4.45 c	15.53 a	95.10 b	115.08 b
F_3S_2	4.05 d	13.08 b	86.77 c	103.90 d
F_3S_3	3.42 f	12.27 bc	74.85 de	90.54 fg
F_4S_1	5.07 a	15.85 a	103.35 a	119.27 a
F_4S_2	4.72 bc	15.60 a	102.43 a	110.75 c
F_4S_3	3.48 ef	12.27 bc	75.92 de	92.67 f
$LSD_{(0.05)}$	0.28	1.08	5.80	2.61
CV (%)	3.87	4.39	4.76	4.33

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

4.7.7 Number of grains cob^{-1}

Effect of fertilizer dose

The number of grains cob^{-1} of white maize was significantly influenced by the various fertilizer application rates (Figure 34). The experiment's findings revealed that the F_4 treatment had the highest number of grains cob^{-1} (405.45). However, the F_1 treatment had the lowest number of grains cob^{-1} (351.33) which was statistically similar with F_2 (359.33) treatment. Pal *et al*. (2017) indicated that application of 120 kg N recorded the maximum number of grains cob^{-1} (283.19). Tomar *et al.* (2017) revealed that combination of 100% NPK + 5 t FYM+ *Azotobacter* + PSB recorded higher yield and yield attributing components *viz*. number of grains cob^{-1} (541.2).

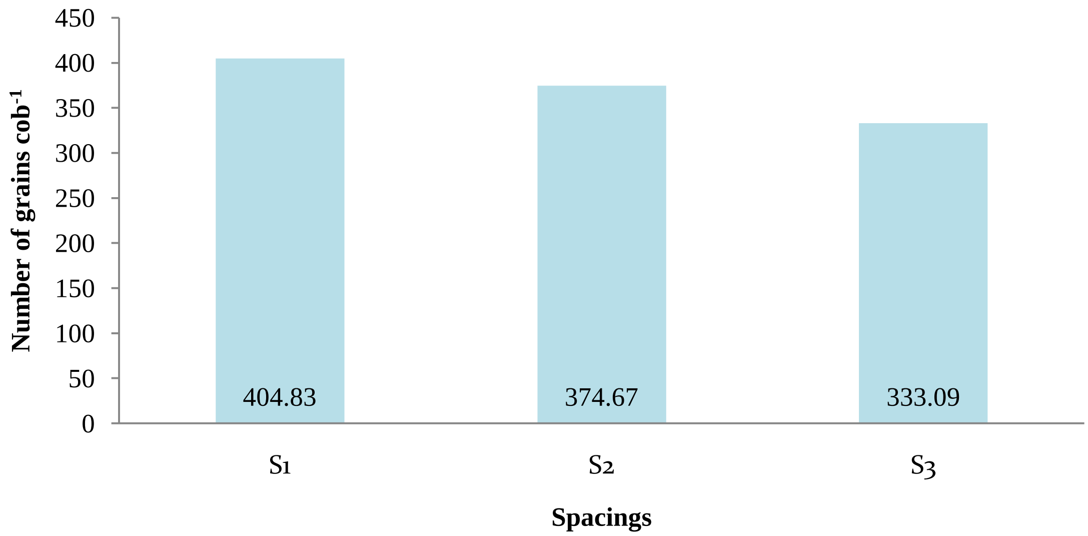


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 34. Effect of fertilizer dose on number of grains cob^{-1}of white maize (LSD$_{(0.05)}$ = 9.61)

Effect of spacing

Different spacing had shown significant effect on number of grains cob^{-1} of white maize (Figure 35). The experimental findings revealed that the S_1 treatment had the highest number of grains cob^{-1} (404.83). However, the S_3 treatment's had the lowest (333.09) number of grains cob^{-1}. Ahmmed *et al.* (2020) concluded that in respect of the spacing effect, the wider spacing showed the highest number of grain per cob compared to other spacings.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 35. Effect of different spacings on number of grains cob^{-1}of white maize ($LSD_{(0.05)}$ = 7.71)

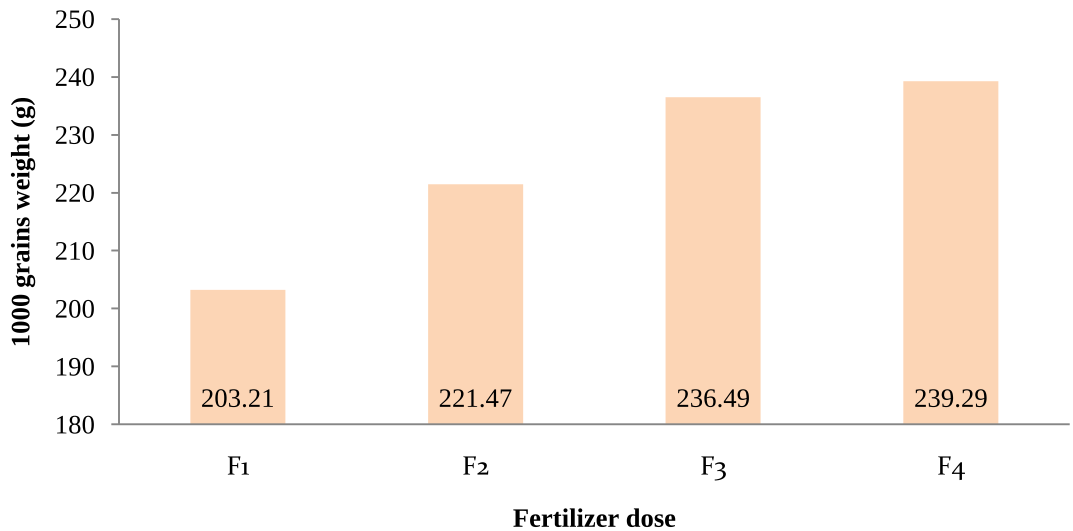
Combined effect of fertilizer dose and spacing

The number of grains cob^{-1}of white maize had significantly changed as a result of the combined effects of fertilizer treatment and spacing (Table 12). The experimental results revealed that F_4S_1 treatment combination had the highest number of grains cob^{-1} (423.67). While F_1S_3 treatment combination had the lowest number of grains cob^{-1} (303.00).

4.7.8 1000 grains weight

Effect of fertilizer dose

The various fertilizer application rates had shown significant effect in respect of 1000 grain weight of white maize (Figure 36). The results of the experiment showed that the F_4 treatment had the highest weight of 1000 grain (239.29 g) which was statistically comparable to F_3 treatment (236.49 g). However the F_1 treatment, had the lowest weight in 1000 grain weight (203.21 g). The 1000 grain weight of maize increased with increased rates of fertilizer dose might be due to the fact that application of increased fertilizer dose to the maize plants maintained greenness of leaves for longer period which in turn helped in greater dry matter accumulation and this might have contributed much as a major source for the development of sink and thereby improved the 1000 grains weight of white maize. Nimje and Seth (2008) reported that the 1000 grain weight of maize was significantly increased due to increased application of nitrogen from 0 to 120 kg N ha^{-1}.

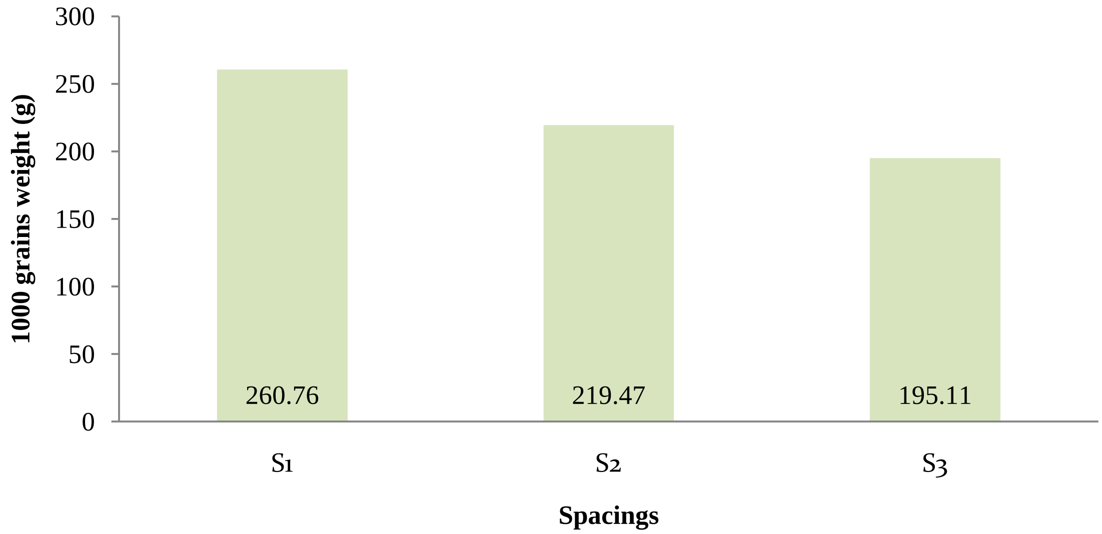


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 36. Effect of fertilizer dose on 1000 grains weight of white maize ($LSD_{(0.05)}$ = 7.53 g)

Effect of spacing

White maize grown at different spacing showed significant effect on 1000 grains weight (Figure 37). The results of the experiment showed that the S_1 treatment had the highest 1000 grains weight (260.76 g). While the lowest 1000 grain weight of white maize (195.11) was found in the S_3 treatment. This increase in grain weight might be attributed to the beneficial effects of spacing and uniform application of top dressed fertilizers by the human labor. Koirala *et al*. (2020) reported that 60×25 cm spacing significantly had the highest 1000 seed weight of maize comparable to other treatments.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 37. Effect of different spacings on 1000 grains weight of white maize ($LSD_{(0.05)}$ = 8.77 g)

Combined effect of fertilizer dose and spacing

The combined effects of fertilizer treatment and different spacing had significantly influenced the 1000 grains of white maize (Table 12). According to the experimental findings, the F_4S_1 treatment combination had the highest 1000 grains of white maize (275.40 g), which was statistically comparable to the F_3S_1 treatment combination (271.13). The lowest 1000 grains weight of white maize (171.93 g) was recorded by the F_1S_3 treatment combination.

Table 12. Combined effect of fertilizer doses and different spacing on no. of grains cob^{-1} and 1000 grains weight of white maize

Treatment combinations	Total no. of grains cob^{-1}	1000 grains weight (g)
F_1S_1	395.33 bc	238.30 de
F_1S_2	355.67 e	199.40 h
F_1S_3	303.00 g	171.93 i
F_2S_1	395.00 bc	258.20 bc
F_2S_2	367.33 de	208.23 gh
F_2S_3	315.67 fg	197.97 h
F_3S_1	405.33 b	271.13 ab
F_3S_2	372.00 d	243.37 cd
F_3S_3	324.67 f	194.97 h
F_4S_1	423.67 a	275.40 a
F_4S_2	403.67 bc	226.90 ef
F_4S_3	389.00 c	215.57 fg
$LSD_{(0.05)}$	15.80	16.15
CV (%)	4.40	4.50

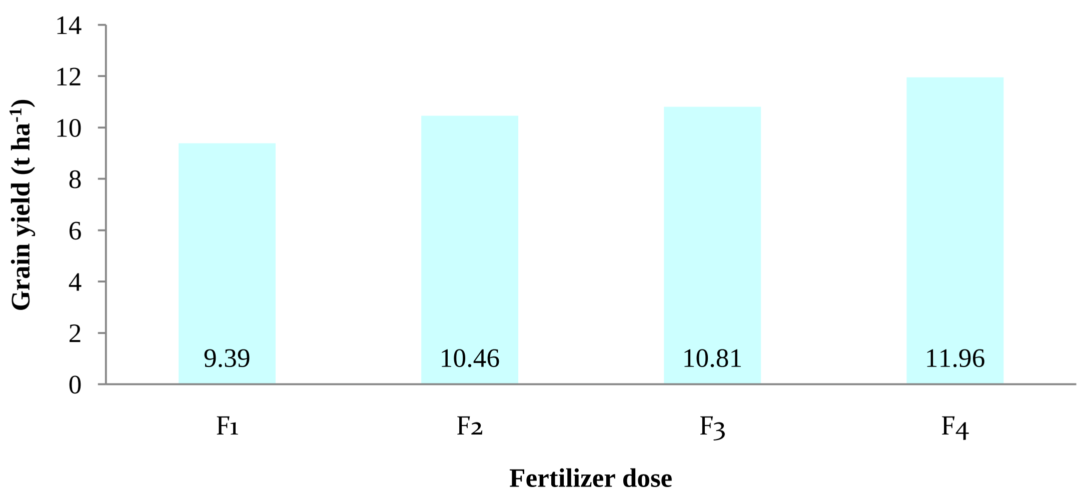
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

4.8 Yield characters

4.8.1 Grain yield

Effect of fertilizer dose

Due to different doses of fertilizer application, grain yield of white maize was significantly influenced (Figure 38). In this experiment result revealed that the F_4 treatment recorded the highest grain yield (11.96 t ha^{-1}). While F_1 treatment had the lowest grain yield (9.39 t ha^{-1}). The result confirmed that higher levels of fertilizers enhanced grain yield on account of higher leaf area index and leaf area duration that lead to more radiation interception, photosynthetic efficiency, growth rate and therefore grain number and grain weight per cob. Jadhav (2018) reported that higher grain yield (7769 kg ha^{-1}) of maize sown during summer was recorded for 120% RDF (180:90:90 kg NPK ha^{-1}) followed by 100% RDF (150:75:75 kg NPK ha^{-1}) and significantly superior over 80% RDF (120:60:60 kg NPK ha^{-1}). Rana *et al*. (2014) found that the maximum grain yield was observed with 150 % RDF.

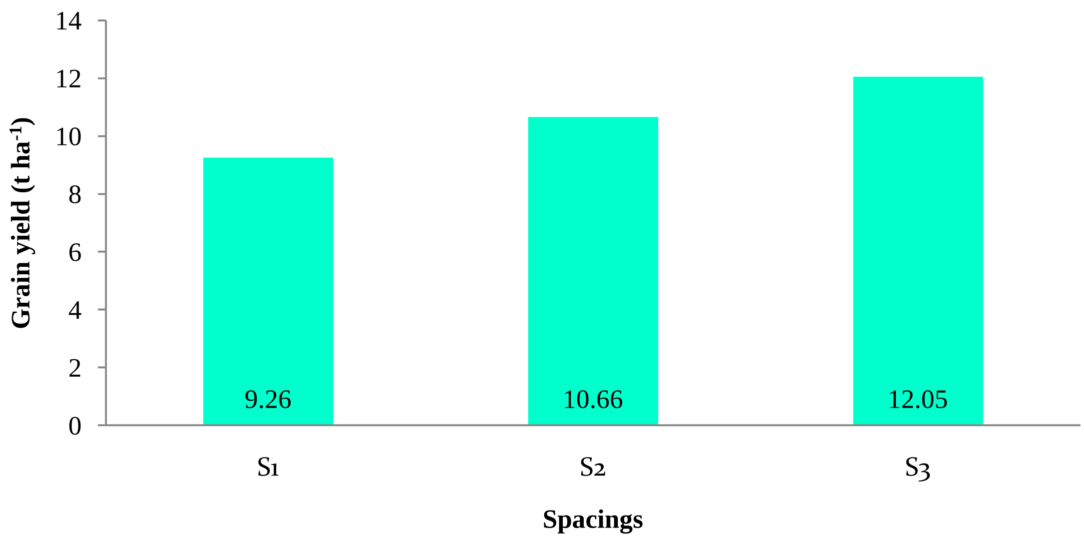


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 38. Effect of fertilizer dose on grains yield of white maize ($LSD_{(0.05)}$ = 0.30 t ha^{-1})

Effect of spacing

The grain yield of white maize had been significantly influenced by different spacing (Figure 39). The experiment's findings revealed that the S_3 treatment had the highest grain yield (12.05 t ha^{-1}). While the lowest grain yield of white maize (9.26 t ha^{-1}) was obtained in the S_1 treatments. The possible reason for the lowest grain yield at widest spacing might be due to the presence of less number of plants per unit area. The result was similar with the findings of Abuzar *et al.* (2011) who showed that the plant population of 40000 ha^{-1} produced maximum number of grains per row and grains per ear. However, 60000 plants ha^{-1} produced the maximum number of ears per plant, number of grain rows per ear, biomass yield and grain yield.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 39. Effect of different spacings on grains yield of white maize ($LSD_{(0.05)}$ = 0.27 t ha^{-1})

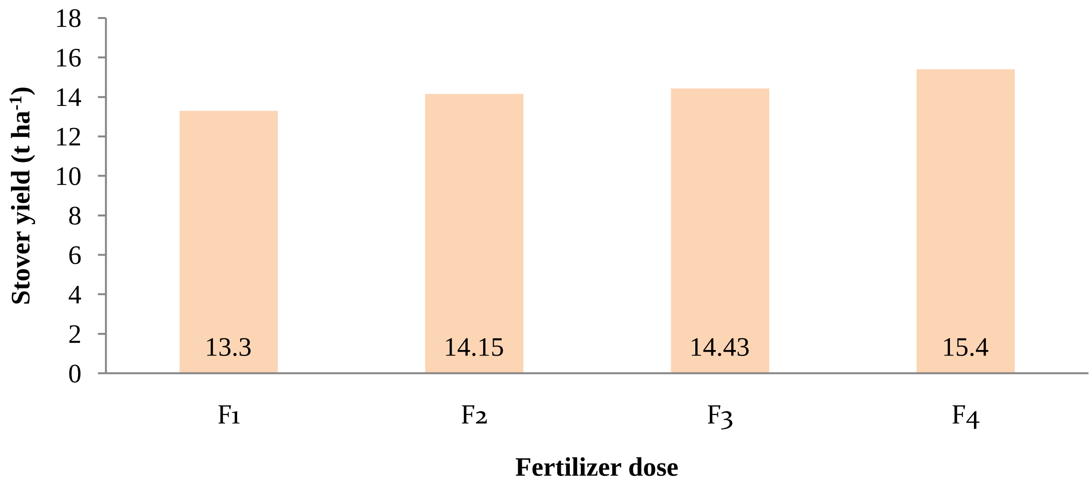
Combined effect of fertilizer dose and spacing

The combined effects of fertilizer treatment and spacing had significantly influenced the grain yield of white maize (Table 13). According to the experimental findings, the F_4S_2 treatment combination had the highest grain yield of white maize (12.90 t ha^{-1}), which was statistically comparable to the F_4S_3 treatment combination (12.65 t ha^{-1}). The lowest grain yield of white maize (7.92 t ha^{-1}) was recorded by the F_1S_1 treatment combination.

4.8.2 Stover yield

Effect of fertilizer dose

The stover yield of white maize was significantly influenced by varying dose of fertilizer application treatment (Figure 40). The F_4 treatment resulted in the highest stover yield in this experiment (15.40 t ha^{-1}). While the F_1 treatment produced the lowest stover yield (13.30 t ha^{-1}). This might be due to the favorable soil condition created by increased fertilizer treatment resulting in better root development thereby enabling plants to uptake more moisture and nutrients to produce high LAI meaning bigger assimilatory system and hence more dry matter production leading to higher stover yield. Singh and Choudhary (2008) reported that amongst fertilizer levels, application of 90+45 kg N and P_2O_5 ha^{-1} significantly improved yield attributes, grain and stover yield of maize over 60+30 kg N and P_2O_5 ha^{-1}.

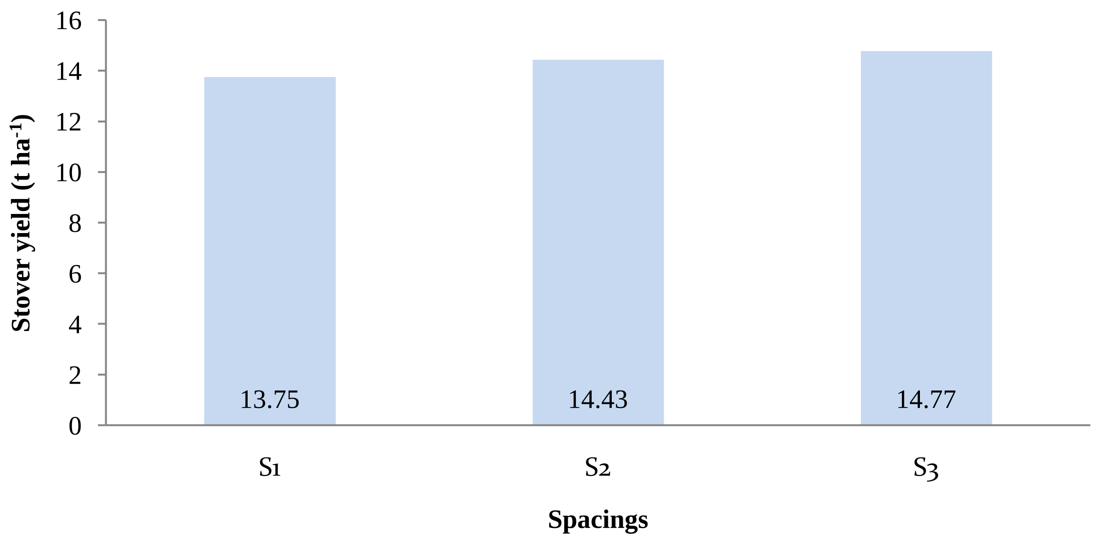


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 40. Effect of fertilizer dose on stover yield of white maize ($LSD_{(0.05)}$ = 0.64 t ha^{-1})

Effect of spacing

Different spacing showed significant effect on stover yield of white maize (Figure 41). From the experiment result revealed that the highest stover yield (14.77 t ha^{-1}) was founded in S_3 treatment which was statistically similar with S_2 (14.43 t ha^{-1}) treatment. Whereas the lowest stover yield (13.75 t ha^{-1}) was observed in S_1 treatment. Worku and Derebe (2020) reported that stover and grain yields were significantly increased with increasing plant density, as plant density is influenced by spacing, wide spacing caused low plant density and narrow spacing caused high plant density which ultimately impact on stover and grain yield of the crop.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 41. Effect of different spacings on stover yield of white maize ($LSD_{(0.05)}$ = 0.50 t ha^{-1})

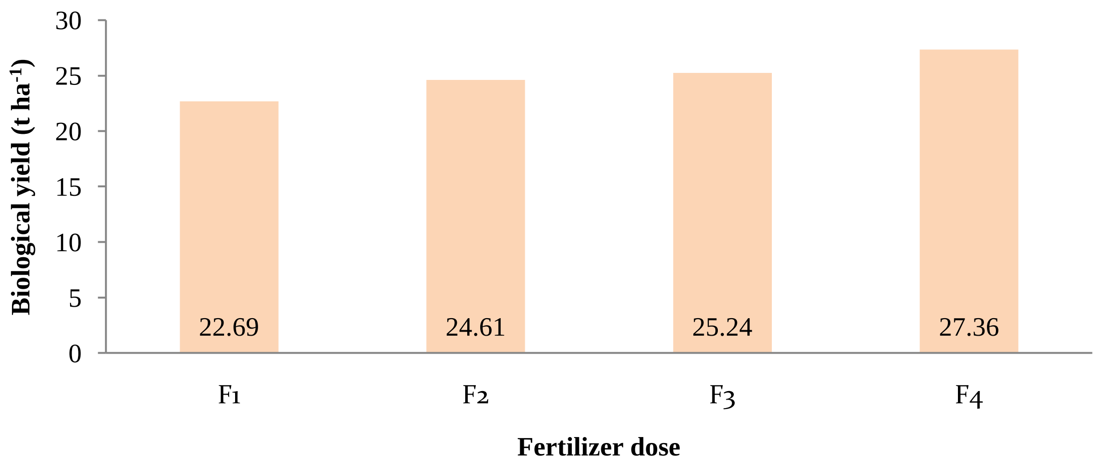
Combined effect of fertilizer dose and spacing

The yield of stover from white maize had been significantly influenced by the interaction of fertilizer treatment and spacing. (Table 13). According to the experimental findings, the F_4S_3 treatment combination had the highest grain yield of white maize (17.00 t ha^{-1}). While the lowest stover yield of white maize (12.90 t ha^{-1}) was recorded by the F_1S_1 treatment combination which was statistically comparable to the F_1S_2 (13.33 t ha^{-1}), F_1S_3 (13.67 t ha^{-1}) and F_2S_1 (13.47 t ha^{-1}) treatment combination.

4.8.3 Biological yield

Effect of fertilizer application

Applying different doses of fertilizer had a significant effect on the biological yield of white maize. (Figure 27). According to the experimental result, the F_4 treatment resulted in the highest biological yield in this experiment (27.36 t ha^{-1}). While the F_1 treatment had the lowest biological yield (22.69 t ha^{-1}). The substantial increased in biological yield due to greater fertilizer doses may be attributable to the plant's favorable effect on absorbing additional nutrition, which ultimately influenced growth features such as increased dry matter accumulation per plant and its subsequent translocation towards sink. Gaire *et al.* (2020), reported that in each increase in fertilizer amount results in a different biological yield.

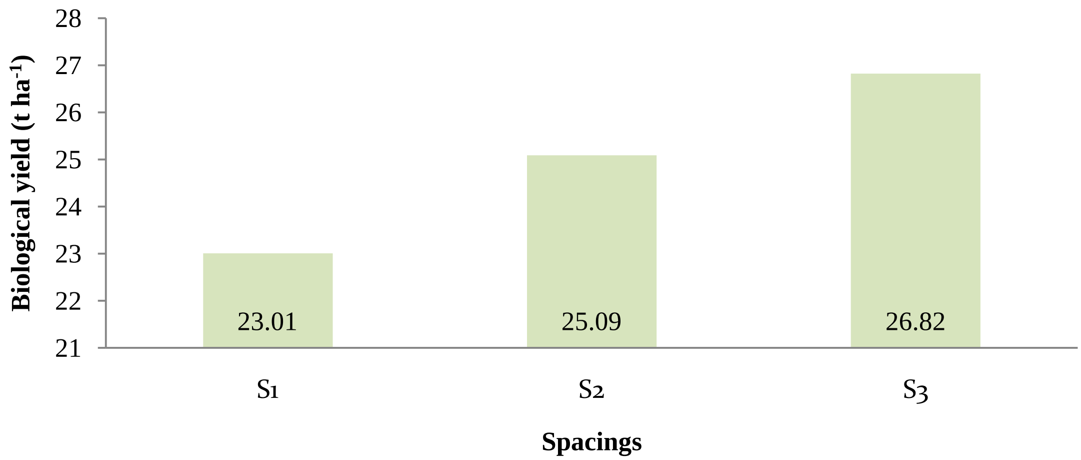


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 42. Effect of fertilizer dose on biological yield of white maize ($LSD_{(0.05)}$ = 0.93 t ha^{-1})

Effect of spacing

White maize biological yield was significantly impacted by different spacing. (Figure 43). Experimental result revealed that the highest biological yield (26.82 t ha^{-1}) was observed in S_3 treatment. Whereas the lowest biological yield (23.01 t ha^{-1}) was observed in S_1 treatment. The possible reason for the lowest biological yield at widest spacing might be due to the presence of less number of plants per unit area. The result was similar with the findings of Abuzar *et al.* (2011) who showed that the plant population of 40000 ha^{-1} produced maximum number of grains per row and grains per ear. However, 60000 plants ha^{-1} produced the maximum number of ears per plant, number of grain rows per ear, biological yield and grain yield.



Here, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

Figure 43. Effect of different spacings on biological of white maize ($LSD_{(0.05)}$ = 0.77 t ha^{-1})

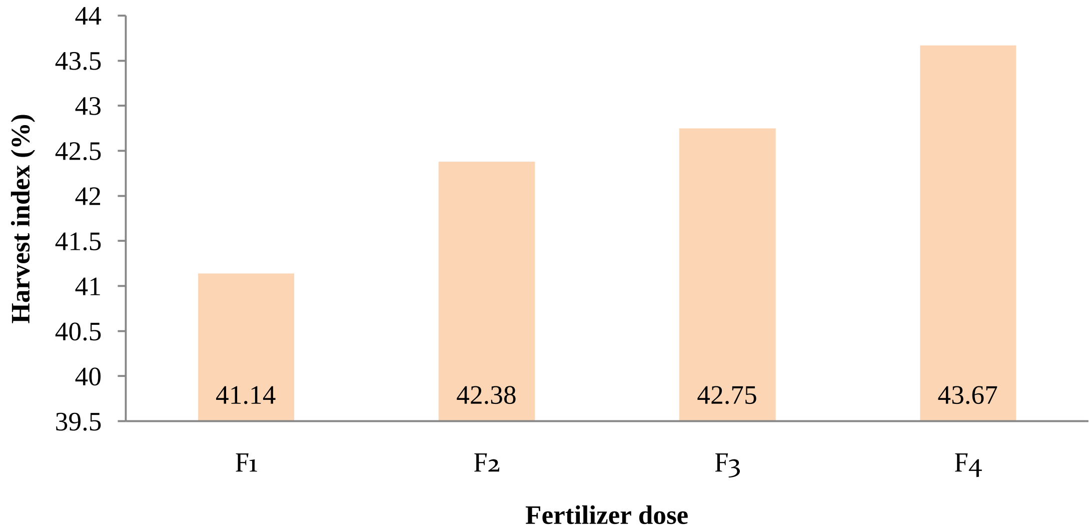
Combined effect of fertilizer dose and spacing

The biological yield of white maize had been significantly influenced by the combined effect of fertilizer treatment and spacing (Table 13). According to the results of the experiment, the F_4S_3 treatment combination had the highest biological yield of white maize, (29.65 t ha^{-1}). However the lowest biological (20.82 t ha^{-1}) was produced by the F_1S_1 treatment combination, which was statistically comparable to the F_1S_2 (20.19 t ha^{-1}) treatment combination.

4.8.4 Harvest index (%)

Effect of fertilizer dose

The harvest index of white maize was significantly influenced by different doses of fertilizer application treatment (Figure 44). The F_4 treatment resulted the highest harvest index in this experiment (43.67 %). While the F_1 treatment had the lowest harvest index (41.14 %). Scientific fertilizer application is a key tool for increasing crop growth, conserving the environment, and ensuring agricultural sustainability. Plant fresh and dry weight, which reflect plant biomass accumulation to some extent, are key measures of growth vigor. Fertilizer application enhanced NPK availability in the root zone, resulting in greater nutrient uptake by the plant, resulting in increased grain and biological yield, which influences crop harvest index. The result was similar with the findings of Raman and Suganya (2018) who reported that the harvest index were favorably influenced with increased fertilizer application.

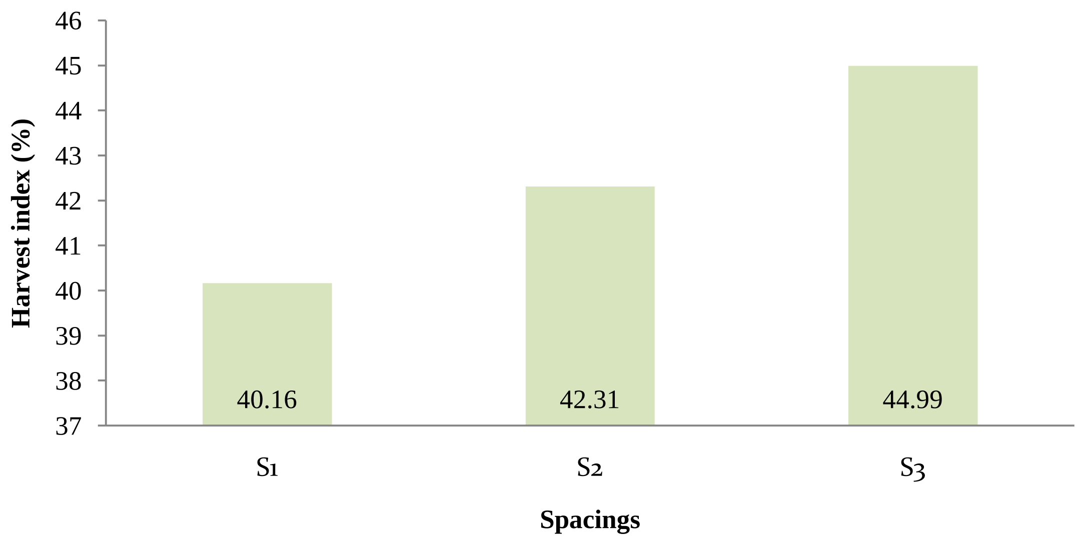


Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 44. Effect of fertilizer dose on harvest index of white maize ($LSD_{(0.05)}$ = 0.62 %)

Effect of spacing

Different spacing showed significant effect on harvest index of white maize (Figure 45). Experimental result revealed that the highest harvest index (44.99 %) was observed in S_3 treatment. Whereas the lowest harvest index (40.16 %) was observed in S_1 treatment.



Here, F_1 = 50 % recommended dose of fertilize, F_2 = 75 % recommended dose of fertilize., F_3 = 100 % recommended dose of fertilize. F_4 = 125 % recommended dose of fertilize

Figure 45. Effect of different spacings on harvest index of white maize ($LSD_{(0.05)}$ = 0.55 %)

Combined effect of fertilizer dose and spacing

The white maize harvest index had been significantly influenced by the combined effect of fertilizer treatment and spacing. (Table 13). Experimental results, revealed that the F_4S_2 treatment combination had the highest harvest index of white maize (46.54 %), which was statistically comparable to the F_3S_3 (45.93 %), F_2S_3 (45.93 %) and F_1S_3 (45.45 %) treatment combinations. However the F_1S_1 treatment combination had the lowest white maize harvest index (38.04 %).

Table 13. Combined effect of fertilizer doses and different spacing on grain, stover, biological yield and harvest index of white maize

Treatment combinations	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
F_1S_1	7.92 i	12.90 e	20.82 h	38.04 e
F_1S_2	8.86 h	13.33 de	22.19 gh	39.93 d
F_1S_3	11.39 c	13.67 c-e	25.06 c-e	45.45 a
F_2S_1	9.28 gh	13.47 c-e	22.75 fg	40.79 cd
F_2S_2	10.04 ef	14.79 b	24.83 c-e	40.43 d
F_2S_3	12.06 b	14.20 b-d	26.26 b-d	45.93 a
F_3S_1	9.51 fg	14.27 b-d	23.78 ef	39.99 d
F_3S_2	10.85 cd	14.79 b	25.64 cd	42.32 b
F_3S_3	12.08 b	14.22 b-d	26.30 bc	45.93 a
F_4S_1	10.33 de	14.37 bc	24.70 de	41.82 bc
F_4S_2	12.90 a	14.82 b	27.72 b	46.54 a
F_4S_3	12.65 a	17.00 a	29.65 a	42.66 b
$LSD_{(0.05)}$	0.55	1.03	1.57	1.10
CV (%)	3.00	4.07	3.59	1.51

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability. Here, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm, S_3 = 30 cm × 20 cm

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University Farm SAU, Dhaka during the period from October- 2019 to February-2020 in *Rabi* season to studying allometry and yield components of white maize to varying levels of spacing and fertilizer application. The experiment was consisted of two factors and followed split plot design with three replications. Factor A: Fertilizer application rate (4) *viz*, F_1 = 50 % recommended dose of fertilizer, F_2 = 75 % recommended dose of fertilizer, F_3 = 100 % recommended dose of fertilizer, F_4 = 125 % recommended dose of fertilizer, Factor B: Different spacings (3) *viz*, S_1 = 50 cm × 20 cm, S_2 = 40 cm × 20 cm and S_3 = 30 cm × 20 cm. The experimental results revealed that different fertilizer dose, spacings and their combination significantly influenced the growth, yield contributing characteristics and yield of white maize.

In case of different fertilizer dose, the highest plant height (34.65, 76.81, 141.68, 176.40 and 189.39 cm) at 20, 40, 60, 80 DAS and at harvest respectively, leaf area index (1.91, 2.54 and 3.78) at 40, 60 and 80 DAS, dry matter weight plant^{-1} (4.15, 22.21, 45.36, 139.71 and 163.00 g) at 20, 40, 60, 80 DAS and at harvest respectively were observed by F_4 (125 % recommended dose of fertilize) treatment. However in case of yield contributing characteristics and yield this treatment (F_4) also recorded the highest cob length plant^{-1} (17.57 cm), cob circumference plant^{-1} (16.34 cm), chaff weight cob^{-1} (4.42 g), shell weight cob^{-1} (14.57 g), grain weight cob^{-1} (93.90 g), cob weight plant^{-1} (107.56 g), number of grains cob^{-1} (405.45), 1000 grain weight (239.29 g), grain yield (11.96 t ha^{-1}), stover yield (15.40 t ha^{-1}), biological yield (27.36 t ha^{-1}) and harvest (43.67 %) comparable to other treatments. However the lowest yield contributing characterizes and yield *viz*, cob length plant^{-1} (16.34 cm), cob circumference plant^{-1} (15.53 cm), chaff weight cob^{-1} (3.37 g), shell weight cob^{-1} (12.62 g), grain weight cob^{-1} (73.03 g), cob weight plant^{-1} (88.79 g), number of grains cob^{-1} (351.33), 1000 grain weight (203.21 g), grain yield (9.39 t ha^{-1}), stover yield (13.30 t ha^{-1}), biological yield (22.69 t ha^{-1}) and harvest (41.14 %) were observed in F_1 (50 % recommended dose) treatment.

In terms of different spacings, S_1 (50 cm × 20 cm) treatment had the highest plant height (37.23, 81.02, 148.49, 185.79 and 205.79 cm) at 20, 40, 60, 80 DAS and at harvest respectively, leaf area index (1.82, 2.54 and 3.56) at 40, 60 and 80 DAS, and the highest dry weight plant^{-1} (4.49, 25.37, 52.07, 160.72 and 187.50 g) at 20, 40, 60, 80 DAS and at harvest respectively. However, in comparison to other treatments, this S_1 (50 cm × 20 cm) treatment also had the highest cob length plant^{-1} (17.86 cm), cob circumference plant^{-1} (16.58 cm), chaff weight cob^{-1} (4.72 g), shell weight cob^{-1} (15.38 g), grain weight cob^{-1} (92.62 g), cob weight plant^{-1} (111.47 g), number of grains cob^{-1} (404.83), 1000 grain weight (260.76 g). While the highest grain yield (12.05 t ha^{-1}), stover yield (14.77 t ha^{-1}), biological yield (26.82 t ha^{-1}) and harvest (44.99 %) were observed in S_3 treatment. Whereas the lowest cob length plant^{-1} (15.71 cm), cob circumference plant^{-1} (15.01 cm), chaff weight cob^{-1} (2.91 g), shell weight cob^{-1} (11.62 g), grain weight cob^{-1} (73.50 g), cob weight plant^{-1} (88.10 g), number of grains cob^{-1} (333.09), 1000 grain weight (219.47 g) were observed in S_3 treatment. However the S_1 treatment had the lowest grain yield (9.26 t ha^{-1}), stover yield (13.75 t ha^{-1}), biological yield (23.01 t ha^{-1}) and harvest (40.16 %).

In case of combination, the F_4S_1 treatment combination demonstrated the best growth traits in terms of plant height, leaf area and stem dry matter weight plant^{-1}. However, in the case of yield contributing traits and yield, this F_4S_1 treatment combination was also demonstrated the highest cob length plant^{-1} (18.57 cm), cob circumference plant^{-1} (17.07 cm), chaff weight cob^{-1} (5.07 g), shell weight cob^{-1} (15.85 g), grain weight cob^{-1} (103.35 g), cob weight plant^{-1} (119.27 g), number of grains cob^{-1} (423.67), 1000 grain weight (275.40 g). While the highest grain yield (12.65 t ha^{-1}) was found in F_4S_2 treatment combination. However the highest stover yield (17.00 t ha^{-1}), biological yield (29.65 t ha^{-1}) and harvest (42.66 %) were observed in F_4S_3 treatment combination. While the lowest cob length plant^{-1} (14.80 cm), cob circumference plant^{-1} (14.77 cm), chaff weight cob^{-1} (2.00 g), shell weight cob^{-1} (10.58 g), grain weight cob^{-1} (69.04 g), cob weight plant^{-1} (80.95 g), number of grains cob^{-1} (303.00), 1000 grain weight (171.93 g) were observed in F_1S_3 treatment combination. While the F_1S_1 treatment combination had the lowest grain yield (7.92 t ha^{-1}), stover yield (12.90 t ha^{-1}), biological yield (20.82 t ha^{-1}) and harvest (38.04 %).

Conclusion

Based on the above findings, the experimental results revealed that, different fertilizer dose, spacings and their combination significantly influenced the growth, yield contributing characteristics and yield of white maize.

i. In case of different dose of fertilizer application, the F_4 treatment recorded the highest cob length plant^{-1} (17.57 cm), cob circumference plant^{-1} (16.34 cm), chaff weight cob^{-1} (4.42 g), shell weight cob^{-1} (14.57 g), grain weight cob^{-1} (93.90 g), cob weight plant^{-1} (107.56 g), number of grains cob^{-1} (405.45), 1000 grain weight (239.29 g), grain yield (11.96 t ha^{-1}), stover yield (15.40 t ha^{-1}), biological yield (27.36 t ha^{-1}) and harvest index (43.67 %) comparable to other treatments.

ii. In case of different spacing the highest grain yield (12.05 t ha^{-1}), stover yield (14.77 t ha^{-1}), biological yield (26.82 t ha^{-1}) and harvest index (44.99 %) were observed in S_3 treatment.

iii. In case of combined effect, the F_4S_2 treatment combination had the highest grain yield (12.90 t ha^{-1}) followed by F_4S_3 (12.65 t ha^{-1}) treatment combination.

Therefore, it was indicated that cultivation of white maize through application of 125 % recommended dose of fertilizer along with maintaining 40 cm × 20 cm spacing (F_4S_2) would enhanced better yield production of white maize.

Recommendations

- ❖ Studies of similar nature could be carried out in different Agro Ecological Zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

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

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

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

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

Appendix III. Monthly meteorological information during the period from October 2019 to March, 2020

Year	Month	Air temperature (^0C)		Relative humidity (%)	Average rainfall (mm)
		Maximum	Minimum		
2019	October	31.2 ^0C	23.9 ^0C	76%	52 mm
	November	29.6 ^0C	19.8 ^0C	53%	00 mm
	December	28.8 ^0C	19.1 ^0C	47%	00 mm
2020	January	25.5 ^0C	13.1 ^0C	41%	00 mm
	February	25.9 ^0C	14 ^0C	34%	7.7 mm

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

Appendix IV. Analysis of variance of the data of plant height of white maize at different DAS

Source of variation	**DF**	Mean square of plant height at				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication (R)	2	25.662	131.729	446.80	663.87	841.18
Fertilize (F)	3	38.950*	101.202*	260.77*	498.23*	362.09*
Error	6	1.525	9.030	35.57	79.64	35.73
Spacing (S)	2	316.436*	816.540*	2146.46*	4109.26*	6614.37*
F×S	6	5.383*	2.056*	9.13*	26.97*	2.53*
Error	16	1.522	8.492	9.50	75.46	37.71

*: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data of leaf area index of white maize at different DAS

Source of variation	DF	Mean square of leaf area index at		
		40 DAS	60 DAS	80 DAS
Replication (R)	2	0.06569	0.13975	0.28830
Fertilize (F)	3	0.23670*	0.42029*	2.12580*
Error	6	0.00842	0.01136	0.00177
Spacing (S)	2	0.22417*	0.59747*	1.86870*
F×S	6	0.02078*	0.02104*	0.24520*
Error	16	0.00792	0.01048	0.02362

*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of net assimilation rate of white maize at different DAS

Source of variation	DF	Mean square of net assimilation rate at			
		40 DAS	60 DAS	80 DAS	100 DAS
Replication (R)	2	3.333E-09	1.033E-36	7.500E-09	1.333E-08
Fertilize (F)	3	9.167E-07*	5.583E-06*	6.000E-06*	2.000E-06*
Error	6	3.333E-09	4.124E-38	7.500E-09	4.444E-09
Spacing (S)	2	3.000E-06*	4.750E-06*	4.000E-06*	7.500E-07*
F×S	6	1.667E-06*	1.083E-06*	3.902E-38*	1.750E-06*
Error	16	3.333E-09	1.000E-08	7.500E-09	6.667E-09

*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of crop growth rate of white maize at different DAS

Source of variation	**DF**	Mean square of crop growth rate at			
		40 DAS	60 DAS	80 DAS	100 DAS
Replication (R)	2	8.333E-08	7.500E-07	0.00001	0.00004
Fertilize (F)	3	1.492E-05*	0.02469*	0.02245*	0.01644*
Error	6	8.333E-08	7.500E-07	0.00001	0.00004
Spacing (S)	2	6.108E-04*	0.17637*	0.00297*	0.26264*
F×S	6	1.942E-05*	1.167E-03*	0.00142*	0.00488*
Error	16	2.083E-07	2.500E-07	0.00001	0.00003

*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of relative crop growth rate of white maize at different DAS

Source of variation	**DF**	Mean square of relative crop growth rate at			
		40 DAS	60 DAS	80 DAS	100 DAS
Replication (R)	2	3.333E-05	7.500E-07	3.333E-09	5.833E-07
Fertilize (F)	3	1.542E-04*	1.158E-05*	1.456E-04*	3.900E-05*
Error	6	3.333E-05	3.056E-07	3.333E-09	3.611E-07
Spacing (S)	2	1.593E-04*	4.622E-04*	7.825E-05*	1.525E-05*
F×S	6	1.525E-05*	6.858E-05*	1.258E-05*	3.425E-05*
Error	16	3.333E-05	4.167E-07	3.333E-09	4.167E-07

*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of on root, stem and lamina dry matter weight plant^{-1} at of white maize at 120 DAS

Source of variation	**DF**	Mean square of plant height at		
		Root dry matter weight plant^{-1} at 120 DAS	Stem dry matter weight plant^{-1} at 120 DAS	Lamina dry matter weight plant^{-1} at 120 DAS
Replication (R)	2	0.1474	2.17	2.08
Fertilize (F)	3	3.3074*	31.34*	109.18*
Error	6	0.1474	2.17	2.08
Spacing (S)	2	58.5923*	1857.42*	1145.94*
F×S	6	0.9480*	72.27*	5.99*
Error	16	0.1377	0.54	1.08

*: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of dry matter weight plant^{-1} of white maize at different DAS

Source of variation	**DF**	Mean square of dry matter weight plant^{-1}				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication (R)	2	0.2874	7.757	41.29	462.7	859.0
Fertilize (F)	3	2.5415*	118.692*	98.69*	420.1*	449.1*
Error	6	0.0181	0.559	3.43	10.1	20.9
Spacing (S)	2	19.0547*	575.916*	1356.25*	11109.0*	14373.8*
F×S	6	0.1916*	3.834*	5.57*	33.4*	48.2*
Error	16	0.0212	0.520	3.62	12.7	44.2

*: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data of cob length and cob circumference of white maize at harvest

Source of variation	**DF**	Mean square of	
		Cob length	Cob circumference
Replication (R)	2	7.2544	8.39833
Fertilize (F)	3	2.2718*	1.10649*
Error	6	0.3553	0.08271
Spacing (S)	2	14.8553*	7.47033*
F×S	6	0.1642*	0.03099*
Error	16	0.3558	0.07920

*: Significant at 0.05 level of probability

Appendix XII. Analysis of variance of the data of chaff weight cob^{-1}, shell weight cob^{-1}, grain weight cob^{-1} and cob weight $plant^{-1}$ of white maize at harvest

Source of variation	**DF**	**Mean square of**			
		Chaff weight cob^{-1}	Shell weight cob^{-1}	Grain weight cob^{-1}	Cob weight $plant^{-1}$
Replication (R)	2	0.37564	4.3983	197.90	279.35
Fertilize (F)	3	1.74549*	6.9023*	668.91*	579.62*
Error	6	0.02657	0.3659	1.47	2.54
Spacing (S)	2	9.99640*	42.5977*	1113.78*	1637.66*
F×S	6	0.35767*	1.6180*	94.66*	28.41*
Error	16	0.02257	0.3468	15.88	1.74

*: Significant at 0.05 level of probability

Appendix XIII. Analysis of variance of the data of number of grains cob^{-1} and 1000 grains weight of white maize at harvest

Source of variation	**DF**	Mean square of	
		Number of grains cob^{-1}	1000 grains weight
Replication (R)	2	4757.4	1328.5
Fertilize (F)	3	5168.5*	2470.4*
Error	6	69.5	42.7
Spacing (S)	2	15573.5*	13215.0*
F×S	6	521.1*	241.1*
Error	16	79.4	102.7

*: Significant at 0.05 level of probability

Appendix XIV. Analysis of variance of the data of on grain, stover, biological yield and harvest index of white maize at harvest

Source of variation	**DF**	**Mean square of**			
		Grain yield	Stover yield	Biological yield	Harvest index
Replication (R)	2	4.0225	7.91641	23.2088	58.7333
Fertilize (F)	3	10.0990*	6.71629*	33.2838*	9.8999*
Error	6	0.0707	0.30496	0.6635	0.2967
Spacing (S)	2	23.2691*	3.23680*	43.5637*	70.3535*
F×S	6	1.1895*	1.58547*	1.2081*	16.1376*
Error	16	0.1014	0.33962	0.8043	0.4120

*: Significant at 0.05 level of probability