EFFECT OF NEXT GENERATION FERTILIZER PRODUCTS ON GROWTH AND YIELDS OF DIFFERENT CROPS

MOHAMMAD ABDULLAH AL - FAROQUE

DEPARTMENT OF SOIL SCIENCE
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR
DHAKA-1207

JUNE 2017

EFFECT OF NEXT GENERATION FERTILIZER PRODUCTS ON GROWTH AND YIELDS OF DIFFERENT CROPS

BY

MOHAMMAD ABDULLAH AL - FAROQUE

REGISTRATION NO. 00096

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
IN
SOIL SCIENCE

SEMESTER: JANUARY - JUNE, 2017

Approved by

Prof. Dr. Alok Kumar Paul
Chairman
Advisory Committee

Dr. M. Shahidul Islam	**Prof. Dr. Md. Asaduzzaman Khan**	**Prof. Dr. Parimal Kanti Biswas**
Member	Member	Member
Advisory Committee	Advisory Committee	Advisory Committee

Dr. Alok Kumar Paul
Professor
Department of Soil Science
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh
Cell: +88 01715 213083
E-mail: alokpaulsau@yahoo.com

CERTIFICATE

*This is to certify that thesis entitled, "**Effect of Next Generation Fertilizer Products On Growth and Yields of Different Crops**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* **DOCTOR OF PHILOSOPHY IN SOIL SCIENCE**, *embodies the result of a piece of bona fide research work carried out by* **MOHAMMAD ABDULLAH AL - FAROQUE**, *Registration No.**00096** 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.

June 2017
Dhaka, Bangladesh

Prof. Dr. Alok Kumar Paul
Chairman
Advisory Committee

DEDICATED

TO

MY BELOVED PARENTS,

WIFE AND SON

ACKNOWLEDGEMENTS

First of all, the author would like to express his profound gratitude to Almighty Allah for his ever ending blessing to carry out this doctoral program and present the dissertation.

With a great pleasure, the author expresses his deep sense of gratitude and sincere appreciation to his supervisor and Chairman, Advisory Committee, Dr. Alok Kumar Paul, Professor, Dept. of Soil Science, Sher-e- Bangla Agricultural University for continuous scholastic guidance and untiring supervision, constructive criticisms, valuable suggestions and immense help throughout the entire period of the research work as well as in preparing the dissertation.

The author whishes to express sincere appreciation and gratitude is also to all the members of the advisory committee, Dr. M. Shahidul Islam, Ex–Director General, Bangladesh Agricultural Research Institute, Jaydebpur, Gazipur, Prof. Dr. Md. Asaduzzaman Khan, Department of Soil Science, Sher-e- Bangla Agricultural University, Dhaka and Prof. Dr. Parimal Kanti Biswas, Dept. of Agronomy, Sher-e- Bangla Agricultural University, Dhaka for their valuable suggestions, constant encouragement and useful criticism throughout the whole period of this study. The author is also grateful to all his honorable teachers of the Department of Soil Science, Sher-e- Bangla Agricultural University, Dhaka.

The author immensely is indebted to Dr. Saikat Chowdhury, Associate Professor and Chairman, Department of Soil Science, Sher-e- Bangla Agricultural University, Dhaka for his constant inspiration and suggestion during the study and author also greatful to Prof. Dr. Shahidur Rashid Bhuiyan, Department of Genetics and Plant Breeding, Sher-e- Bangla Agricultural University, Dhaka for his continuous constant encouragement and suggestion in the period of PhD program.

The author is grateful to Mr. KSM Mostafizur Rahman, Chairman, Sayed Monena Montaj Foundation and Managing Director, National AgriCare Group, Dhaka for an award which enabled him to pursue higher studies leading to Ph.D. The author is also grateful to Dr. Mian Sayeed Hassan, Director, Project Implementation Unit, National Agricultural Technology Project, Bangladesh Agricultural Research Council, Dhaka for giving opportunity to carry out the Ph.D. studies.

Author's heartiest thanks are also to Dr. Md. Kabir Ikramul Haque, Executive Chairman, Bangladesh Agricultural Research Council (BARC), Dr. Md. Abul Kashem, Professor, Sylhet Agricultural University, Dr. Md. Aziz Zilani Chowdhury, Member Director (Crops), BARC, Mahiuddin Mamaun, SO, SRDI, and his colleagues of NATP for their inspiration, moral support and all-out help. Author's special thanks are to the staff of the Department of Soil Science, Sher-e-Bangla Agricultural University, Dhaka.

The author is forever indebted to his beloved wife Syeda Roksana and son Md. Abdullah Al Fawwaz for encouragement and sacrificing a lot for the successful completion of the study.

Dhaka, Bangladesh ***The Author***

EFFECT OF NEXT GENERATION FERTILIZER PRODUCTS ON GROWTH AND YIELDS OF DIFFERENT CROPS

ABSTRACT

To reduce the existing yield gap between research and farmer's field, three separate experiments were carried out during the period from March, 2014 to June, 2015 at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. To evaluate the effects of next generation fertilizers along with other recommended fertilizers on the growth, yield and soil chemical properties, the research was conducted based on selected maize, tomato and rice varieties. The experiments were laid out in RCBD method with three replications. The first experiment was conducted on maize in *kharif* season with eight treatments including control *viz.* T_0 = control (no fertilizer), $\mathbf{T_1}$ = recommended dose N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 kg ha^{-1}, $\mathbf{T_2}$ = American NPK + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1, $\mathbf{T_3}$ = Bio-forge + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 ,$\mathbf{T_4}$ = Wuxal + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1, $\mathbf{T_5}$ = Peak + $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$, $\mathbf{T_6}$ = Root Feed + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 and $\mathbf{T_7}$ = Nitro Plus + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 and three maize varieties namely V_1 = BARI Hybrid Bhutta-5 , V_2 = BARI Hybrid Bhutta-6 & V_3 = BARI Hybrid Bhutta-9. Growth and yield contributing characters mainly plant height, cob length, cob weight, 100-kernel weight and kernel yield of maize crop were significantly influenced by the next generation fertilizers. Bio-forge along with other recommended fertilizers performed the best compared to other treatments of the study in aspect of kernel yield (5.95 tha^{-1}) and statistically similar result showed by Root feed along with other recommended fertilizers and produced 5.12 tha^{-1} kernel yield. Among the varieties, BARI Hybrid Bhutta-9 performed the best compared to other two varieties. The second experiment was conducted on tomato in *rabi* season with six treatments including control *viz.* T_0 = control (no fertilizer), $\mathbf{T_1}$ = recommended dose $N_{140}P_{35}K_{75}S_{15}$ Zn_2B_1 kg ha^{-1}, $\mathbf{T_2}$ = Bio-forge + $N_{140}P_{35}K_{75}S_{15}$ Zn_2B_1, $\mathbf{T_3}$ =Wuxal Super + $N_{140}P_{35}K_{75}S_{15}$ Zn_2B_1, $\mathbf{T_4}$ = Root Feed + $N_{140}P_{35}K_{75}S_{15}$ Zn_2B_1, $\mathbf{T_5}$ = Nitro Plus + $N_{140}P_{35}K_{75}S_{15}$ Zn_2B_1 and three tomato varieties namely V_1 = BARI Tomato-2, V_2 = BARI Tomato-14 & V_3 = BARI Tomato-15. Among the next generation fertilizers, Bio-forge along with other recommended fertilizers performed the best compared to other treatments of the study in aspect of growth and yield contributing characters mainly plant height, flower cluster $plant^{-1}$, number of fruits $cluster^{-1}$, fruit $plant^{-1}$ and fruit yield (114.43 t ha^{-1}). Among the varieties BARI Tomato-14 performed the best compared to other two varietal treatments. The third experiment was conducted in *boro* rice with six treatments including control *viz* $\mathbf{T_0}$ = Control (no fertilizer), $\mathbf{T_1}$=recommended dose $N_{140}P_{20}K_{60}S_{18}Zn_2$ kg ha^{-1}, $\mathbf{T_2}$ = Bio-forge + $N_{140}P_{20}K_{60}S_{18}Zn_2$, $\mathbf{T_3}$ = Wuxal Super + $N_{140}P_{20}K_{60}S_{18}Zn_2$, $\mathbf{T_4}$ = Root Feed + $N_{140}P_{20}K_{60}S_{18}Zn_2$, $\mathbf{T_5}$ = Nitro Plus + $N_{140}P_{20}K_{60}S_{18}Zn_2$ and three rice varieties namely V_1 = BRRI dhan29, V_2 = BRRI dhan28 & V_3 = BRRI dhan58. Among the next generation fertilizers, Bio-forge along with other recommended fertilizers performed the best compared to other treatments of the study in aspect of growth and yield contributing characters mainly plant height, effective tiller $hill^{-1}$, panicle length , filled grain $panicle^{-1}$, 1000-grain weight, harvest index and grain yield (8.61 tha^{-1}). Among the varieties BRRI dhan29 showed best performance compared to other two treatments. There was no significant variation found for soil pH, organic carbon in postharvest soil of three experimental fields due to application of next generation fertilizers. Available S in maize field, total N content, available P and available S in tomato field and total N content, available P and available S in rice field showed a positive significant change. The next generation fertilizer viz. Bio-forge and Root feed along with other recommended fertilizers would be ideal for better crop growth and yield.

CONTENTS

CHAPTER		TITLE	PAGE NO

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICS

List of Acronyms, Abbreviations and Symbol

AEZ	=	Agro-Ecological Zone	IR	=	International Rice
ANOVA	=	Analysis of Variance	IRRI	=	International Rice Research Institute
AS	=	Ammonium Sulphate	J.	=	Journal
ASN	=	Ammonium Sulphate Nitrate	L	=	Liter
AVRDC	=	Asian Vegetable Research and Development Centre	LAI	=	Leaf Area Index
BARC	=	Bangladesh Agricultural Researcher Council	LLP	=	Low Lift Pump
BARI	=	Bangladesh Agricultural Research Institute	LSD	=	Least Significant Difference
BAU	=	Bangladesh Agricultural University	meq	=	Milliequivalent
BBS	=	Bangladesh Bureau of Statistics	mgL^{-1}	=	Milligram per litre
BRRI	=	Bangladesh Rice Research Institute	MoP	=	Muraite of Potash
BSMRAU	=	Bangabandhu Sheikh Mujibur Rahman Agricultural University	MSS	=	Mean Sum of Square
CD	=	Cowdung	NARS	=	National Agricultural Research System
CIMMYT	=	International Maize and Wheat Improvement Centre	NS	=	Non Significant
cm	=	Centimeter	NUE	=	Nutrient Use Efficiency
CV	=	Coefficient of Variance	ºC	=	Degree Centigrade
DAP	=	Days After Planting	p.	=	Page/pages
DMRT	=	Duncan’s Multiple Range Test	PI	=	Panicle Initiation
e.g.	=	Exempli gratia (by way of example)	ppm	=	Parts Per Millions
ed.	=	Editor	Pub	=	Publication
EPBS		East Pakistan Bureau of Statistics	RCBD	=	Randomized Complete Block Design
et al.	=	And others	RD	=	Recommended Dose
FAO	=	Food and Agriculture Organization	RDF	=	Recommended Dose of Fertilizer
Fig.	=	Figure	Res.	=	Research
FYM	=	Farm Yard Manure	RFD	=	Recommended Fertilizer Dose
g	=	Gram	SAU	=	Sher–E–Bangla Agricultural University
ha^{-1}	=	Per Hectare	Sci.	=	Science
HI	=	Harvest index	t	=	Tonne
HYV	=	High Yield Variety	TSP		Triple Super Phosphate
i.e	=	edest (means That is)	UN	=	United Nation
IFDC	=	International Fertilizer Development Centre	USG	=	Urea Super Granule
INM	=	Integrated Nutrient Management	var.	=	Variety
Inst.	=	Institute	VFRC	=	Virtual Fertilizer Research Council

CHAPTER I

INTRODUCTION

Bangladesh is a densely populated and agriculture based country. Agriculture is the main stem of livelihood for more than 80% of the country's population. The main purpose of agriculture is to provide food for the increasing population. Fertilizer is considered one of the main inputs for increasing crop yields and farmer's profit. To understand the role of fertilizer for increasing production, Tandon and Narayan (1990) cited the Nobel prize-winning wheat scientist Dr. Norman E Borlaug's dialogue as "*If the high yielding wheat and rice varieties were the catalyst that ignited the green revolution, then chemical fertilizer was the fuel that poured its forward thrust*". It is true for Bangladesh agriculture because it has virtually no possibility of increasing its cultivable land area.

In early 1950's, farmers applied organic manures (***first generation***) such as cow dung, bone meal to *aus* and *aman* rice and farmyard manure (FYM), mustard oil cake and fish meal to mustard and vegetable crops (EPBS,1958). Ahmed (1987) pointed out that the use of inorganic fertilizer (***second generation***) started in the country in 1951 with the import of 2,698 tons of ammonium sulphate, phosphates in 1957 and muriate of potash in 1960. Quasem (1978) reported that fertilizer was introduced at the farm level in 1959. The spread of 'seed-fertilize-water' technology popularly known as green revolution began in Bangladesh in the 1960s. At that time farmers rarely used fertilizers, pesticides and modern irrigation equipments. Then, in 1965, the government launched a 'grow more food' campaign and provided fertilizers and low lift pump (LLP) at a highly subsidized rate with pesticide as free of cost to popularize these inputs among the farmers and meet the country's food shortage. After liberation, 1971 Bangladesh experienced magnificent increase in food production due to effect of green revolution. Thus, fertilizer consumption began to increase rapidly with the introduction of HYV rice (i.e. IR 5 & IR 8) and LLP use. Hossain (1987) reported that the HYV acreage and irrigation have a significant positive influence on fertilizer consumption.

Food security has become a major and fast growing concern worldwide. It is proposed that there is a need to double the world food production in order to feed the ever increasing population which is set to reach nine billion marked by 2050 (UN, 2009).

The climate in Bangladesh is changing and it is becoming more unpredictable every year due to global warming. The impacts of higher temperatures, more variable precipitation, more extreme weather events, and sea level rise are already felt in Bangladesh and will continue to intensify. Climate change poses now-a-days severe threat mostly in agricultural sector and food security among all other affected sectors. Crop yields are predicted to fall by up to 30 per cent, creating a very high risk of hunger and only sustainable climate-resilient agriculture is the key to enabling farmers to adapt and increase food security (Climate change cell, 2007).

On the other hand, at present, about 220 ha of agricultural land per day go to urbanization and homestead area expansion in rural area (Anon, 2007). For this reason the net cropped sown area of the country is decreasing but the cropping intensity is increasing over times. This resulted in soil losing nutrient and increasing demand for nutrients, which was reflected in more nutrient deficiencies exhibited by the crops.

Bangladesh, a sub-tropical country, possesses soils poor in organic matter and obviously deficient in nutrients. The fertility of a soil is not a fixed property. It changes depending on how intensively the land is used; nutrients are added and removed through crops. Fertilizers used in Bangladesh are mainly urea, triple super phosphate (TSP) and muriate of potash (MoP) as ***second generation fertilizer***. It appears that the Government of Bangladesh imported large amount of urea, TSP and MoP from abroad to meet the demand even though first two fertilizers are produced in our country. The farmers of Bangladesh could not harvest additional yield advantage of crops due to lack of knowledge in using of ***next generation fertilizers***, although the role of growth controlling in various physiological and biochemical processes is well known. Even though some farmers are following recommended fertilizer done under IPNS basis but still some hidden hunger is remaining in plants. As a result farmer are not getting desired yield of the crops. In developed countries, they are using Next Generation Fertilizers with inorganic fertilizer done under INM or IPNS basis and increasing crops yield as well as keeping soil health & environmental sustainable. ***Next generation fertilizer*** means nutritional mixed fertilizers to provide total nutritional requirements for crops / plants without compromising on productivity while protecting ecology and also address "*First Generation*" & "*Second Generation*" fertilizer.

Bangladesh has no alternative to maximize crop yields per unit area through intensive use of land and soil resources. Future soil & fertilizer research and development should be directed towards maximizing crop yields per unit area in intensive cropping systems as well as making the achieved yield levels sustainable through fighting intelligently against soil deterioration. Soil organic matter level is alarmingly low in all soil types of the country. The poor efficiency of applied NPK in wetland rice culture as well as in upland crops has been always a problem in world's agriculture. Bangladesh need continue her efforts to search effective and usable means of improving NPKS use efficiency and alternative sources of fertilizer. With this view the present research will be taken out on next generation fertilizer products for soil fertility and crop production.

Technologies generated on balanced fertilization practices for different crops and cropping patterns at the various National Agricultural Research System (NARS) institutes and also at the agricultural and public universities are transferred to the end users through various mechanisms. The International Fertilizer Development Center (IFDC) has been playing a significant role in developing and disseminating nutrient use technologies in the country since long.

IFDC has launched the Virtual Fertilizer Research Center (VFRC), a global research initiative to create the next generation fertilizers and production technologies. Besides, many organizations and companies of USA, Australia, Germany, China, Japan, Philippines and India continuing their research on the next generation fertilizer for sustainable agriculture.

In Bangladesh, so many researches had taken initiative on fertilizer management like effect, doses and timing etc. but no enough research on next generation fertilizer materials are still found.

Proper soil fertility management emphasizing balanced fertilization is one of the most important cultivation techniques that ensure optimum supply of nutrients for successful crop production and maintenance of soil health. The supply of nutrients to the soil-plant system comes from various sources, the most important sources being the organic manure and chemical fertilizers. The use efficiency of the chemical fertilizers are low and unsatisfactory because of imbalanced or under use/sometimes over use resulting in huge wastage which the country cannot afford. For example, two out of three bags of urea go unused and environmental hazard in wetland rice production (IFDC, 2011). Therefore, the practice of balanced fertilization should receive top priority to increase crop productivity when food security is so crucial for poverty stricken people. Bangladesh is facing challenges of increasing population and shrinking natural resources including agricultural land and also when there exists big gap between research and farmer’s yield. Some identifying problems in sustainable fertilizer and crop production management in Bangladesh are: continuous mining of nutrients from soil (soil fertility depletion); inadequate & imbalanced fertilizer use; decline in crop response to fertilizers; lack of nutrient use efficiency (NUE); lack of integrated nutrient management (INM). Therefore, increasing deficiency of secondary and micronutrient have started limiting crop response to NPK application.

Three fundamental issues are important in soil fertility and fertilizer management research (Bhuiyan, 1998) - nutrient requirement of crops to be grown; nutrient supplying capacity of soil; fertilizer management and /or soil amendment.

A major challenge of agriculture production is the deterioration of natural resource e.g. land & water due to over exploitation of agricultural land; depletion of soil organic matter and soil fertility; increasing soil salinity and soil acidity; submergence & flooding and drought and heat; excessive use of imbalance chemical fertilizer. These would impact food and nutrition insecurity of increasing population.

From the above aspect, the present study was conducted to investigate the effects of next generation fertilizers in combination with NPK on the growth, yield and nutrient uptake of selected crop maize, tomato and rice. Considering the above facts, the present research study was, therefore, undertaken with following objectives:

i. To investigate the effect of Next Generation Fertilizers along with other recommended fertilizers on growth and yield of different crops;

ii. To observe the residual effect of Next Generation Fertilizers on chemical properties of post harvested soils; and

iii. To evaluate the prospective of Next Generation Fertilizer technologies for better crop growth and maximizing yield.

CHAPTER II

REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief and relevant review of many researchers in relation to the effects of next generation fertilizers along with other recommended fertilizers and crop varieties on the aspect of growth, yield of maize, tomato and rice in Bangladesh perspective and also in the other parts of the world. Related review regarding status in postharvest soil was also reviewed in this chapter under the following headings:

2.1 Experiment 1: Effect of next generation fertilizers on growth and yield of maize

2.1.1. Effect of next generation fertilizers (NGF) on growth, yield attributes and yield of maize

Idris *et al.* (2016) conducted two field experiments with the liquid bio-fertilizer levels were (Zero, 06.25, 12.5, 18.75 and 25.00 L ha^{-1}) corresponding to F1, F2, F3, F4 and F5 treatments. The two maize cultivars were HUDAIBA (HD) and MUGTAMA45 (MG). The results revealed that plant height, cob length, stem diameter and leaf area and 100-grain weight and grains number per cob were increased due to the increase in level of bio-fertilizer. Also, the aforementioned characters were significantly increased for HD cultivar particularly under application of F4 and F5 levels. Further, the highest grain yield (5.76 & 5.57 t ha^{-1}) was obtained from application of F4 dose to the two cultivars in the both seasons. This high response of the two maize cultivars to bio-fertilizer could be of a great value in using it in maize nutrition in the Sudan.

Ali *et al.* (2016) conducted a field experiment to study the effect of spraying three concentrations: control (spray water only), 0.50% and 100% of the extracts of three types of organic fertilizer (waste Poultry, wheat residue, remnants of palm fronds) on growth and yield of maize. The extract of poultry waste fertilizer was superior compared to residues of wheat and palm fronds. Extract fertilizer spraying led to increase yield components (cob rows number, row grains number, cob grains number, weight of 500 grains, weight of grain, ear grain weight) and grain yield significantly compared with control, and the extract of poultry waste fertilizer was superior compared to the other both extracts.

Maulana *et al*. (2015) conducted a research to evaluate the bio liquid fertilizer Ultra Gen consisted of four levels, i.e. without liquid fertilizer (P_0), 0,8 liter ha^{-1} (P_1), 1,7 liter ha^{-1} (P_2), and 2,5 liter ha^{-1} (P_3). Varieties consisted of two levels, i.e. Pertiwi (V_1) and local Aceh (V_2). The result showed that the varieties treatment very significantly effect on plant height at 15, 30, and 45 days after planting, the number of leaves at the age of 30 and 45 DAP, corn length with cornhusk, corn diameter with cornhusk and without cornhusk; and significantly affect on the number of leaves on age 15 DAP, corn length without cornhusk; and not significantly effect on corn weight with cornhusk and without cornhusk, weight of 100 grain dry seeds, shelled seeds weight dry per plant and yield. The result showed that the treatment and varieties had significantly effect on grain yield (6.22 t ha^{-1}) by P_3.

Rogaciano and Rosill (2015) conducted a research to determine the effects of three liquid fertilizers (Nitrofert, Crop Gaint and Nutriplant AG) on the growth of glutinous corn. Findings revealed that the height a corn 15, 30, 45 and 60 days after planting and on the number days from seed emergence to flowering were not significantly affected by the supplementation of different liquid fertilizers. The number of glutinous corn per plot, weight of glutinous corn in kilogram per plot, and weight of glutinous corn in tons per hectare were significantly affected by the different liquid fertilizers. In terms of cost and return, Nutriplant AG also gave the highest profit. Thus, application of Nutriplant AG can increase growth and yield and can increase profits of the farmer.

Ali *et al.* (2012) investigated the response of maize genotypes against the application of two types of liquid humic fertilizers (derived from peat and leonardite). Results from mean comparison indicate that ZP677 had the highest (20.89 ton/ha) biological yield, whereas OS 499 had the lowest (16.93 t ha^{-1}). Application of leonardite based liquid humic fertilizer proved to be more productive than the two other conditions. This humic fertilizer produced the highest values for biological yield (21.99 t ha^{-1}) and grain yield (7.09 t ha^{-1}).

Sutharsanr and Rajendran (2010) investigate the effect of liquid organic mixture (Jeetvamirta) on growth and yield of maize (cv. Pacific 984) with four treatments T_l: once a week application, T_2: once in two weeks application, T_3: once in three weeks application and T_4: as control plot. The results revealed that there were significant ($p<0.05$) differences in leaf area and plant biomass. Highest leaf area and biomass were produced by plants belong to T_l, during reproductive and maturity stages. Significant differences ($p<0.05$) were found in the grain yield and its components. The highest yield (6.1 t ha^{-1}) was obtained in T_I, followed by T_2 and lowest grain yield (1.9 t ha^{-1}) was obtained from control treatment. The results indicated that application of Jeewamirta once a week could be a viable technique to increase maize production.

2.1.2. Effect of NPK fertilizers on growth, yield attributes and yield of maize

Yihenew (2015) reported that there is no significant variation among treatments in plant height, shelling percentage and 100-grain weight. However, nitrogen fertilizer rates significantly affected kernel number per cob and number of cobs per plant. The yield parameters have also shown a significant increase up to the rate of 90 kg N ha^{-1}. Increasing the N rate from 90 to 200 kg N ha^{-1}, however, did not give a significant grain, dry stubble and dry aboveground biomass yields.

Asghar *et al.* (2010) investigated the effect of different NPK rates on growth and yield of maize cultivars; Golden and Sultan. The plant height was significantly affected by different rates of NPK. Treatment NPK (250-110-85) of NPK produced tallest plants than two other treatments in both the varieties. Too low or high NPK levels reduced the yield and yield parameters of maize crop. Treatment NPK (175-80-60) seems to be the most appropriate level to obtain maximum grain yield under the prevailing conditions.

Woldesenbet and Haileyesus (2016) found that maize response to high nitrogenous fertilization levels 0, 23, 46, 69 and 92 kg Nha^{-1} with three replications. The tallest plant (360.66 cm) was recorded from the application of 92 kg N ha^{-1} and the shortest (347.33 cm) from no N application. For the number of kernels per cob showed that the lowest kernels per cob (497.86) were obtained from no N application and the highest kernels per cob (588) were obtained from the application of 92 kg N ha^{-1} although there was no significant difference between the application of 69 and 92 kg N ha^{-1}. Regarding to cob length the data showed that the longest cob (23.63 cm) was obtained from the application of 92 kg N ha^{-1}.The effect of N on grain yield indicated that there is no significant difference between the application of 69 and 92 kg N ha^{-1} even if there is a slight difference on yield.

Amali and Namo (2015) conducted an experiment to investigate the growth and yield responses of four varieties of maize (SUWAN-1-Y, TZSR-Y, DMESR-W and ACROSS-97 TZL) to time of fertilizer application (2,4 and 6 weeks after planting). The results indicated that the mean number of leaves per plant, leaf area index (LAI), plant height, Nos. of cob, mean number of rows per cob, cob length, cob weight, shelling %, kernel weight and total grain yield significantly ($P<0.05$) increased when fertilizer was applied at two weeks after planting. The interactions of variety and time of fertilizer application on the number of rows per cob, mean cob weight, kernel weight and shelling % were significant. The study revealed that the yield of maize could be enhanced by the cobly application of fertilizer at two weeks after planting.

Amin (2011) investigated the effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.) with N sources are urea, nitrophoska (NPK), ammonium sulphate nitrate (ASN) and ammonium sulphate (AS). The results showed that, plant height, the number of the days for 50% tasseling, fresh forage yield and dry forage yield were significantly affected by nitrogen sources during two seasons. Moreover, dry and fresh forage yield, increased progressively by ASN and NPK as compared with other nitrogen sources.

Muthaura *et al.* (2017) conducted a rescobch to determine the effects of applying different nutrients on growth and yield of maize with 8 treatments (control, NPK+ CaMgS micronutrient fertilizer (Ca, Mg, S, B, Mn, Cu, Zn,), NPK+ Manure, NPK+ Lime, NPK, NP, NK, and PK). Treatment inputs were applied at rates of 100 kg ha^{-1} N, 30 kg ha^{-1} P, 60 kg ha^{-1} K, 10 kg ha^{-1} Ca, 10 kg ha^{-1} Mg, 5 kg ha^{-1} S, 10 t ha^{-1} manure and 1 t ha^{-1} lime. The results showed that control, PK and NK treatment achieved means that were significantly different for leaf number and bio-volume during the 2 cropping seasons. The grain and stover yields for control, NK and PK showed significant differences were showed.

2.2 Experiment 2: Effect of next generation fertilizers on growth and yield of tomato

2.2.1. Effect of next generation fertilizers (NGF) on growth, yield attributes and yield of tomato

Chaurasia *et al.* (2005) state that application of 5 foliar sprays of water soluble fertilizers significantly increased the plant height, number of branches, Number of fruits, average fruit weight, fruit length, fruit diameter, yield and the net profit of tomatoes. The maximum plant height, number of branches $plant^{-1}$, fruit length, yield, net profit along with maximum C:B ratio were recorded by 5 foliar sprays of water soluble liquid fertilizers 19:09:19 followed by NPK 19:19:19. The minimum values in all the parameters were recorded in the control having only recommended dose of fertilizer.

Islam *et al.* (2017) studied that the effect of humic acid (HA) applied at 4.8, 9.6 and 14.4 kg ha^{-1} on the growth and productivity of two tomato hybrids Nema 1400 and Platinium 5043 under hot continental climate. HA was applied twice to soil: the first one-three weeks from transplanting and the second one, after one week from the first application, in both seasons. Application of HA during the summer season targeted a great results on tomato plant growth and productivity. Humic acid at 14.4 kg ha^{-1}increased the vegetative growth of tomatoes (plant height and fresh weight) and flowering parameters (number of flower clusters and number of fruits per cluster) as well as yield characters (fruit number per plant and fruit weight, which resulted in higher early and total yield) of variety Platinium 5043 in both seasons. HA application had the least impact on fruit number per plant, and on vitamin C and total soluble solids (TSS) concentration as compared with control.

Souri *et al.* (2017) conducted a study to evaluate the effects of soil (six split applications at a final volume of 5 mL) and foliar application (six applications at 0.2% concentration) of a commercial aminochelate (liquid fertilizer consisting of 2.0% N-amino acid, 2.5% Zn, 2.0% Fe, 1.5% Mn and 0.4% Cu) on growth, yield, and quality traits in three vegetable crops including tomato (*Solanum lycopersicum*), cucumber (*Cucumis sativus*), and green bean (*Phaseolus vulgaris*) under field conditions in lime soil. Plant growth, yield, and quality parameters significantly increased in response to foliar application, and to lesser extent soil application of aminochelate fertilizer. Plants treated with foliar application of aminochelate had a significantly higher chlorophyll index, number of lateral shoots, shoot dry weight, number of fruits, plant yield, and leaf N concentration in all three vegetable crops compared to the control. Soil application of aminochelate resulted in significantly higher fruit or pod vitamin C content and total soluble solids content versus the control. However, for most traits, there was no significant difference between soil applications of amino chelate versus chemical fertilizer a (N, P, K mixture).

2.2.2. Effect of NPK fertilizers on growth, yield and yield attributes of tomato

Singh *et al.* (2005) conducted an experiment to study the effects of N, P, and K at 200:100:150, 350:200:250, and 500:300:350 kg ha^{-1} on the growth and yield of tomato hybrids Rakshita, Karnataka, and Naveen in New Delhi, India during the early winter of 2000-02. Naveen had the highest number of flower clusters per plant and the earliest picking period and fruit setting. On the other hand, Karnataka produced the highest yield during both cobs (2.85 and 3.07 kg $plant^{-1}$). Plant height, number of leaves $plant^{-1}$, leaf length, stem thickness, number of flower clusters $plant^{-1}$, and picking period were the highest with the application of 500:300:350 kg NPK ha^{-1} during both years. Fruit yield (30.2 and 34.8 kg ha^{-1} 2000-01 and 2001-02, respectively) and number of pickings (14 during both years) were the highest with the application of 350:200:250 kg NPK ha^{-1}.

2.3 Experiment 3: Effect of next generation fertilizers on growth and yield of rice

2.3.1. Effect of next generation fertilizers on growth, yield attributes and yield of rice

Rongting *et al.* (2017) conducted pot experiment, the liquid organic fertilizers significantly promoted root and aboveground growth of chrysanthemum by 10.2–77.8% and 10.7–33.3%, respectively, compared with the chemical fertilizer. The order of growth promotion was: L1 (shrimp extracts) > L2 (plant decomposition) > L4 (seaweed extracts)/L5 (fish extracts) > L3 (vermicompost). The shrimp extract treatment significantly increased the nutrient contents and altered the soil's functional microbial community at the rhizospheric level compared with the chemical fertilizer treatment.

Akhila *et al.* 2017 conducted an experiment with foliar application of different levels of seaweed extract and enriched banana psuedostem sap on different varieties of green gram (*Vigna radiata*) to check the nutrient uptake by the crop and soil properties. The result revealed that non-significant effect on all the soil property tested due to liquid fertilizer except available N.

2.3.2. Effect of NPK fertilizers on growth, yield attributes and yield of rice

Sarkar (2014) found that the application of 75% RD of inorganic fertilizers + 50% cowdung showed superiority in terms of plant height (123.3 cm) and total tillers hill^{-1} (13.87) where those were also highest in combination of BRRI dhan34 × 75% RD of inorganic fertilizers + 50% cowdung. Nutrient management of 75% RD of inorganic fertilizers + 50% cowdung (5 t ha^{-1}) gave the highest grain yield (3.97 t ha^{-1}) and the lowest grain yield (2.87 t ha^{-1}) was found in control. The highest grain yield (4.18 t ha^{-1}) was found in BRRI dhan34 coupled with 75% RD of inorganic fertilizers + 50% cowdung and the lowest grain yield (2.7 t ha^{-1}) was found in BRRI dhan37 in control.

Hasan (2014) showed that the treatment T_6 (5 t CD + USG @ 78kg N ha^{-1}) produced the highest grain yield of 5.56 t ha^{-1} and straw yield was highest (5.95 t ha^{-1}) in treatment T_1. The treatment T_6 also showed highest (23 kg^{-1} grain kg^{-1} N applied) N use efficiency. The N, P and K uptake by BRRI dhan32 rice were influenced profoundly due to the application of USG alone or in combination with cowdung. USG application generated available NH_4-N and NO_3-N slowly over the entire growth period; indicating a beneficial role of USG. The overall results indicate that application of USG in combination with cowdung could be considered more effective in rice production for reducing N-losses, conserving-N and increasing the efficiency of applied N.

Liza *et al.* (2014) found that the treatment T_6 (50% RFD + residual effect of CD 2.5 t ha^{-1}, PM 1.5 t ha^{-1}, and Com. 2.5 t ha^{-1}) produced the highest grain yield (6.87 t ha^{-1}) and straw yield (7.24 t ha^{-1}). The lowest grain yield (3.22 t ha^{-1}) and straw yield (4.55 t ha^{-1}) were found in T_0. Treatment T_6 receiving 50% RFD along with the residual effect of 2.5 t ha^{-1} cowdung, 1.5 t ha^{-1} poultry manure and 2.5 t ha^{-1} compost was found to be the best combination of organic and inorganic nitrogen for obtaining the maximum yield of BRRI dhan29 and nutrient content and uptake by grain and straw.

Shaha (2014) reported that the different rates of cowdung with inorganic fertilizers showed significant effect on all growth parameters viz. plant height and tillers $hill^{-1}$. Among the cowdung levels with BRRI RD of inorganic fertilizers, highest grain yield (5.62 t ha^{-1}) was obtained from cowdung 7.5 t ha^{-1} with inorganic fertilizers and lowest (5.07 t ha^{-1}) was recorded in control. Similarly, the highest grain yield (6.25 t ha^{-1}) was obtained from the treatment combination of BR11 and cowdung 7.5 t ha^{-1} with inorganic fertilizers which was statistically identical with all BR11 in cowdung treated plot.

Shiyam *et al.* (2014) conducted an experiment to evaluate the performance of four Chinese hybrid rice varieties where it was showed comparative superiority of FARO 15 to the hybrids in all growth and yield components assessed. FARO 15 was taller (140 cm) with more productive tillers (11.0), higher spikelets plant^{-1} (166.0), higher filled grains panicle^{-1} (156.17), higher filled grains (92.17%), highest 100-grain weight of 2.63 g and the higher paddy yield (5.021 t ha^{-1}) than others. Despite the comparative poor performance of the hybrids, Xudao151 came close to FARO15 with grain yield of 2.987 t ha^{-1}.

Sarker *et al.* (2013) found that the BRRI dhan28 was shorter in plant height, having more tillering capacity, higher leaf number which in turn showed superior growth character and yielded more than those of the local cultivars. The BRRI dhan28 produced higher grains panicle^{-1} and bolder grains resulted in higher grain yield over the local cultivars. The BRRI dhan28 produced higher grain yield (7.41 tha^{-1}) and Bashful, Poshurshail and Gosi yield ha^{-1}, respectively. Among the local rice cultivars, Gosi showed the higher yielding ability than Bashful and Poshursail.

Naidu *et al.* (2013) reported that the highest growth, yield attributes, lesser spikelet sterility and higher grain yield were obtained with the application of 100-50-50 kg ha^{-1} N, P_2P_5, K_2O respectively and these parameters were at their minimum with the supply of 60-30-30 kg ha^{-1} of N, P_2P_5, K_2O. The increase in yield with supply of 100-50-50 kg ha^{-1} N, P_2P_5, K_2O (N_3), compared to supply of 60-30-30 kg ha^{-1} N, P_2P_5, K_2O (N_1) was 15.1 and 15.4% respectively during 2006 and 2007 respectively.

Mahamud *et al.* (2013) showed that rice cultivars differed significantly in all growth characters, such as plant height, tillers number, chlorophyll content and dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, filled grain percentage, 1000-grain weight, grain yield and straw yield.

Islam *et al*. (2013) found that the highest plant height (116.00 cm) was found in the variety Morichsail and the lowest in the variety Khaskani. Filled grains panicle^{-1} was found highest (100) with the variety Khaskani and the lowest was recorded in the variety Raniselute. Raniselute produced the highest 1000-grain weight (32.09 g) and the lowest (13.32 g) was recorded from the variety Kalijira. The variety Morichsail produced the highest grain yield (2.53 t ha^{-1}) followed by Kachra (2.41 t ha–1), Raniselute (2.13 t ha^{-1}) and Badshabhog (2.09 t ha^{-1}) and the lowest grain yield (1.80 t ha^{-1}) was obtained from Kalijira.

Fakhrul *et al*. (2013) studied the fertilizer and manure effect on the growth, yield and nutrient concentration of BRRI dhan28 at Sher-e-Bangla Agricultural University rescobch farm, Dhaka. The T_5 (50% RDCF + 4 ton PM ha^{-1}) showed the highest effective tillers hill^{-1}, plant height, panicle length, 1000 grain wt., grain yield (5.92 kg plot^{-1}) and straw yield (5.91 kg plot^{-1}). The higher grain and straw yields were obtained organic manure plus inorganic fertilizers than full dose of chemical fertilizer and manure.

Uddin *et al*. (2013) found that application of nitrogen at 80 kg ha^{-1} produced the highest total spikelets and maximum grains panicle^{-1} resulted in the highest grain yield. Based on the results it may be recommended that nitrogen should be applied at 80 kg for obtaining the higher grain yield of NERICA1 rice.

Panwar *et al.* (2012) studied to evaluate the performance of rice varieties. Growth parameters viz plant height (cm), no. of tillers m^{-2}, leaf area index and dry matter accumulation (g) was highest in JGL-3844 over rest of varieties. The effective tillers m^{-2} (331.6), panicle length (25.63 cm), grains $panicle^{-1}$ (68.23 g), sterility per cent (12.1), grain yield (60.9 q ha^{-1}) and straw yield (92.58 q ha^{-1}) yield were also highest in variety JGL-3844.

Oka *et al.* (2012) assessed the agronomic characteristics of 15 selected indigenous and newly introduced hybrid rice varieties in Ebonyi State, Nigeria. Significant variation ($P<0.05$) was detected among the 20 rice varieties for all the traits evaluated. The results showed that plant height ranged between 144.01 cm in "Mass (I)" and 76.00 cm in "Chinyeugo". Cv. "E4197" had the highest value of 38±0.02 cm for panicle length and "Chinyereugo" had the highest value of 6.3g ± 0.03 for panicle weight. Leaf area showed the highest value of $63.8cm^{-2}$ ± 0.01 in "Mass (I)". Cv. "Co-operative" had high number of seeds $panicle^{-1}$ (139 ± 0.19). "Chinyereugo" had the highest value of 25.9g ±1.4 for 1000-grain weight. The grain of "E4314" was the longest (8.00 mm ± 0.89) of the varieties studied.

Yao *et al*. (2012) found insignificant difference in grain yield between the cv. AWD and CF. On average, YLY6 produced 21.5% higher yield than HY3 under AWD conditions. Like grain yield, YLY6 showed consistently higher water productivity and physiological nitrogen use efficiency than HY3. Both total dry weight and harvest index contributed to higher grain yield of YLY6.

Sritharan and Vijayalakshmi (2012) evaluated the physiological traits and yield potential of six rice cultivars *viz.*, PMK 3, ASD 16, MDU 3, MDU 5, CO 47 and

RM 96019. The plant height, total dry matter production and the growth attributes like leaf area index, crop growth rate and R:S ratio were found to be higher in the rice cultivar PMK 3 that showed significant correlation with yield. Yield and yield components like number of productive tillers, fertility co-efficient, panicle harvest index, grain weight and harvest index were found to be higher in PMK 3.

Alam *et al*. (2012) found that the cultivar BRRI dhan33 gave significantly the tallest plant (113.17 cm), while the shortest plant was found in BRRI dhan32 cultivar (105.07 cm). Among the cultivars, BR11 produced the maximum total tillers hill^{-1} (12.33), maximum fertile spikelets panicle^{-1} (103.83) while lowest fertile spikelets panicle^{-1} (102.10) and minimum total tillers hill^{-1} (10.17) were found in BRRI dhan32. BR11 also produced the highest 1000–grain weight (23.79g) and highest grain yield (5.92 t ha^{-1}) while BRRI dhan33 produced the lowest 1000-grain weight (21.69 g) and grain yield. The cultivar BR11 produced the highest grain yield, it might be due to the highest number of total tillers hill^{-1}, number of effective tillers hill^{-1} and 1000–grain weight and lowest number of sterile spikelets panicle^{-1}.

Rashid *et al*. (2011) examine the effect of urea– nitrogen, cowdung, poultry manure and urban wastes on growth and yield of transplant *Boro* rice, cv. BRRI dhan29. Among the treatments, T_6 (N_{50} + PM_{50}) produced 43.39% higher number of effective tiller hill^{-1}than control treatment. Application of 47.5 kg N along with 9.5 t poultry manure ha^{-1}produced the maximum panicle length (27.03 cm) with an increase of 18.03 percent over control treatment. Treatment T_6 further produced the maximum number of filled grains panicle^{-1} (121), highest weight of 1000-grains (29.30 g), maximum grain yield (5.54 t ha^{-1}) and maximum straw yield (5.89 t ha^{-1}). The lowest number of filled grains panicle^{-1} (89), lowest weight of 1000-grains (21.17 g), lowest grain yield (3.06 t ha^{-1}) and the lowest straw yield (3.39 t ha^{-1}) was noted in control treatment.

Mia and Shamsuddin (2011) reported that the aromatic rice cultivars showed tallest plant stature, profuse tillers hill, grain yield, lowest straw yield and harvest index compare modern rice. Modern rice cultivars generally had higher TDM, LAI, LAR, CGR, RGR whereas aromatic cultivars resulted in higher NAR. The highest grain yield of modern rice cultivars was due to the higher harvest index. Poor yield in aromatic rice cultivars was due to lower translocation of assimilates panicle hill^{-1} and larger panicle but smaller grain, higher.

Hoshain (2010) observed that no. of effective tiller, no. of grains panicle^{-1}, grain yield and straw yield were significantly increased with the increasing rates of N 120 kg ha^{-1}as urea where harvest index increased from up to N 80 kg ha^{-1}application.

Salahuddin *et al.* (2009) found gradual increase in panicle length (24.50 cm), grains panicle^{-1} (110) and grain yield (4.91 t ha^{-1}) due to the increase in nitrogen levels up to 150 kg ha^{-1}and declined thereafter. Thousand-grain weight was not significantly influenced by application of different levels of nitrogen.

Sohel *et al*. (2009) found that BRRI dhan41 produced higher grain yield (4.7 t ha^{-1}) which was the contribution of higher number of grains panicle and heavier grain weight. Lower yield (4.51 t ha^{-1}) was recorded in BRRI dhan40.

Rahman *et al*. (2009) reported that the *Chola Boro* and *Sada Boro* are two local land races having potentials for producing higher effective tillers and higher 1000-

GW. Sada *Boro* and Chola *Boro*, two local cultivars were found very high in grain N content compared to other test cultivars. These two cultivars could be a nice tool for rice breeder to develop high nitrogen content rice. Chola *Boro*, IRATOM 24 and BR 14 are three high straw-K containing varieties having breeding potentials to make our future rice plant strong.

Hossain *et al*. (2008) reported that all the yield contributing characters differed significantly due to cultivar. The tallest plant was observed in Chinigura (162.8 cm) which statistically similar to Kataribhog. Kalizira produced the maximum number of grains panicle^{-1} (135.90). Among the cultivars, BRRI dhan 38 gave the maximum grain yield (4.00 t ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

Conducting a research study, methodology is one of the prime considerations for generating valid and reliable findings. Appropriate methodology enables the researcher to collect valid and reliable information and to analyze the information properly in order to arrive at correct conclusions. However, the methods and operational procedures followed in conducting three separate experiments have been described in the subsequent sections of this chapter.

3.1 Experimental plan

Three separate experiments were carried out during the period from March 2014 to May 2015. These were:

Experiment-1: Effect of Next Generation Fertilizers on growth and yield of maize

Experiment-2: Effect of Next Generation Fertilizers on growth and yield of tomato

Experiment-3: Effect of Next Generation Fertilizers on growth and yield of rice

3.2 Experimental site and duration

The first experiment was conducted for maize during March 2014 to June 2014 and second experiment was conducted for tomato during December 2014 to March 2015 at research field of Sher-e-Bangla Agricultural University, Dhaka. Third experiment was conducted for rice during *Boro* season January 2015 to May 2015 at research field of Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

3.3 Site description

3.3.1 Geographical location

The experimental area was situated at $23^0 77^0$N latitude and $90^0 33^0$E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.3.2 Agro–ecological zone (AEZ)

The experimental field belongs to the Agro–ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1998a). This region was complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1998b).

3.3.3 Soil

The soil of the experimental site belongs to Tejgaon Series under the general soil type, “Shallow Red Brown Terrace” soils. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The initial physio-chemical properties of three experimental fields were shown in Tables 3.1 and 3.2.

Table 3.1 Morphological characteristics of the experimental field

Physiological properties	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka, Bangladesh
AEZ	Madhupur tract
General soil type	Deep red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

Table 3.2 Physical and chemical properties of the initial soil sample

Soil Analysis	Soil of experiment-1 (Maize)	Soil of experiment-2 (Tomato)	Soil of experiment-3 (Rice)
% Sand	28.2	26.0	30.0
% Silt	41.2	42.4	40.4
% Clay	30.6	30.6	29.6
Textural class	Clay Loam	Clay Loam	Clay Loam
pH	5.8	5.5	6.8

Soil Analysis	Soil of experiment-1 (Maize)	Soil of experiment-2 (Tomato)	Soil of experiment-3 (Rice)
Bulk density (g/cc)	1.45	1.40	1.47
Particle density (g/cc)	2.52	2.47	2.50
Organic carbon (%)	0.62	0.61	0.68
Organic matter (%)	1.07	1.05	1.18
Total N (%)	0.06	0.07	0.06
Available P (ppm)	25.75	24.64	20.32
Exchangeable K (meq/100g soil)	0.14	0.16	0.15
Available S (ppm)	11.75	15.29	12.40

3.3.4 Climate

The area has sub tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in *Kharif* season (April–September) and scanty rainfall associated with moderately low temperature during the *Rabi* season (October–March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in Table 3.3.

Table 3.3 Monthly records of air temperature, relative humidity, total rainfall and total sunshine of the experimental site during the period from March 2014 to May 2015

Months	Air temperature °C		Relative humidity (%)	Total rainfall (mm)	Total sunshine (hr) per day
	Maximum	Minimum			
Experiment-1 (Maize)					
March 2014	34.8	25.0	70	2	5.9
April 2014	35.8	25.0	75	5	6.4
May 2014	34.8	25.0	75	2	5.9
June 2014	34.8	25.0	82	10	6.0
Experiment-2 (Tomato)					
November 2014	29.7	20.1	65	0	6.4
December 2014	26.9	15.8	68	0	7.0
January 2015	24.6	12.5	66	0	5.5
February 2015	33.7	23.8	69	0	5.8
March 2015	34.8	25.0	70	2	5.9
Experiment-3 (Rice)					
December 2014	26.9	15.8	68	0	7.0
January 2015	24.6	12.5	66	0	5.5
February 2015	33.7	23.8	69	0	5.8
March 2015	34.8	25.0	70	2	5.9
April 2015	35.8	25.0	75	5	6.4

Source: Bangladesh Meteorological Department (Climate & Wealth Division), Agargoan, Dhaka-1212

3.4 Experimental materials, design and crop growing

3.4.1 Experiment-1: Effect of Next Generation Fertilizers on growth and yield of maize

Three varieties of maize were used in this experiment for growth measurement under six next generation fertilizers with control following a two factor experiment in RCBD design with three replications.

Factor A: NGF + recommended fertilizers with control (8)

Factor B: Varieties (3)

3.4.1.1 Factor A: Next generation fertilizers and recommended fertilizers

The following Next generation fertilizers (NGF) were used in the experiment

Sl. No.	Name of NGF	Composition (%)	Dosage (ha^{-1})
i.	Wuxal Super	N - 8.60 P - 9.2 K - 6.5 S - 6.82	5.00 lit
ii.	Bio-forge	N - 4.20 P - 4.43 K - 6.23 S - 1.30	1.20 lit
iii.	American NPKS	N - 9.30 P - 0.73 K - 3.03 S - 0.67	9.88 lit
iv.	Peak	N - 10.25 P- 7.18 K - 8.5 S - 16.02	1.20 kg
v.	Root Feed	N - 4.20 P - 5.06 K - 4.0 S - 0.13	1.20 kg

Sl. No.	Name of NGF	Composition (%)	Dosage (ha^{-1})
vi.	Nitro Plus	N - 9.0 P - 0.30 K - 3.0 S - 0.90	1.20 lit

The following recommended fertilizers were used in the experiment.

Sl. No.	Name of nutrient	Name of fertilizer & composition	Dosage ($kg\ ha^{-1}$)
i.	Nitrogen, N	Urea, 46.0 % N	250.0
ii.	Phosphorus, P	TSP, 20.0 % P	50.0
iii.	Potassium, K	MoP, 50.0 % K	100.0
iv.	Sulphur, S	Gypsum, 18.0 % S	25.0
v.	Zinc, Zn	Zinc Sulphate, 36.0% Zn	2.0
vi.	Boron, B	Boric Acid, 17.0% B	1.0

Sources: According to Fertilizer Recommended Guide 2012, BARC

3.4.1.2 Factor B: Varietal descriptions

The following three varieties were selected for the experiment.

V_1: BARI Hybrid Bhutta-5

V_2: BARI Hybrid Bhutta-6

V_3: BARI Hybrid Bhutta-9

V_1: BARI Hybrid Bhutta-5

BARI Hybri Bhutta-5 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh in 2004. Average plant height in *rabi* season 195-200 cm and *kharif* season 110-115 cm, weight cob 250 g., seed weight / cob 230 g., cob tightly covered with husk, seed/ ear 420, grain orange color, 1000 grain weight 290-310 g., Yield in *rabi* season 10-10.5 t/ha and *kharif* season 7-7.5 t ha^{-1} (Mia, 2017).

V_2: BARI Hybrid Bhutta-6

BARI Hybrid Bhutta-6 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh in 2006. Plant height 200-210 cm, weight of cob 250-260 g., seed weight / cob 200-210 g., seed/ cob 700-780, kernel are bold, yellow color and semi flint type, 1000 grain weight 380-390 g, crop duration in rabi season 142-146 days and 95-105 days in *Kharif* season. Yield is in *Rabi* season 9.8-10.0 t ha^{-1} (Mia, 2017).

V_3: BARI Hybrid Bhutta-9

BARI Hybrid Bhutta-9 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh in 2007. Deep violet glumes (Anthocynin color) ring in male flowers and silk kernels are yellow color and dent type. In rabi season silk formation time 94-160 days, plant height 208-239 cm, height of ear 100-115 cm, 1000 grain weight 340-360 g, ear are covered with tight husk. Planting season and time is *Rabi*: mid November to December, mid March to April (*kharif*-1). Yield is in *rabi* season 10.20-12.00 t ha^{-1} (Mia, 2017).

3.4.1.3 Next generation fertilizer along with other recommended fertilizers

The following eight treatments including control treatment were included in the experiment where the treatments were the combinations of next generation fertilizers and other recommended fertilizers.

T_0 = Control (No fertilizer)

T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_2 = American NPKS + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_3 = Bio-forge + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_4 = Wuxal Super + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_5 = Peak + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_6 = Root Feed + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_7 = Nitro Plus + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

There were on the whole 24 (3x8) treatments combination as T_0V_1, T_1V_1, T_2V_1, T_3V_1, T_4V_1, T_5V_1, T_6V_1, T_7V_1, T_0V_2, T_1V_2, T_2V_2, T_3V_2, T_4V_2, T_5V_2, T_6V_2, T_7V_2, T_0V_3, T_1V_3, T_2V_3, T_3V_3, T_4V_3, T_5V_3, T_6V_3 and T_7V_3.

3.4.1.4 Experimental design

The experiment was laidout in a Randomized Complete Block Design (RCBD) with three replications. Each block was sub–divided into twenty four unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 72 (24×3). The unit plot size was 3 m × 2 m. Block to block distance was 1 m and plot to plot distance was 0.5 m. Maize seed were sowing at a distance 20 cm seed to seed and row to row 75 cm.

3.4.1.5 Seed collection

Healthy and vigor seeds of BARI Hybrid Bhutta-5, BARI Hybrid Bhutta-6 and BARI Hybrid Bhutta-9 were collected from Genetics and Plant Breeding Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.4.1.6 Preparation of land

The experimental field was first opened on March 22, 2014 with the help of a tractor drawn disc plough, later on March 23, 2014 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. 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 March 24, 2014 according to experimental specification. Individual plots were cleaned and finally leveled.

3.4.1.7 Sowing of maize seed

On 24 March, 2014 , seeds were sowing in the experiment field keeping plant to plant distance 20 cm and row to row distance 75 cm. Gap filling was made up to 7 days after transplanting to maintain proper treatment and similar plant population density for every plot.

3.4.1.8 Application of fertilizers

The triple super phosphate (TSP), muriate of potash (MoP), gypsum ($CaSO_4$) zinc sulphate and boron (boric acid) fertilizers were applied in the experimental plots @ P_{50}, K_{100}, S_{25}, Zn_2 and B_1 kg ha^{-1}, respectively as basal dose in the experimental plots except control plots. The recommended dose of N was 250 kg ha^{-1}. N was applied as per treatment in three equal splits. The first split was applied as basal dose in the preparation of experimental layout. In the time of tassel initiation or opening of 8-10 leaves, the second split was applied and one week before silking or gain filling the third split was applied.

The next generation fertilizers American NPKS, Bio-forge, Wuxal Super, Peak, Root feed and Niro-Plus were sprayed at 25, 45 and 65 DAS on plants of the experimental plots @ 9.88 lit ha^{-1}, 1.20 lit ha^{-1}, 5.0 lit ha^{-1}, 1.2 kg ha^{-1} 1.20 kg ha^{-1}, and 1.2 lit ha^{-1} respectively.

3.4.1.9 Intercultural operations

Thinning and gap filling

After one week of direct seed sowing thinning was done to maintain the constant population number. Gap filling was done whenever it was necessary.

Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for every method, first weeding was done at 15 days after seed sowing followed by second weeding at 15 days after first weeding.

Application of irrigation water

First irrigation was applied in the day of seed sowing. Then second irrigation was applied at vegetative stage (8-10 leaf stage) and finally, at one week before silking or grain stage.

Plant protection measures

Seedling plants were infested with cut worm to some extent and which was successfully controlled by applying sevin 10 % dust @ 10 kg ha^{-1} on 10 April 2014. Some plants were infested with leaf hopper which was also controlled by applying malathion 60EC (1cc in 1 liter water and spray on the infested plants. Crop was protected from birds and rats during the grain filling period. Field trap and foxtoxin poisonous bait was used to control the rat. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.1.10 Harvesting

The cobs were harvested at maturity on 27 June, 2014. The harvested cobs were threshed plot–wise. Kernel and stover yields were recorded separately plot–wise and moisture percentage was calculated after sun drying. Dry weight for both kernel and stover were also recorded.

3.4.1.11 Collection of data at harvest

Plants from 1 m^2 were randomly selected from each plot to record the yield contributing characters like plant height (cm), number of cobs per plant, cob length (cm), cob weight without husk (g), 100-kernel weight (g) and kernel yield (t ha^{-1}). The selected plants were collected before harvesting. Kernel and stover yields were recorded plot–wise and expressed at t ha^{-1} on sundry basis.

3.4.1.12 Collection of Data

The following data on growth and yield contributing characters of maize were recorded:

i. Plant height (cm)
ii. Number of cobs per plant
iii. Cob length (cm)
iv. Single cob weight without husk (g)
v. 100-kernel weight (g)
vi. Kernel yield (t ha^{-1})

Plant height (cm): The plant height was measured from the ground level to the base of the tassel. Three plant heights were measured and average for each plot.

Number of cobs per plant: The number of cob each plant were counted manually.

Cob length (cm): Measurement was taken from base of cob to apex of each cob. Each observation was an average of 10 cobs.

100–kernel weight (g): 100 dried clean kernels were counted from the seed stock per plot and weighed by using an electric balance.

Kernel yield (t ha^{-1}): Kernels obtained from the harvested area of 1m x lm from the middle of each unit plot were first threshed sun dried and weighed carefully and converted to t ha^{-1}.

3.4.2 Experiment-2: Effect of Next Generation Fertilizers on growth and yield of tomato

Three varieties of tomato were used in this experiment for growth measurement under four Next Generation Fertilizers with control following a two factor experiment in RCBD design with three replications.

Factor A: NGF + recommended fertilizers with control (6)

Factor B: Varieties (3)

3.4.2.1 Factor A: Next generation fertilizers and recommended fertilizers

The following next generation fertilizers (NGF) were used in the experiment

Sl. No.	Name of NGF	Composition (%)	Dosage (ha^{-1})
i.	Bio-forge	N - 4.20 P - 4.43 K - 6.23 S - 1.30	1.20 lit
ii.	Wuxal Super	N - 8.60 P - 9.2 K - 6.5 S - 6.82	5.00 lit
iii.	Root Feed	N - 4.20 P - 5.06 K - 4.0 S - 0.13	1.20 kg
iv.	Nitro Plus	N - 9.0 P - 0.30 K - 3.0 S - 0.90	1.20 lit

The following recommended fertilizers were used in the experiment.

Sl. No.	Name of nutrient	Name of fertilizer & composition	Dosage (kg ha^{-1})
i.	Nitrogen, N	Urea, 46.0 % N	140.0
ii.	Phosphorus, P	TSP, 20.0 % P	35.0
iii.	Potassium, K	MoP, 50.0 % K	75.0
iv.	Sulphur, S	Gypsum, 18.0 % S	15.0
v.	Zinc, Zn	Zinc Sulphate, 36.0% Zn	2.0
vi.	Boron, B	Boric Acid, 17.0% B	1.0

Sources: According to Fertilizer Recommended Guide 2012, BARC

3.4.2.2 Factor A: Varietal descriptions

The following three varieties were selected for the experiment.

V_1: BARI Tomato-2

V_2: BARI Tomato-14

V_3: BARI Tomato-15

V_1: BARI Tomato-2

BARI Tomato-2 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh in 1985. It is high yielding fruit, plant height 75-80 cm, fruit round and red in color, fruit weight 85-90 g, 30-35 numbers of fruit /plant, fruit weight/plant 2.0-2.5 kg, crop duration 105-110 days. Planting season and time: Rabi, September to October. Harvesting time started 75-80 days after transplantation first harvest. Yield 80-85 t ha^{-1} (Mia, 2017).

V_2: BARI Tomato-14

BARI Tomato-14 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh in 2007. It's fruit is large, round with fruit attractive red flesh color, average fruit weight/plant 90-95 g, number of fruit per plant 30-35, prolonged harvesting period (40-60 days), storage quality high, life time 110-120days. Planting season and time: September to October, Harvesting time started 80-85 days after transplanting first harvest. Fruit harvest up to 45-65 days. Yield 90-95 t ha^{-1} (Mia, 2017).

V_3: BARI Tomato-15

BARI Tomato-15 was developed by Bangladesh Agriculture Research Institute (BARI), Gazipur, Bangladesh in 2009. It is high yielding winter variety with thick skin and edible flesh having very good self-life. fruit oval shape, less seeded fruits with 65-70g in weight, Attractive red flesh color with number of 40-45 fruits per plant, life time 100-110 days. Planting season and time is Rabi and October medium to late. Harvesting time started within 60-70 days after transplantation. Yield is 80-85 t ha^{-1} (Mia, 2017).

3.4.2.3 Next generation fertilizer along with other recommended fertilizers

The following six treatments including control were incorporated in the experiment where the treatments were the next generation fertilizers along with other recommended fertilizers.

T_0 = Control (No fertilizer)

T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_2 = Bio-forge + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_3 = Wuxal Super + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_4 = Root Feed + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_5 = Nitro Plus + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

There were the whole 18 (6 x 3) treatments combination such as T_0V_1, T_1V_1, T_2V_1, T_3V_1, T_4V_1, T_5V_1, T_0V_2, T_1V_2, T_2V_2, T_3V_2, T_4V_2, T_5V_2, T_0V_3, T_1V_3, T_2V_3, T_3V_3, T_4V_3 and T_5V_3.

3.4.2.4 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was sub–divided into eighteen unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 54 (18×3). The unit plot size was 2 m × 2 m. Block to block distance was 1 m and plot to plot distance was 0.5 m.

3.4.2.5 Collection of seed

Healthy and vigor seeds of BARI Tomato-2, BARI Tomato-14 and BARI Tomato-15 were collected from Genetics and Plant Breeding Division, Bangladesh Agricultural Research Institute, Joydebpur, Gazipur.

3.4.2.6 Preparation of seedling nursery and seed sowing

A piece of high land was selected in the Agriculture field, SAU, Dhaka for raising seedlings. The land was prepared well with spade followed by cleaning and leveling with ladder. Healthy seeds were sown in the nursery bed on 15 November 2014. Proper care was taken to raise the seedlings virus free in the nursery bed with mosquito net. Weeds were cleaned and irrigation was given in the seedbed indeed.

3.4.2.7 Preparation of land

The experimental field was first opened on November 22, 2014 with the help of a tractor drawn disc plough, later on November 23, 2014 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. 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 December 08, 2014 according to experimental specification. Individual plots were cleaned and finally leveled.

3.4.2.8 Uprooting of seedlings

Nursery beds were made wet by application of water on the previous day of uprooting the seedlings. The seedlings were uprooted on December 08, 2018 carefully without causing dry injury to the roots. The uprooted seedlings were kept on soft mud under shade.

3.4.2.9 Transplanting of seedlings

On 09 December, 2014, 23 days-old seedlings were transplanted in the experiment field keeping plant to plant distance 40 cm and row to row distance 50 cm. Gap filling was made 7 days after transplanting to maintain proper treatment and similar plant population density for each plot.

3.4.2.10 Application of fertilizers

The full of triple super phosphate (TSP), one third of muriate of potash (MoP) Gypsum, zinc sulphate and boric acid fertilizers were applied in the experimental plots @ P_{35}, K_{75}, S_{15}, Zn_2 and B_1 kg ha^{-1} respectively as basal dose in the experimental plots except control plots. The recommended dose of N was 140 kg ha^{-1}. Urea was applied as nitrogenous fertilizer as per treatment in three equal splits. The three splits were applied in the experimental plot 10, 25 and 40 days after transplanting (DAT) respectively. The rest of two splits of MoP were applied in the experimental plot 25 and 40 day after transplanting (DAT) respectively.

The next generation fertilizers Bio-forge, Wuxal, Root feed and Niro-Plus were sprayed at 20, 35 and 50 DAT on plants of the experimental plots @ 1.20 L ha^{-1}, 5.0 L ha^{-1}, 1.20 kg ha^{-1} and 1.2 L ha^{-1}, respectively.

3.4.2.11 Intercultural operations

Gap filling

After transplanting the seedlings of the research field, gap filling was done whenever it was necessary to maintain the constant population number.

Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for every method, first weeding was done at 15 days after seedlings transplanted followed by second weeding at 15 days after first weeding.

Application of irrigation water

First irrigation was applied in the day of seedling transplanting. Next irrigations were applied to tomato field whenever necessary.

Plant protection measures

In the seedling stage, nursery beds were protected from virus vector by using mosquito net. Plants were infested with tomato fruit warm (*Helicoverpa zea*) which was successfully controlled by applying Deviquin @ 1 ml/L of water at 10 days interval. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.2.12 Harvesting

Tomato fruits were harvested at maturity and started on 15 February 2015. Fruits were harvested at 3-days interval during early ripe stage when they developed slightly red color. The harvested fruits were collected plot-wise.

3.4.2.13 Collection of data at harvest

Plants from 1 m^2 were randomly selected from each plot to record the yield contributing characters like plant height (cm), number of tomato per plant, tomato fruit diameter (cm), weight of each tomato fruit (g).

3.4.2.14 Collection of data

The data on the following growth and yield contributing characters of the crop were recorded:

i. Plant height (cm)

ii. Number of flower clusters per plant

iii. Number of fruits per cluster

iv. Number of fruit per plant

v. Fruit diameter (cm)

vi. Fruit length (cm)

vii. Fruit yield (t ha^{-1})

Plant height (cm)

The plant height was measured from the ground level to the base of the tassel. Three plant heights were measured and average for each plot.

Number of flower clusters per plant

The number of flower clusters was counted from the sample plants and the average number of clusters borne per plant was recorded at the time of final harvest.

Number of fruits per cluster

The number of fruits per cluster was counted from the sample cluster and the average number of fruits borne per cluster was recorded at the time of final harvest.

Number of fruits per plant

Total numbers of fruits were counted from selected plants and their average was taken as the number of fruits per plant at harvest.

Diameter of fruit (cm)

The diameter of fruit was measured with slide-calipers from one side of middle point of tomato to other side of 5 selected marketable fruits and their average was taken in cm as the diameter of fruit.

Length of fruit (cm)

The length of fruit was measured with slide-calipers from the neck to the bottom of 5 selected marketable fruits and their average was taken in cm as the length of fruit.

Yield per hectare (ton)

The yield per hectare was calculated from per plot yield data.

3.4.3 Experiment-3: Effect of Next Generation Fertilizers on growth and yield of rice

Three varieties of rice were used in this experiment for growth measurement under four next generation fertilizers, recommended fertilizers with control following a two factor experiment in RCBD with three replications.

Factor A: NGF + Recommended fertilizers with control (6)

Factor B: Variety (3)

3.4.3.1 Factor A: Next Generation Fertilizers and recommended fertilizers

The following next generation fertilizers (NGF) were used in the experiment

Sl. No.	Name of NGF	Composition (%)	Dosage (ha^{-1})
i.	Wuxal Super	N - 8.60 P - 9.2 K - 6.5 S - 6.82	5.00 lit
ii.	Bio-forge	N - 4.20 P - 4.43 K - 6.23 S - 1.30	1.20 lit
iii.	Root Feed	N - 4.20 P - 5.06 K - 4.0 S - 0.13	1.20 kg
iv.	Nitro Plus	N - 9.0 P - 0.30 K - 3.0 S - 0.90	1.20 lit

The following recommended fertilizers were used in the experiment.

Sl. No.	Name of nutrient	Name of fertilizer & composition	Dosage (kg ha^{-1})
i.	Nitrogen, N	Urea, 46.0 % N	140.0
ii.	Phosphorus, P	TSP, 20.0 % P	20.0
iii.	Potassium, K	MoP, 50.0 % K	60.0
iv.	Sulphur, S	Gypsum, 18.0 % S	18.0
v.	Zinc, Zn	Zinc Sulphate, 36.0% Zn	2.0

Sources: According to Fertilizer Recommended Guide 2012, BARC

3.4.3.2 Factor B: Varietal descriptions

The following three varieties of rice were selected for the experiment.

V_1: BRRI dhan29

V_2: BRRI dhan28

V_3: BRRI dhan58

V_1: BRRI dhan29

BRRI Dhan29 was developed by Bangladesh Rice Research Institute, Gazipur, Bangladesh in 1994. The main characteristics are plant height 95 cm, medium slender and white. Life time 160 days. Planting season *Boro*, late October to mid November. Harvesting time is mid April to mid May. Yield 7.5 t ha^{-1} (Mia, 2017).

V_2: BRRI dhan28

BRRI Dhan28 was developed by Bangladesh Rice Research Institute, Gazipur, Bangladesh in 1994. The main characteristics are plant height 90 cm, clean rice, medium slender and white. Life time 140 days. Planting season *Boro*, mid to late November. Harvesting time is early to mid April. Yield 6.0 t ha^{-1} (Mia, 2017).

V_3: BRRI dhan58

Hybridization rice BRRI Dhan58 was developed by Bangladesh Rice Research Institute, Gazipur, Bangladesh in 2012. The main characteristics are plant height 100-105 cm, in vegetative stage size and shape taller than BRRI dhan29, grain as like BRRI dhan29 but slight slender,1000grain weight 24 g, ripe grain colour as like straw colour, life time 150-155 days. Planting season *Boro*, late November to mid December. Harvesting time was mid April to early May. Yield 7-7.5 t ha^{-1} (Mia, 2017).

3.4.3.3 Next generation fertilizers along with recommended fertilizers

The following six treatments including control treatment were included in the experiment where the treatments were the combinations of next generation fertilizers and recommended fertilizers.

T_0 = Control (No next generation fertilizer and recommended fertilizers)

T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_2 = Bio-forge + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_3 = Wuxal Super + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_4 = Root Feed + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_5 = Nitro Plus + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

There were the whole 18 (6Tx3V) treatments combination such as T_0V_1, T_1V_1, T_2V_1, T_3V_1, T_4V_1, T_5V_1, T_0V_2, T_1V_2, T_2V_2, T_3V_2, T_4V_2, T_5V_2, T_0V_3, T_1V_3, T_2V_3, T_3V_3, T_4V_3 and T_5V_3.

3.4.3.4 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was sub-divided into eighteen unit plots. The treatments were randomly distributed to the unit plots in each block. The total number of plots was 54 (18×3). The unit plot size was 2 m × 2 m. Block to block distance was 1 m and plot to plot distance was 0.5 m.

3.4.3.5 Collection of seed

Healthy and vigor seeds of BRRI dhan28, BRRI dhan29 and BRRI dhan58 were collection from Genetics and Plant Breeding Division, Bangladesh Rice Research Institute, Joydebpur, Gazipur.

3.4.3.6 Preparation of seedling nursery and seed sowing

A piece of high land was selected in the Agriculture Field, SAU, Dhaka for raising seedlings. The land was puddled well with country plough followed by cleaning and leveling with ladder. Sprouted seeds were sown in the wet nursery bed on 19 November 2014. Proper care was taken to raise the seedlings in the nursery bed. Weeds were removed and irrigation was given in the seedbed as and when necessary.

3.4.3.7 Preparation of land

The experimental field was first opened on December 22, 2014 with the help of a tractor drawn disc plough, later on December 23, 2014 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. 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 January 03, 2015 according to experimental specification. Individual plots were cleaned and finally leveled with the help of wooden plank so that no water pocket could remain in the puddled field.

3.4.3.8 Uprooting of seedlings

The seedling bed was made wet by application of water on the previous day of uprooting the seedlings. The seedlings were uprooted carefully without causing any injury to the roots. The uprooted seedlings were kept on soft mud under shade.

3.4.3.9 Transplanting of seedlings

On 03 January, 2015, 45 days old seedlings were transplanted in the experiment field keeping plant to plant distance 15 cm and row to row distance 25 cm. Gap filling was made up to 7 days after transplanting to maintain proper treatment and similar plant population density for each plot.

3.4.3.10 Application of fertilizers

The full triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc fertilizers were applied in the experimental plots @ P_{20}, K_{60}, S_{18}, Zn_2 kg ha^{-1}

respectively as basal dose in the experimental plots except control plots. The recommended dose of N was 140 kg ha^{-1}. N was applied as per treatment in three equal splits. The first split was applied after 15 days of transplanting, the second split was applied after 35 days of transplanting i.e. at active vegetative stage and the third split was applied after 60 days of transplanting i.e. at panicle initiation stage.

The next generation fertilizers e.g. Wuxal super, Bio-forge, Root feed and Niro-Plus were sprayed at 20, 40 and 60 DAS on plants of the experimental plots @ 5.0 L ha^{-1}, 1.20 L ha^{-1}, 1.20 kg ha^{-1} and 1.2 L ha^{-1}, respectively.

3.4.3.11 Intercultural operations

Gap filling

After transplanting the seedlings of the research field, gap filling was done whenever it was necessary. Within week, seedlings were transplanted to the gap to maintain the constant population number.

Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for every method, first weeding was done at 15 days after seedlings transplanted followed by second weeding at 15 days after first weeding.

Application of irrigation water

Irrigation water was added to each plot whenever necessary. Partial amount of water was applied to keep the soil moist, and it was even allowed to dry out for 2 to

4 days during tillering. This was done to keep the soil well aerated, to allow better root growth. From panicle initiation (PI) to hard dough stage, a thin layer of water (2-3 cm) was kept on the plots. Again water was drained from the plots during ripening stage.

Plant protection measures

Plants were infested with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by applying diazinone @ 10 ml/10 liter of water for 5 decimal lands on February 7, 2015 and by ripcord @ 10 ml/10 liter of water for 5 decimal lands on February 25 and March 5, 2015. Crop was protected from birds and rats during the grain filling period. Field trap and foxtoxin poisonous bait was used to control the rat. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.3.12 Harvesting

The crop was harvested at maturity stage and started on 02 May 2015 for BRRI dhan28 and BRRI dhan58 and BRRI dhan29 was harvested on 14 May 2015. The harvested crop was collected plot-wise. Grain and straw yields were recorded separately plot–wise and moisture percentage was calculated after sun drying. Dry weight for both grain and straw were also recorded.

3.4.3.13 Data collection at harvest

Plants from 1m^2 were randomly selected from each plot to record the yield contributing characters like plant height (cm), number of effective tillers $hill^{-1}$, number of non effective tillers $hill^{-1}$, panicle length (cm), number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, 1000-grain weight (g) and grain yield (t ha^{-1}). The selected hills were collected before harvesting. Grain and straw yields were recorded plot-wise and expressed at t ha^{-1} on sundry basis.

3.4.3.14. Collection of data

The data on the following growth and yield contributing characters of the crop were recorded:

i. Plant height (cm)
ii. Number of effective tillers hill^{-1}
iii. Number of non effective tillers hill^{-1}
iv. Panicle length (cm)
v. Number of filled grains panicle^{-1}
vi. Number of unfilled grains panicle^{-1}
vii. 1000–grain weight (g)
viii. Grain yields (t ha^{-1})
ix. Straw yields (t ha^{-1})
x. Biological yields (t ha^{-1})
xi. Harvest index (%)

Plant height (cm): The plant height was measured from the ground level to the top of the panicle. Plants of 10 hills were measured and average for each plot.

Number of effective tillers hill^{-1}: Ten hills were taken at random from each plot and the number of tillers hill^{-1}was counted and thereafter the numbers of effective tillers hill^{-1} was determined.

Number of non effective tiller hill^{-1}

The total number of non effective tiller hill^{-1} was counted as the number of non panicle bearing hill plant^{-1}. Data on non effective tiller hill^{-1} were counted from 10 selected hills and average value was recorded.

Panicle length (cm): Measurement was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

Number of filled grains panicle^{-1}: Presence of any food material in the spikelet was considered as grain and numbers of grains present in each panicle were counted. Ten panicles were taken at random to count grains and averaged.

Unfilled grain panicle^{-1}: The total numbers of unfilled grain was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grain panicle^{-1} was recorded.

1000-grain weight (g): One thousand clean dried grains were counted from the seed stock per plot and weighed by using an electric balance.

Grain yield (t ha^{-1}): Grains obtained from the harvest area of 1m^2 from the middle of each unit plot were sun dried and weighed carefully and converted to t ha^{-1}.

Straw yield (t ha^{-1}): The collected straw from each plot was sun dried properly to record the final straw yield plot^{-1}and finally converted to t ha^{-1}.

Biological yield (t ha^{-1}): Grain and straw yields are altogether regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield= Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

Harvest index (%): It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al*., 1985).

Harvest index (%) = $\frac{\text{Economic yield}}{\text{Biological yield}} x\ 100$

Where, Economic yield = Grain yield, and Biological yield = Grain yield + Straw yield

3.5. Chemical analysis of soil sample

Soil samples were analyzed for both physical and chemical properties in the laboratory of Soil Science and Agril. Chemistry, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka. The properties studied included total N, available P and exchangeable K. The chemical properties of the initial soil have been presented in Table 3.2. The soil was analyzed by standard methods:

Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being maintained at 1: 2.5 as described by Page *et al.* (1982).

Organic carbon

Organic carbon in soil sample was determined by wet oxidation method. The underlying principle was used to oxidize the organic matter with an excess of 1N $K_2Cr_20_7$ in presence of conc. H_2SO_4 and conc. H_3PO_4 and to titrate the excess $K_2Cr_20_7$ solution with 1N $FeSO_4$. To obtain the content of organic matter was calculated by multiplying the percent organic carbon by 1.73 (Van Bemmelen factor) and the results were expressed in percentage (Page *et al.*, 1982).

Total nitrogen (N)

Total N content of soil were determined followed by the Micro Kjeldahl method. One gram of oven dry ground soil sample was taken into micro kjeldahl flask to which 1.1 gm catalyst mixture (K_2SO_4: $CuSO_4$. $5H_2O$: Se in the ratio of 100:10:1), and 6 ml H_2SO_4 were added. The flasks were swirled and heated 200ºC and added 3 ml H_2O_2 and then heating at 360ºC was continued until the digest was clear and colorless. After cooling, the content was taken into 100 ml volumetric flask and the volume was made up to the mark with distilled water. A reagent blank was prepared in a similar manner. These digests were used for nitrogen determination (Page *et al*., 1982).

Then 20 ml digest solution was transferred into the distillation flask, Then 10 ml of H_3BO_3 indicator solution was taken into a 250 ml conical flask which is marked to indicate a volume of 50 ml and placed the flask under the condenser outlet of the distillation apparatus so that the delivery end dipped in the acid. Sufficient amount of 10N-NaOH solutions were added in the container connecting with distillation apparatus. Water runs through the condenser of distillation apparatus was checked. Operating switch of the distillation apparatus collected the distillate.

The conical flask was removed by washing the delivery outlet of the distillation apparatus with distilled water. Finally the distillates were titrated with standard 0.01 N H_2SO_4 until the color changes from green to pink (Bremner and Mulvaney, 1982). The amount of N was calculated using the following formula:

$$\% \text{ N} = \frac{(\text{T} - \text{B}) \times \text{N} \times 0.014 \times 100}{\text{S}}$$

Where,

T = Sample titration (ml) value of standard H_2SO_4

B = Blank titration (ml) value of standard H_2SO_4

N = Strength of H_2SO_4

S = Sample weight in gram

Available phosphorus (P)

Available phosphorus was extracted from soil by shaking with 0.5 M $NaHCO_3$ solution of pH 8.5 (Olsen *et al*., 1954). The phosphorus in the extract was then determined by developing blue colour using ascorbic acid of phosphomolybdate complex. The absorbance of the molybdophosphate blue color was measured at 660 nm wave length by Spectrophotometer and available P was calculated with the help of standard curve.

Exchangeable potassium (K)

Exchangeable K was determined by 1N NH_4OAc (pH 7) extraction methods and by using flame photometer and calibrated with a standard curve (Black *et al*., 1965).

Available Sulphur (S)

Sulphur content was determined from the digest of the samples (soil) with $CaCl_2$ (0.15%) solution as described by (Page *et al*., 1982). The digested S was determined by developing turbidity by adding acid seed solution (20 ppm S as K_2SO_4 in 6N HCl) and $BaCl_2$ crystals. The intensity of turbidity was measured by spectrophotometer at 420 nm wavelengths (Hunter, 1984).

3.6. Statistical analysis

Data recorded for yield and yield contributing characters including the nutrient content and uptake were compiled and tabulated in proper form for statistical analyses. Analysis of variance was done with the help of MSTAT-C computer package program developed by Russel (1986). The mean differences among the treatments were evaluated with DMRT test (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Three separate experiments were conducted to achieve the objectives of the study. The experimental results of the research works are presented experiment wise with relevant head and sub heads as follows:

4.1 Experiment 1: Effect of next generation fertilizers on growth and yield of maize

Results obtained from the present study regarding the influence of various treatment combinations of next generation fertilizers along with NPK and varieties on growth, yield and yield attributes of maize are presented and discussed in this chapter. The results have been presented in Tables 4.1 to Table 4.6 and Figure 4.1 to Figure 4.10. All ANOVA are presented in Appendices I-III. The kernel yield with yield contributing characters of the maize varieties have been presented and discussed under separate heads and sub-heads as follows:

4.1.1 Yield and yield attributes of maize

4.1.1.1 Plant height of maize

4.1.1.1.1 Effect of Next Generation Fertilizer (NGF) along with other recommended fertilizers of maize

Plant height varied significantly due to the effect of next generation fertilizers along with other recommended fertilizers at harvest while plant height ranges from 129.1 cm to 151.0 cm (Figure 4.1, Table 4.1 and Appendix I). It is revealed that all the treatments were recorded significantly higher plant height over the control (T_0).

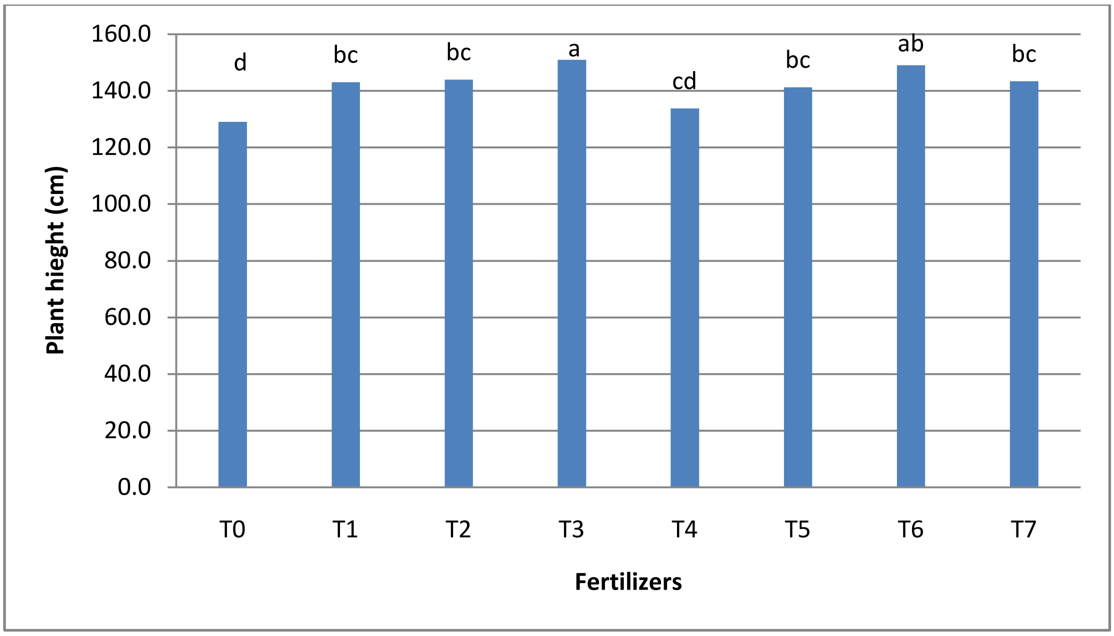

Figure 4.1. Effect of NGF along with other recommended fertilizers on plant height of maize

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

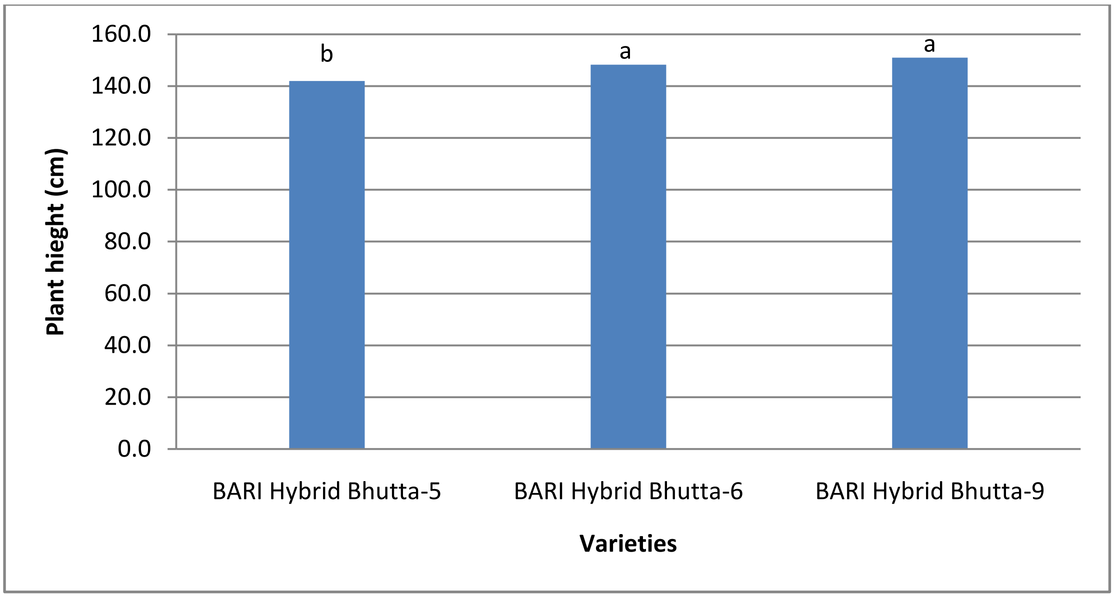

Figure 4.2. Effect of varieties on plant height of maize

It is also revealed that the tallest plant of 151.0 cm was found from the treatment T_3 receiving Bio-forge along with other recommended fertilizers which was statistically similar with treatment T_6 (149.0 cm). The shortest plant height of 129.1 cm was found in control treatment T_0. These result expressed that the plant height of maize progressively increased in apply of Bio-forge along with other recommended fertilizers. Such effect of Bio-forge with other recommended fertilizers on plant height might be associated with the stimulating effect of Bio-forge and N on various physiological processes including cell division and cell elongation of the plant.

Rogaciano and Rosill (2015) found that the height of a corn plant at 15, 30, 45 and 60 days after planting and on the number of days from seed emergence to flowering were not significantly affected by the supplementation of different liquid fertilizers (Nitrofert, Crop Gaint and Nutriplant AG).

4.1.1.1.2 Effect of varieties on plant height of maize

Plant height is one of the most efficient attribute for greater yield of maize which is also directly related to stover yield. A significant difference in plant height was recorded at harvest stage due to the effect of variety (Appendix I, Figure 4.2 and Table 4.2). Among the three varieties, BARI Hybrid Bhutta-9 plant was the tallest (151.0 cm) which was statistically similar to BARI Hybrid Bhutta- 6 plant (148.3 cm) during the *kharif-1* season. The above variation in plant height was observed due to the variation in genetic variability and adaptability in studied area.

Asghar *et al.* (2010) found that the plant height was not significantly affected by maize cultivars; Golden and Sultan. Besides, the climatic and soil condition of the studied area were favorable for better growth of BARI Hybrid Bhutta-9 which ultimately showed highest plant height than BARI Hybrid Bhutta-5.

4.1.1.1.3 Interaction effect of NGF along with other recommended fertilizers and varieties on plant height of maize

Plant height at harvest was varied significantly due to the interaction effect of next generation fertilizers with other recommended fertilizers and maize varieties. Plant height was varied from 127.0 cm to 157.8 cm (Appendix I and Table 4.3). The highest plant height of 157.8 cm was found in the treatment combination T_3V_3 (Bio-forge along with recommended fertilizers and BARI Hybrid Bhutta-9) which was statistically different with the other treatments except treatment combination of T_6V_1 (151.6 cm). The shortest plant height of 127.0 cm was found in the treatment combination of T_0V_3 which was statistically similar to T_0V_1 (129.9 cm) and T_0V_2 (129.8 cm).

4.1.1.2 Numbers of cob per plant of maize

4.1.1.2.1 Effect of NGF along with other recommended fertilizers on number of cobs per plant

Number of cobs per plant of maize was not statistically significant but numerically varied among the treatments of next generation fertilizers along with other recommended fertilizers (Appendix I and Table 4.1). The highest mean number of cobs (1.27) was obtained in the treatment T_3 having Bio-forge along with other recommended fertilizers and also observed in T_5 having Peak along with other recommended fertilizers. The lowest number of cob (1.09) was found in the treatment of T_0.

These result revealed that Bio-forge along with other recommended fertilizers was highly effective than other next generation fertilizers along with other recommended fertilizers to produce the maximum number of cob. This result was supported by Ali *et al.* (2016) who conducted a field experiment to study the effect of spraying three concentrations: control (spray water only), 0.50% and 100% of the extracts of three types of organic fertilizer (waste Poultry, wheat residue, remnants of palm fronds) on growth and yield of maize. Extract of organic fertilizer spraying led to increase yield components (cob number, cob grains number, cob grain weight) and grain yield significantly compared with control. Similar findings also agreed by the research work of Rogaciano and Rosill (2015), Amali and Namo (2015*),* Yihenew (2015) and other researchers of the home and abroad.

4.1.1.2.2 Effect of varieties on cob number of maize

Analysis of variance data on number of cobs per plant was not influenced by the variety (Appendix I and Table 4.2). Though the effect of varieties on number of cobs was statistically insignificant but maximum numbers of cobs were found in the treatment V_3 (1.34) and minimum number of cobs (1.17) found in the variety V_2.

This result is in agreement with the findings of Idris *et al.* (2016), Amali and Namo (2015) and many other scientists. They also found variation in number of cobs per plant due to the variation in genetic makeup of the varieties of maize.

Table 4.1 Effect of NGF and other recommended fertilizers on yield and yield contributing characters of maize

Fertilizers	Plant height (cm)	Number of cobs per plant	Cob length (cm)	Cob weight (g)	100- kernel weight (g)	Kernel yield ($t.ha^{-1}$)
T_0	129.1 d	1.09	19.24 d	95.20 c	27.06 c	2.37 c
T_1	143.1 bc	1.17	20.33 cd	121.65 bc	27.99 bc	4.1 b
T_2	144.0 bc	1.24	21.50 b-d	119.44 bc	28.23 bc	4.75 b
T_3	151.0 a	1.27	23.00 a	137.50 a	30.31a	5.83 a
T_4	133.8 cd	1.22	20.30 cd	121.75 bc	28.22 bc	3.83 b
T_5	141.3 bc	1.27	20.45 cd	121.73 bc	28.44 bc	3.80 b
T_6	149.0 ab	1.23	21.71 b	129.13 ab	29.69 ab	5.82 ab
T_7	143.4 bc	1.26	21.52 b-d	120.63 bc	28.25 bc	3.89 b
Level of Significance	**	**NS**	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly
Here,

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

Table 4.2 Effect of varieties on yield and yield contributing characters of maize

Varieties	Plant height (cm)	Number of cobs per plant	Cob length (cm)	Cob weight (g)	100 kernel weight (g)	Kernel yield ($t.ha^{-1}$)
V_1	142.0 b	1.17	21.78 b	105.63 b	26.03 b	4.45 c
V_2	148.3 a	1.16	21.89 b	131.88 a	26.20 b	4.52 b
V_3	151.0 a	1.34	22.87 a	134.38 a	28.01 a	5.83 a
Level of Significance	*	**NS**	*	**	*	*

In a column, figures having similar letter (s) do not differ significantly
Here,

V_1 = BARI Hybrid Bhutta-5
V_2 = BARI Hybrid Bhutta-6
V_3 = BARI Hybrid Bhutta-9

Table 4.3 Interaction of NGF along with other recommended fertilizers and variety on plant height, yield contributing characters and yield of maize

Fertilizers x Variety	Plant Height (cm)	Number of cobs per plant	Cob length (cm)	Cob weight (g)	100 kernel weight (g)	Yield (t ha^{-1})
T_0 x V_1	129.9 ef	0.88	20.20 d	91.88 ef	24.59 c	1.97 c
T_0 x V_2	129.8 ef	1.10	20.88 cd	91.25 ef	24.68 c	2.33 c
T_0 x V_3	127.0 ef	1.29	20.71 cd	96.25 ef	24.72 c	2.73 c
T_1 x V_1	137.8 de	1.13	21.37 bc	108.13 de	25.21 bc	4.22 bc
T_1 x V_2	141.2 cd	1.17	21.34 bc	117.50 cd	24.82 bc	3.55 bc
T_1 x V_3	147.7 bc	1.23	22.25 bc	139.63 bc	24.97 bc	4.24 b
T_2 x V_1	142.0 cd	1.19	22.01 bc	133.13 bc	26.18 bc	4.18 bc
T_2 x V_2	141.0 cd	1.15	21.60 bc	125.00 cd	25.80 bc	4.11 bc
T_2 x V_3	146.7 bc	1.38	22.9 bc	140.13 bc	25.77 bc	4.25 b
T_3 x V_1	149.1 bc	1.19	22.20 bc	121.25 cd	26.41 bc	4.22 bc
T_3 x V_2	144.5 bc	1.17	22.23 bc	139.13 bc	26.18 bc	4.25 b
T_3 x V_3	157.8 a	1.50	23.67 a	153.75 a	28.05 a	5.95 a
T_4 x V_1	134.4 de	1.15	21.66 bc	108.13 de	26.07 bc	4.26 b
T_4 x V_2	135.4 de	1.17	22.35 bc	132.50 bc	26.21 bc	4.25 b
T_4 x V_3	147.7 bc	1.31	21.20 bc	137.50 bc	25.68 bc	4.22 bc
T_5 x V_1	141.0 cd	1.10	21.79 bc	101.88 de	25.93 bc	3. 24 b
T_5 x V_2	143.0 cd	1.27	21.58 bc	136.25 bc	25.10 bc	4.10 bc
T_5 x V_3	145.8 bc	1.44	22.18 bc	138.75 bc	26.13 bc	3.98 bc
T_6 x V_1	151.6 ab	1.42	22.17 bc	113.13 de	26.16 bc	4.22 bc
T_6 x V_2	149.9 bc	1.08	22.38 bc	110.00 de	26.26 bc	4.25 b
T_6 x V_3	146.1 bc	1.19	23.31 ab	145.25 ab	27.45 ab	5.12 ab
T_7 x V_1	138.7 cd	1.35	21.63 bc	103.75 de	25.96 bc	4.15 bc
T_7 x V_2	137.2 de	1.19	21.43 bc	126.88 cd	26.05 bc	4.02 bc
T_7 x V_3	144.7 bc	1.42	21.50 bc	130.63 bc	26.28 bc	4.24 b
Level of Significance	*	NS	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

V_1 = BARI Hybrid Bhutta-5
V_2 = BARI Hybrid Bhutta-6
V_3 = BARI Hybrid Bhutta-9

4.1.1.2.3 Interaction effect of variety and NGF along with other recommended fertilizers on number of cobs per maize plant

Analysis of variance data on cob numbers at harvest did not differ varied significantly due to the effect of interaction of treatment combination of next generation fertilizer with other recommended fertilizers and variety (Appendix I and Table 4.3). The maximum number of cobs per plant (1.5) was found from T_3V_3, the variety BARI Hybrid Bhutta-9 receiving Bio-forge along with other recommended fertilizers. The lowest no of cobs per plant (0.88) was found in the variety BARI Hybrid Bhutta-5 while it did not receive any levels of next generation fertilizer and other recommended fertilizers ((T_0V_1).

4.1.1.3 Cob length of maize

4.1.1.3.1 Effect of NGF along with other recommended fertilizers on cob length

Analysis of variance data on cob length showed significant variation among the next generation fertilizers (Appendix -I and Fig. 4.3 and Table 4.1). The longest cob (23.00 cm) was obtained from the treatment T_3 having Bio-forge along with other recommended fertilizers which was statistically differed from other treatments. The shortest cob length (19.24 cm) was found T_0 treatment which was statistically similar with T_1, T_2, T_4, T_5 and T_7 treatments. These result reveled that Bio-forge along with other recommended fertilizers was highly effective than other next generation fertilizers along with other recommended fertilizers to produced longest cob. Maulana *et al*. (2015) found that the Bio liquid fertilizer Ultra Gen was significantly effective in increasing cob length. The above findings also agreed by the research work of Sutharsanr and Rajendran (2017), Woldesenbet and Haileyesus (2016); Idris *et al.* (2016) Ali *et al.* (2016) and other researchers of the home and abroad.

4.1.1.3.2 Effect of variety on cob length of maize at harvest

Cob length was significantly influenced by the variety (Appendix I and Fig. 4.4 and Table-4.2). From the 4.4, it was found that the longest cob (22.87 cm) was observed in the variety V_3 (BARI Hybrid Bhutta-9). The minimum cob length (21.78 cm) was found in V_1 treatment which was statistically similar with V_2 treatment. These results showed that there was difference in cob length among the varieties might be due to its genetic variation. This result is in agreement with the findings of Idris *et. al.* (2016); Maulana *et al*. (2015); Amali and Namo (2015) and many other scientists.

4.1.1.3.3 Effect of interaction of NGF along with other recommended fertilizers and variety on cob length of maize

Cob length at harvest varied significantly due to the effect of interaction of treatment next generation fertilizer and variety. From the table 4.3 it was found that cob length varied from 20.20 cm to 23.67 cm. The maximum cob length of 23.67 cm was found from treatment combination of T_3V_3 which was statistically similar with the treatment combination of T_6V_3. The shortest cob (20.20 cm) was found under the treatment combination of T_0V_1 which was statistically similar with T_0V_2 and T_0V_3 treatment combination. A regular trend of increase in the cob length was observed with Bio-forge along with other recommended fertilizers.

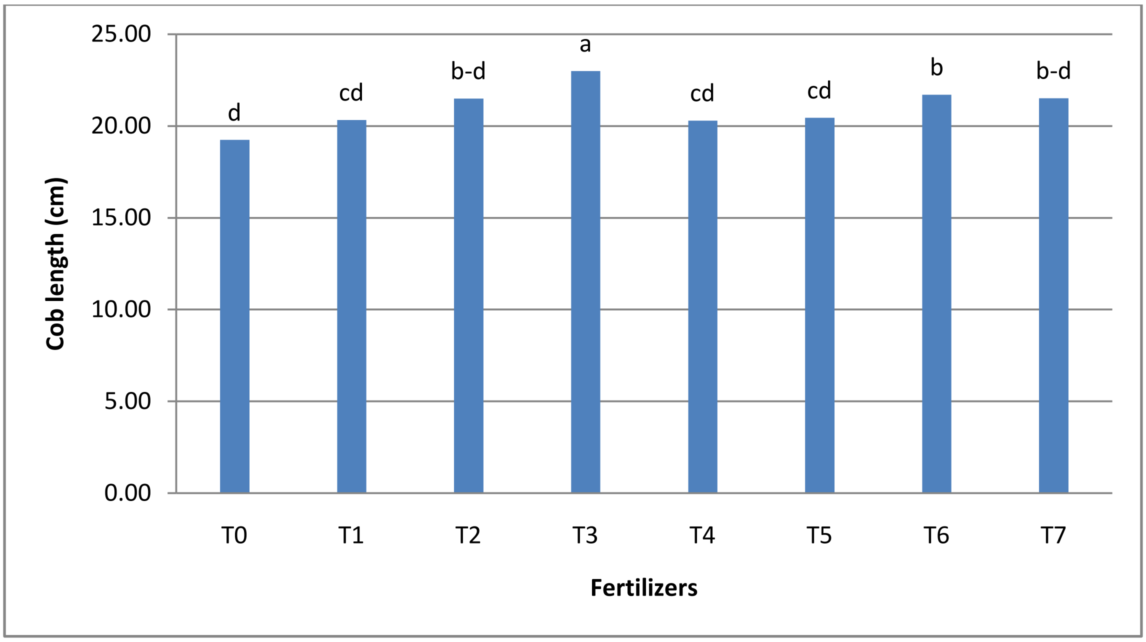

Figure 4.3. Effect of NGF along with other recommended fertilizers on cob length of maize

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

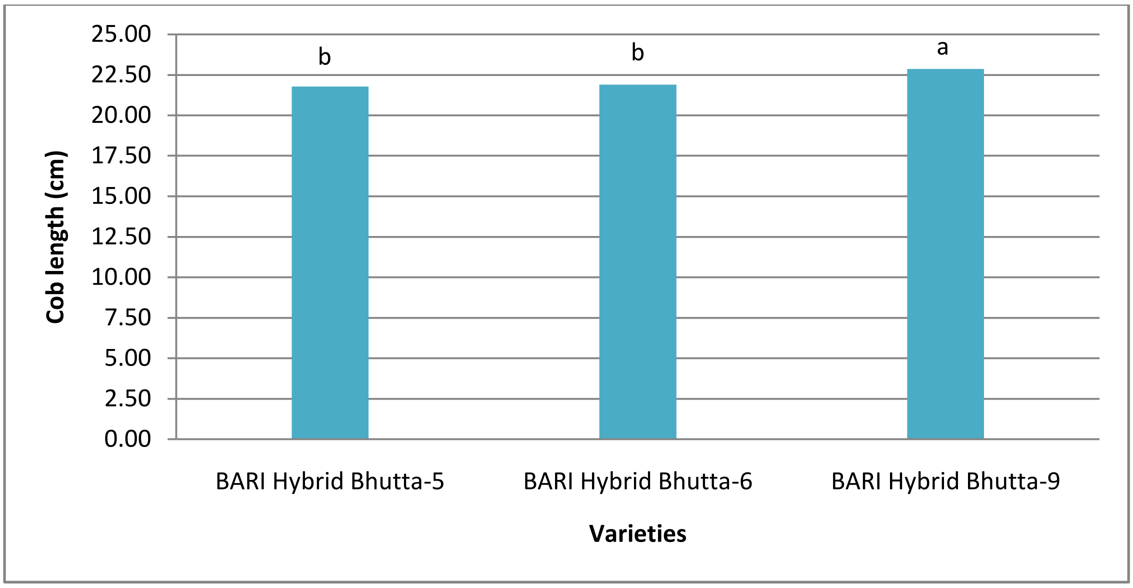

Figure 4.4. Effect of varieties on cob length of maize

4.1.1.4 Weight of cob without husk of maize

4.1.1.4.1 Effect of NGF with other recommended fertilizers on cob weight of maize

Cob weight of maize significantly influenced by the next generation fertilizers and other recommended fertilizers (Appendix II and Fig. 4.5). From the Table-4.1, the maximum cob weight of maize (137.50g) was obtained from the treatment T_3 having Bio-forge along with other recommended fertilizers which was statistically similar with the treatment T_6. The minimum cob weight of maize (95.20g) was found from the treatment T_0 which was statistically insignificant with T_1, T_2, T_4, T_5 and T_7 treatment. These result reveled that Bio-forge along with other recommended fertilizers was highly effective than other next generation fertilizers along with other recommended fertilizers to produce weight cob. Similarly, Maulana *et al*. (2015) found that the Bio liquid fertilizer Ultra Gen was significantly influenced on the cob weight. The above findings also agreed by the research work of Amali and Namo (2015); Sutharsanr and Rajendran (2017); Idris *et al.* (2016) and other researchers of the home and abroad.

4.1.1.4.2 Effect of varieties on cob weight at harvest

Analysis of variance data on cob weight was significantly influenced by the varieties (Fig. 4.6 and Appendix II). From the Table 4.2, it was found that the highest cob weight (134.38) was observed in the cultivar V_3 (BARI Hybrid Bhutta-9) which was statistically similar with V_2 (BARI Hybrid Bhutta-6). This result was in agreement with the findings of Idris *et al.* (2016); Maulana *et al*. (2015); Amali and Namo (2015) and many other scientists.

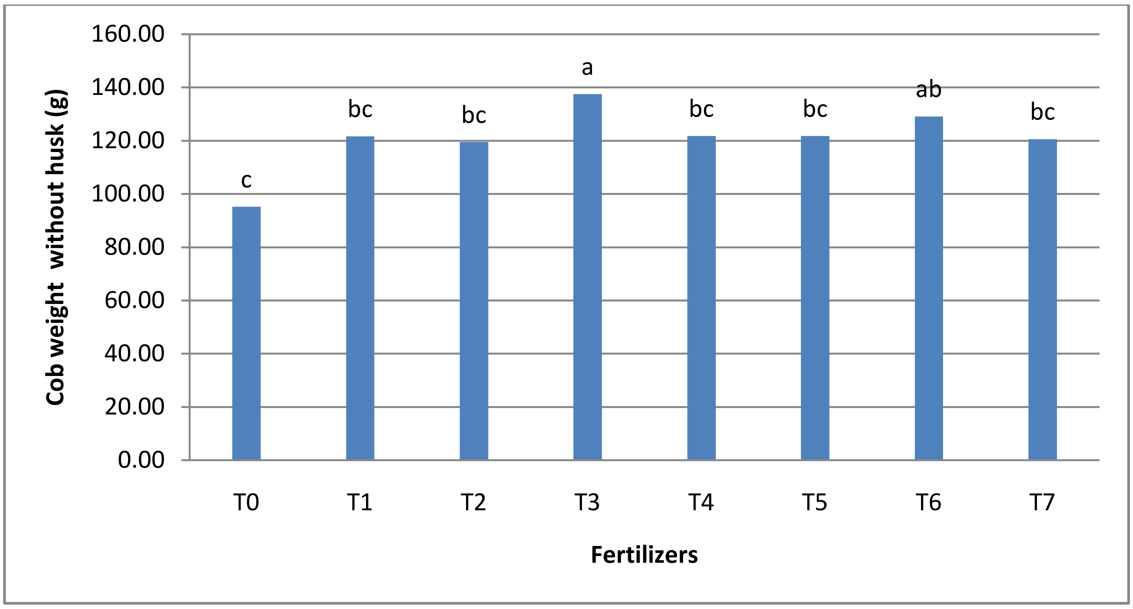

Figure 4.5. Effect of NGF along with other recommended fertilizers on cob weight of maize

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

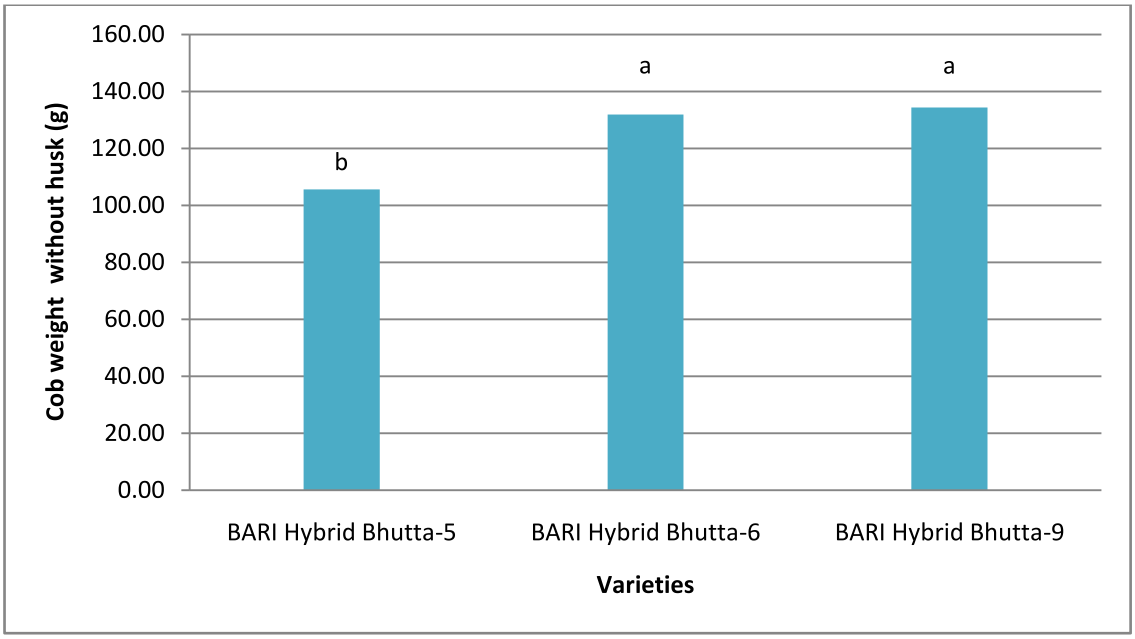

Figure 4.6. Effect of varieties on cob weight of maize

4.1.1.4.3 Effect of interaction of NGF along with other recommended fertilizers and varieties on cob weight of maize

Analysis of variance data on cob weight at harvest varied significantly due to the effect of interaction of treatment next generation fertilizer with NPK and variety where cob weight varied from 91.25 to 153.75 g (Appendix II and Table 4.3). The highest cob weight of 153.75 g was found from the variety BARI Hybrid Bhutta -9 receiving Bio-forge along with other recommended fertilizers (T_3V_3) which was statistically similar with the treatment combination of T_6V_3. The lowest cob weight of 91.25 g was found from the variety BARI Hybrid Bhutta-6 with treatment combination of T_0V_2 which was statistically similar with T_0V_1 and T_0V_3 treatment combination.

4.1.1.5 100 - kernel weight of maize

4.1.1.5.1 Effect of NGF along with other recommended fertilizers on 100-kernel weight of maize

The next generation fertilizer along with other recommended fertilizers showed significant effect on 100-kernel weight (Appendix II and Table - 4.1). Among the treatments, treatment combination T_3, Bio-forge along with other recommended fertilizers showed effect on the maximum 100-kernel weight (30.31g) which was statistically similar to treatment of T_6 (29.69 g). On the other hand, control treatment (T_0) produced the minimum (27.06 g) weight of 100-kernel (Fig 4.7). These result indicated that kernel size increased significantly with the application of next generation fertilizer along with other recommended fertilizers which might be supplied adequate nutrients in certain levels. Similar result was agreed by Ali *et al.* (2016) through a study to applied extract fertilizer spraying led to significant increase yield components (weight of 100 grains, and ear grain weight) and grain yield significantly compared with control. Yihenew (2015) who reported that there is no significant variation among treatments in 100-kernel weight of maize where N increase 90-200 kg ha^{-1}. Maulana *et al*. (2015) also found that no significant effect on weight of 100 grain dry seeds yield with the Bio liquid fertilizer Ultra Gen consisted of four levels, i.e. without liquid fertilizer (P_0), 0.8 liter ha^{-1} (P_1), 1.7 liter ha^{-1} (P_2), and 2.5 liter ha^{-1} (P_3).

4.1.1.4.2 Effect of varieties on 100 kernels weight of maize.

The effect of maize varieties on 100-kernel weight was statistically significant due to control of genetically makeup of variety (Appendix II and Figure 4.8). From the Table 4.2, it was found that variety V_3, BARI Hybrid Bhutta-9 produce maximum 100-kernel weight (28.01 g) whereas minimum 100 kernel weight was found in V_1 (26.03 g) which was statistically similar to V_2 (26.20 g).

4.1.1.5.3 Effect of interaction of NGF along with other recommended fertilizers and varieties on 100 kernel weight of maize

Analysis of variance data on 100- kernel weight at harvest statistically significant due to the effect of interaction of treatment next generation fertilizer along with other recommended fertilizers and variety where 100- kernel weight varied from 24.59 to 28.05 g (Appendix II and Table 4.3). The maximum 100- kernel weight of 28.05 g was found from the variety BARI Hybrid Bhutta -9 receiving Bio-forge along with other recommended fertilizers (T_3V_3) which was statistically similar with treatment combination T_6V_3 (27.45). The lowest 100- kernel weight of 24.59 g was found from the variety BARI Hybrid Bhutta-5 while it did not receive any levels of fertilizers which were statistically similar to treatment combination T_0V_2 (24.68 g) and T_0V_3 (24.72).

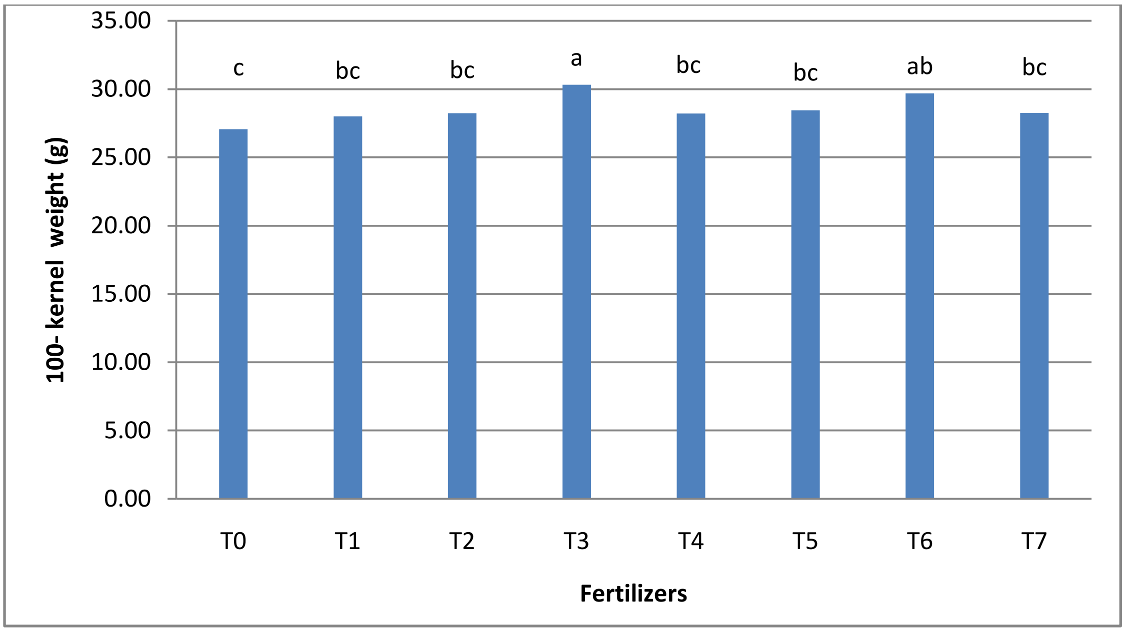

Figure 4.7. Effect of NGF along with other recommended fertilizers on 100- kernel weight of maize

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

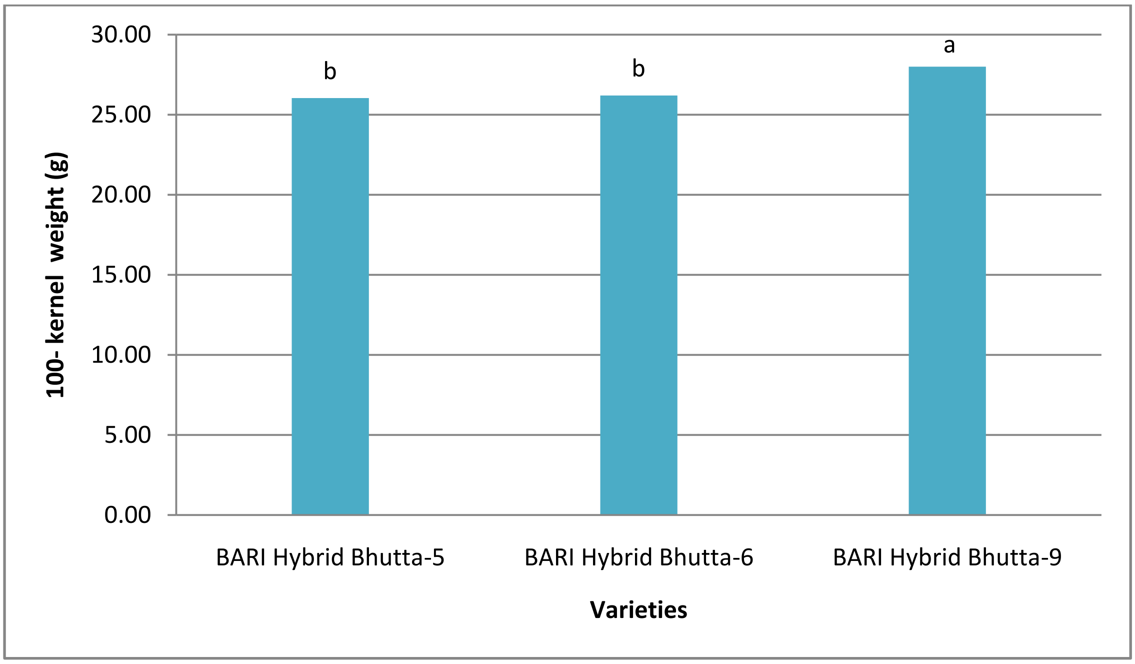

Figure 4.8. Effect of varieties on 100- kernel weight of maize

4.1.1.6 Kernel yield of maize

4.1.1.6.1 Effect of NGF along with other recommended fertilizers on kernel yield of maize

A significant variation was found for the character of kernel yield due to the effect of next generation fertilizers along with other commanded fertilizers (Fig 4.9, Table 4.1 and Appendix II). Among the treatments, T_3 (Bio-forge along with other commanded fertilizers) produced significantly the highest yield of kernel 5.83 t ha^{-1} which is similar to treatment T_6 (Root feed along with other commanded fertilizers). Treatment T_0 showed the lowest yield of maize (2.37 t ha^{-1}). This result is revealed that the Bio-forge + other commanded fertilizers and Root feed along with other commanded fertilizers showed the greater effect on kernel yield which might be due to the produce more long cob, high weight of cob, more kernels per cob and overcome stress condition of *Kharif-1* season. The above findings indicated that the treatment combinations of T_3 and T_6 would be ideal for getting the highest kernel yield of maize.

Similar findings found from the Idris *et al.* (2016) who conducted field experiments with the liquid bio-fertilizer (effective microorganism, EM) and found the highest grain yield. Similar results by Sutharsanr and Rajendran (2017) who found the effect of liquid organic mixture (Jeetvamirta) on growth and yield of maize. The results indicated that application of Jeewamirta once a week could be a viable technique to increase maize production. Maulana *et al*. (2015) who conducted research to evaluate the Bio liquid fertilizer Ultra Gen. The result showed that treatment and varieties had significantly effect on increase of grain yield.

4.1.1.6.2 Effect of variety on kernel yield of maize at harvest period

There was a significant difference between the varieties in respect of kernel yield (Appendix II, Figure 4.10 and Table). Between the varieties, BARI Hybrid Bhutta-9 (V_3) produced the highest kernel yield (5.83 t ha^{-1}) where BARI Hybrid Bhutta-5 (V_1) produced the minimum yield (4.45 t ha^{-1}). This variation in kernel yield found due to their genetic difference between the varieties.

Asghar *et al.* (2010) investigated the effect of different NPK rates on growth and yield of maize cultivars; Golden and Sultan. The grain yield was significantly affected by different rates of NPK and varieties. Similar findings also agreed by the research work of Sutharsanr and Rajendran (2017) and Maulana *et al.* (2015) and other researchers of home and abroad.

4.1.1.6.3 Effect of interaction of NGF along with other recommended fertilizers and varieties on kernel yield of maize

Analysis of variance data on kernel yield of maize at harvest significantly varied due to the effect of interaction effect of treatment next generation fertilizer with other recommended fertilizers and variety where kernel yield varied from 1.97 to 5.95 t ha^{-1} (Appendix II and Table 4.3). The highest kernel yield of 5.95 t ha^{-1} was found from the variety BARI Hybrid Bhutta-9 receiving Bio-forge along with other recommended fertilizers of (T_3V_3) which was statistically similar with T_6V_3 treatment combination. The lowest kernel yield of 1.97 t ha^{-1} was found from the variety BARI Hybrid Bhutta-5 while it did not receive any levels of next generation fertilizer along with other recommended fertilizers (T_0V_1) which was statistically similar with T_0V_2 and T_0V_3 treatment combinations.

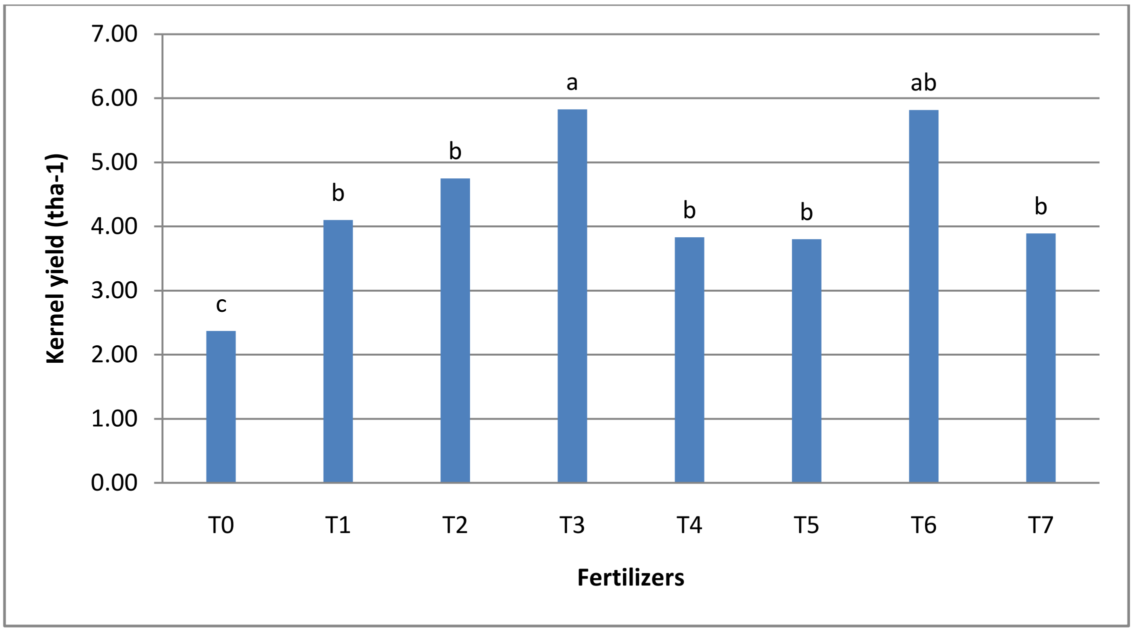

Figure 4.9. Effect of NGF along with other recommended fertilizers on kernel yield of maize

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}
T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$
T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

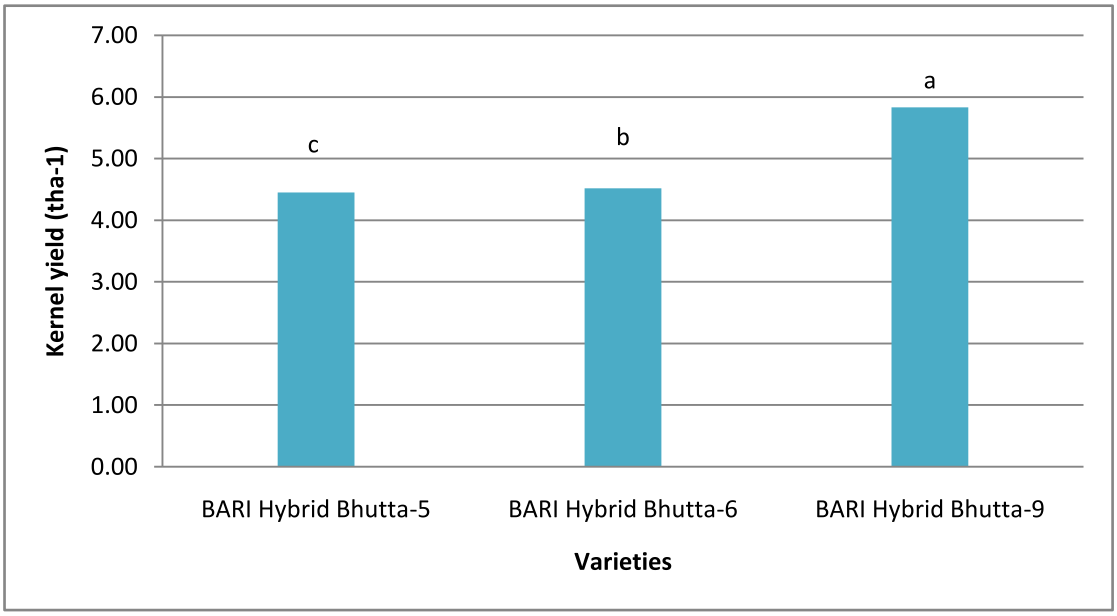

Figure 4.10. Effect of varieties on kernel yield of maize

4.1.2 Soil chemical properties in postharvest soil of maize crop field

4.1.2.1 Effect of NGF along with other recommended fertilizers on soil chemical properties in postharvest soil of maize crop field

Effect on soil pH and soil organic carbon (SOC)

Soil pH

The availability of soil nutrient is greatly influenced by soil pH. There was no significance change in pH of post harvest soil due to application of next generation fertilizers along with other recommended fertilizers where pH varied from 5.53 to 5.84 (T_0) (Table 4.4) and compared to initial soil pH (5.8).

Soil organic carbon

Soil organic carbon influences the nutrient supply and water holding capacity. There was no significant change in soil organic carbon (SOC) of post harvest soil due to application of next generation fertilizers along with other recommended fertilizers where SOC varied from 0.59 % to 0.68 % (Table 4.4) and compared to initial soil organic carbon content 0.62 % (Table 3.2).

Effect on NPKS nutrients of Soil

Total N content in postharvest soil also showed no significant variation due to presence of NGF with other recommended fertilizers where N content varied from 0.059 % to 0.065 % (Table 4.4).

Available P content in post harvest soil was also non significant due to application of NGF along with other recommended fertilizers, the result varied from from 13.45 ppm to 15.24 ppm (Appendix III and Table 4.4).

Table 4.4 Effect of NGF along with other recommended fertilizers on chemical properties in postharvest soil of the experimental crop field of maize

Fertilizers	pH	Organic Carbon (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq100^{-1}g)	Available S (ppm)
T_0	5.84	0.59	0.059	13.45	0.130	13.27
T_1	5.70	0.64	0.065	14.41	0.143	14.16
T_2	5.72	0.60	0.065	14.73	0.132	12.77
T_3	5.56	0.66	0.065	14.91	0.147	11.77
T_4	5.83	0.60	0.060	14.37	0.143	14.67
T_5	5.73	0.62	0.062	14.27	0.136	13.86
T_6	5.60	0.67	0.062	14.49	0.138	12.92
T_7	5.53	0.68	0.065	15.24	0.145	13.65
Level of Significance	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

In a column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)

T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}

T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

Table 4.5 Effect of varieties on soil chemical properties in postharvest soil of the experimental crop field of maize

Varieties	Soil pH	Organic Carbon (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq100^{-1}g)	Available S (ppm)
V_1	5.8	0.62	0.064	14.54	0.135	13.86
V_2	5.7	0.65	0.063	14.77	0.140	12.64
V_3	5.6	0.63	0.062	14.19	0.142	13.65
Level of Significance	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**

In a column, figures having similar letter (s) do not differ significantly

Here,

V_1 = BARI Hybrid Bhutta-5

V_2 = BARI Hybrid Bhutta-6

V_3 = BARI Hybrid Bhutta-9

Exchangeable K content in post harvest soil was also non significant due to application of NGF along with other recommended fertilizers , the result varied from 0.130 meq 100^{-1}g to 0.145 meq 100^{-1}g (Appendix III and Table 4.4).

Due to application of NGF with other recommended fertilizers in maize filed available S content of post harvest soil was insignificant. Available S content varied from 11.77 ppm to 14.67 ppm (Appendix III and Table 4.4).

Rongting *et al.* (2017) who conducted pot experiment, the liquid organic fertilizers significantly promoted root and aboveground growth of chrysanthemum compared with the chemical fertilizer. The shrimp extract treatment significantly increased the nutrient contents and altered the soil's functional microbial community at the rhizospheric level compared with the chemical fertilizer treatment.

4.1.2.2 Effect of variety on soil chemical properties in postharvest soil of maize crop field

Soil pH, Organic carbon and nutrient (NPKS) content in postharvest soil were insignificant by the effect of varieties (Appendix III and Table 4.5). From Table 4.5, the results were found that the soil pH varied (5.6 to 5.8), Organic carbon varied (0.62 to 0.65%), total N varied (0.062 to 0.064 %), available P varied (14.19 to 14.77 ppm), available K varied (0.135 to 0.142 meq100^{-1}g) and available S (12.64 to 13.86 ppm) in soil.

4.1.2.3 Effect of interaction of NGF along with others fertilizers and varieties on soil chemical properties in postharvest soil of maize crop field

Analysis of variance data of the Appendix III and Table 4.6 revealed that there was no significant variation for soil pH, organic carbon and nutrient content except available S in postharvest soil due to the effect of interaction of NGF along with other recommended fertilizers and varieties in soil of post harvest soil of maize.

Table 4.6 Effect of interaction of NGF along with other recommended fertilizers and varieties on soil chemical properties of crop field of maize

Interaction Fertilizers x Varieties	pH	Organic Carbon (%)	Total N (%)	Available P (ppm)	Exchangeable K (meq100^{-1}g)	Available S (ppm)
T_0 x V_1	5.87	0.61	0.059	15.33	0.130	9.64 c
T_0 x V_2	5.80	0.65	0.059	14.19	0.130	14.16 bc
T_0 x V_3	5.87	0.69	0.059	13.70	0.130	14.24 bc
T_1 x V_1	5.67	0.61	0.065	15.98	0.130	12.25 bc
T_1 x V_2	5.77	0.62	0.065	14.31	0.130	12.38 bc
T_1 x V_3	5.73	0.59	0.064	13.13	0.136	13.68 bc
T_2 x V_1	5.80	0.56	0.067	13.89	0.136	10.87 bc
T_2 x V_2	5.70	0.69	0.064	13.84	0.143	12.45 bc
T_2 x V_3	5.60	0.66	0.065	13.69	0.149	13.05 bc
T_3 x V_1	5.60	0.64	0.065	13.78	0.143	18.99 a
T_3 x V_2	5.63	0.65	0.065	15.77	0.149	11.70 bc
T_3 x V_3	5.43	0.68	0.064	15.18	0.149	12.74 bc
T_4 x V_1	5.83	0.63	0.060	15.14	0.143	14.10 bc
T_4 x V_2	5.87	0.60	0.060	14.26	0.136	11.98 bc
T_4 x V_3	5.80	0.68	0.060	13.72	0.130	13.03 bc
T_5 x V_1	5.97	0.60	0.062	14.02	0.143	13.56 bc
T_5 x V_2	5.60	0.68	0.065	15.21	0.136	11.99 bc
T_5 x V_3	5.63	0.68	0.060	13.58	0.149	12.51 bc
T_6 x V_1	5.70	0.62	0.064	14.82	0.130	15.51 ab
T_6 x V_2	5.33	0.71	0.062	13.79	0.143	12.51 bc
T_6 x V_3	5.77	0.68	0.062	14.85	0.143	14.27 bc
T_7 x V_1	5.67	0.67	0.065	14.08	0.136	14.11 bc
T_7 x V_2	5.57	0.67	0.065	16.75	0.149	14.16 bc
T_7 x V_3	5.37	0.71	0.065	14.90	0.149	11.70 bc
Level of Significance	**NS**	**NS**	**NS**	**NS**	**NS**	*****

In column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)

T_1 = Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ kg ha^{-1}

T_2 = American NPK (9.88 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_3 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_4 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_5 = Peak (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_6 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

T_7 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$

V_1 = BARI Hybrid Bhutta-5

V_2 = BARI Hybrid Bhutta-6

V_3 = BARI Hybrid Bhutta-9

From Table 4.6, the results were found that pH in soil varied (5.33 to 5.97), organic carbon (0.56 % to 0.71 %), total N varied (0.059 % to 0.067 %), available P content varied (13.13 ppm to 16.75 ppm) and exchangeable K varied (0.130 to 0.149 $meq100^{-1}g$).

The maximum level of available S content (18.99 ppm) in post harvest soil was found from the treatment combination of T_3V_1 which was statistically similar to T_6V_1 (15.51 ppm). The minimum level of available S found from the interaction of T_0V_1 (9.64 ppm)

4.2 Experiment 2: Effect of next generation fertilizers on growth and yield of tomato

Results obtained from the present study regarding the influence of various treatment combinations of next generation fertilizers along with other recommended fertilizers and tomato variety on growth, yield attributes and fruit yield of tomato are presented and discussed in this chapter. The results have been presented in Tables 4.7 to Table 4.12 and Figure 4.11 to Figure 4.20. All ANOVA are presented in Appendices IV - VI. The fruit yield and fruit yield contributing characters of the Tomato varieties have been presented and discussed under separate heads and sub–heads as follows:

4.2.1 Yield attributes and yields of tomato

4.2.1.1 Plant height of tomato

4.2.1.1.1 Effect of NGF along with other recommended fertilizers on plant height of tomato

The effect of next generation fertilizers along with other recommended fertilizers was statistically significant on the plant height at vegetative stage where plant height ranges from 84.42 cm to 93.04 cm (Appendix IV, Table 4.7 and Fig. 4.11). From the figure 4.11, it was observed that the tallest plant of 93.04 cm was found from the treatment T_2 receiving Bio-forge along with other recommended fertilizers which was statistically similar to T_4 treatment (Root Feed along with other recommended fertilizers). The shortest plant height of 84.42 cm was found in T_0 control treatment.

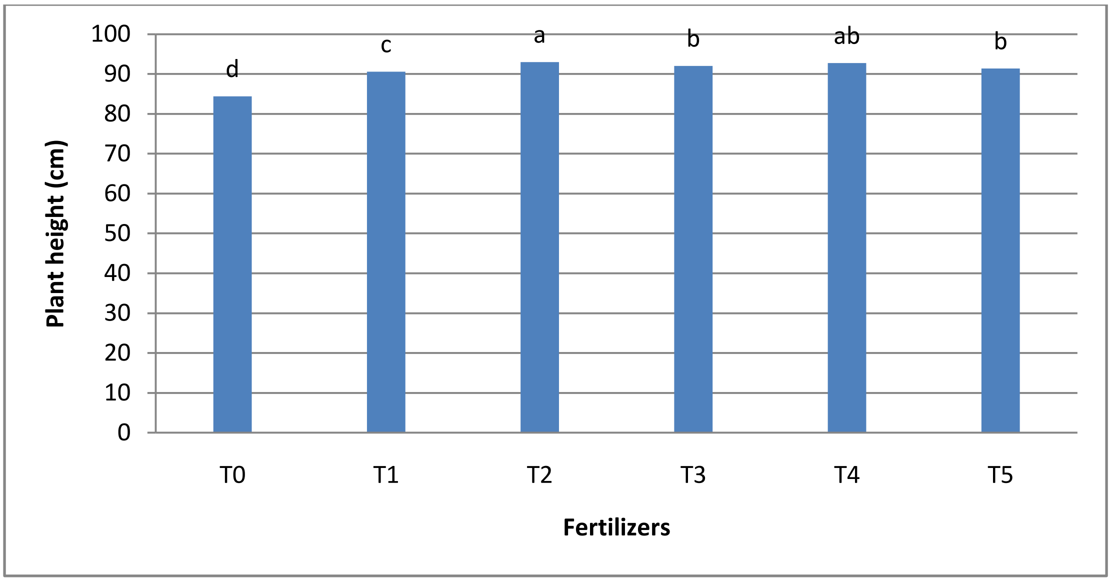

Figure 4.11. Effect of NGF along with other recommended fertilizers on plant height of tomato

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

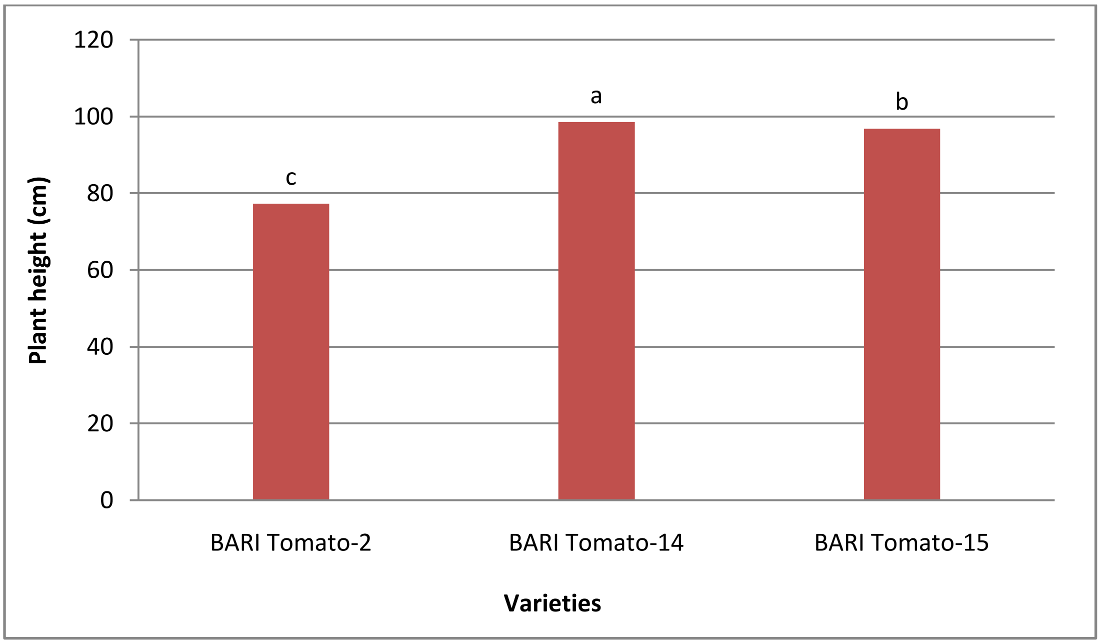

Figure 4.12. Effect of varieties on plant height of tomato

Various physiological processes including cell division and cell elongation of the plant, as a result increased the plant height of tomato might be influenced by the application of Bio-forge with along with other recommended fertilizers and Root feed along with other recommended fertilizers.

Similar result was found from Chaurasia *et al.* (2005) who applied foliar sprays of water soluble fertilizers significantly increased the plant height, number of fruits, average fruit weight, fruit length, fruit diameter, yield and the net profit of tomatoes. The similar result also obtained by Singh *et al.* (2005) who conducted an experiment to study the effects of N, P, and K at 200:100:150, 350:200:250, and 500:300:350 kg ha^{-1} on the growth and yield of tomato hybrids Rakshita, Karnataka, and Naveen.

4.2.1.1.2 Effect of variety on plant height of tomato

Plant height was significantly influenced due to the effect of variety (Appendix IV, Figure. 4.12 and Table 4.8). Among the varieties, BARI Tomato-14 was the tallest (98.53 cm) compared to other two varieties, BARI Tomato-15 (96.83 cm) and BARI Tomato-2 (77.27 cm) during winter season. The above variation in plant height was observed might be due to the genetic variation of the varieties.

4.2.1.1.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on plant height of tomato

Plant height of tomato was significantly varied due to the effect of interaction of variety and NGF along with other recommended fertilizers where plant height varied from 72.77 cm to 100.50 cm (Appendix IV and Table 4.9). The highest plant height of tomato (100.50 cm) was found in the variety BARI Tomato-14 receiving Bio-forge along with other recommended fertilizers (T_2V_2) which was statistically similar to T_4V_2 (99.89 cm) treatment combination. The shortest plant height of 72.77 cm was found in T_0V_1 treatment combination.

4.2.1.2 Flower cluster plant^{-1} of tomato

4.2.1.2.1 Effect of NGF with other recommended fertilizers on number of cluster plant^{-1} of tomato

Number of flower clusters per plant was highly significant due to the effect of next generation fertilizers (NGF) treatment along with other recommended fertilizers. The number of clusters per plant ranges from 6.44 to 7.90 (Appendix IV, Table-4.7 and Fig. 4.13). Figure 4.15 revealed that the maximum number of clusters per plant (7.90) was found in the treatment T_2 (Bio-forge with other recommended fertilizers) which was statistically similar to T_4 treatment (7.88). The lowest number of clusters per plant of 6.44 was found in T_0 control treatment. This result was expressed that the number of cluster per plant of tomato progressively increased in application of Bio-forge along with other recommended fertilizers. Similar result was found from Islam *et al.* (2017) who applied humic acid (HA) at 4.8, 9.6 and 14.4 kg ha^{-1} on the growth and productivity of two tomato hybrids Nema 1400 and Platinium 5043 under hot continental climate.

4.2.1.2.2 Effect of variety on number of cluster plant^{-1} of tomato

Number of flower clusters per plant was insignificant due to the effect of variety (Appendix IV, Table- 4.8 and Fig. 4.14). Among the varieties, maximum number of clusters per plant (10.12) was produced by BARI Tomato-14 (V_2) which was statistically significant with V_1 (8.98) and V_3 (8.11).

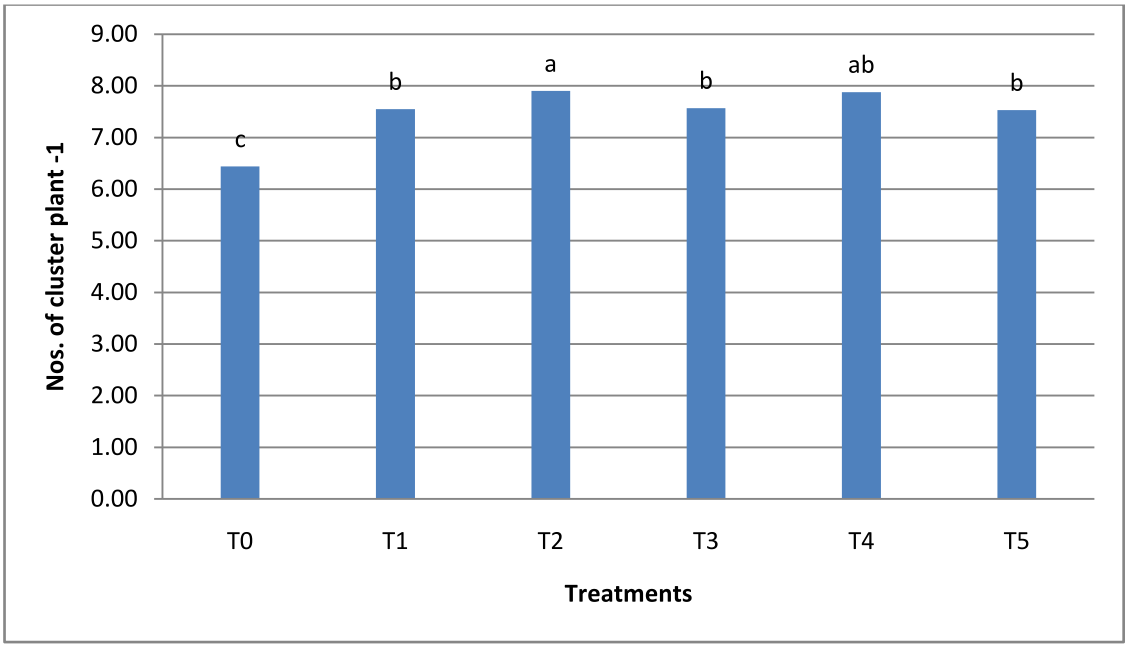

Figure 4.13. Effect of NGF along with other recommended fertilizers on number of flower cluster per plant of tomato

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

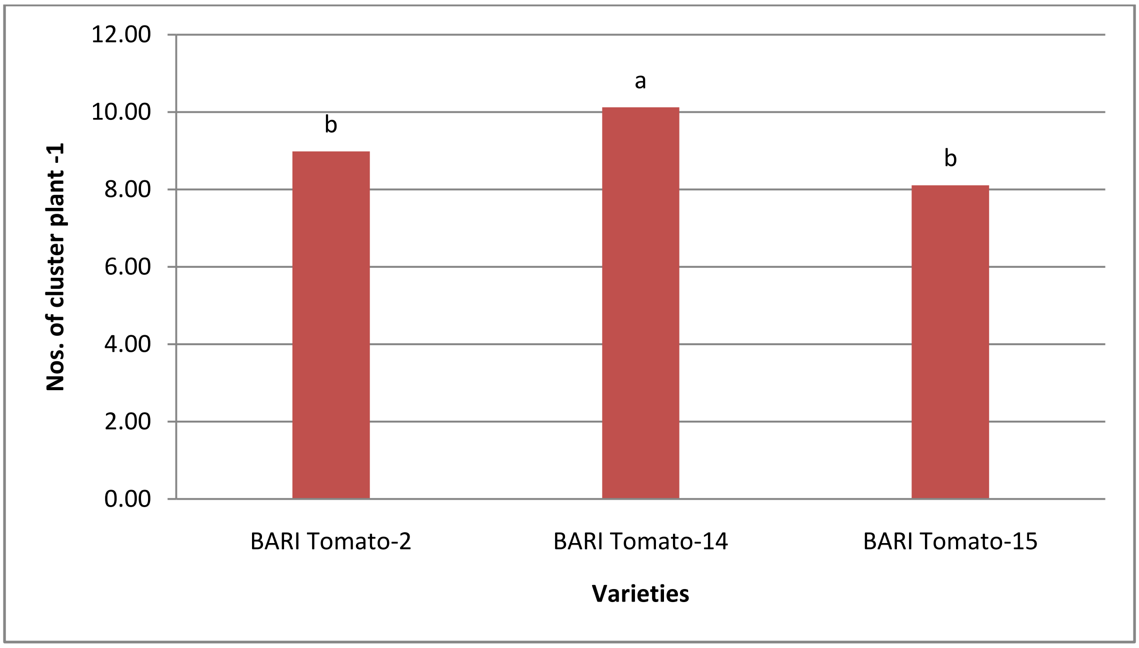

Figure 4.14. Effect of varieties on number of flower clusters per plant of tomato

The similar results was found from Islam *et al.* (2017) who conduct the research with application of humic acid (HA) applied at the rate of 4.8, 9.6 and 14.4 $kg \cdot ha^{-1}$ on the growth and productivity of two tomato hybrids Nema 1400 and Platinium 5043. HA at 14.4 $kg \cdot ha^{-1}$ increased the yield characters (number of fruits per cluster, fruit number per plant and fruit weight) of the hybrid variety Platinium 5043.

4.2.1.2.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on cluster plant^{-1} of tomato

Number of clusters per plant was significantly varied due to the effect of interaction of variety and NGF with other recommended fertilizers where number of cluster varied from 6.44 to 8.89 (Appendix IV and Table 4.9). The maximum number of flower cluster of 8.89 was produced from the variety BARI Tomato-14 receiving of Bio-forge (T_2V_2) along with other recommended fertilizers which was statistically similar to the treatment combination of T_2V_3 and T_4V_2. The lowest number of flower cluster (6.44) was found from the treatment combination of T_0V_1.

4.2.1.3 Number of fruits cluster^{-1} of tomato

4.2.1.3.1 Effect of NGF along with other recommended fertilizers on fruits per cluster of tomato

Number of fruits per cluster of tomato were significant due to application of NGF along with other recommended fertilizers. The fruits per cluster ranges from 3.11 to 4.57 (Appendix IV Table-4.7 and Fig. 4.15). It was revealed that the maximum number of fruits per cluster (4.57) was found from the treatment T_2 receiving Bio-forge along with other recommended fertilizers which was statistically similar to T_4 treatment (4.30). The lowest number of fruits per cluster (3.11) was found in the T_0 control treatment.

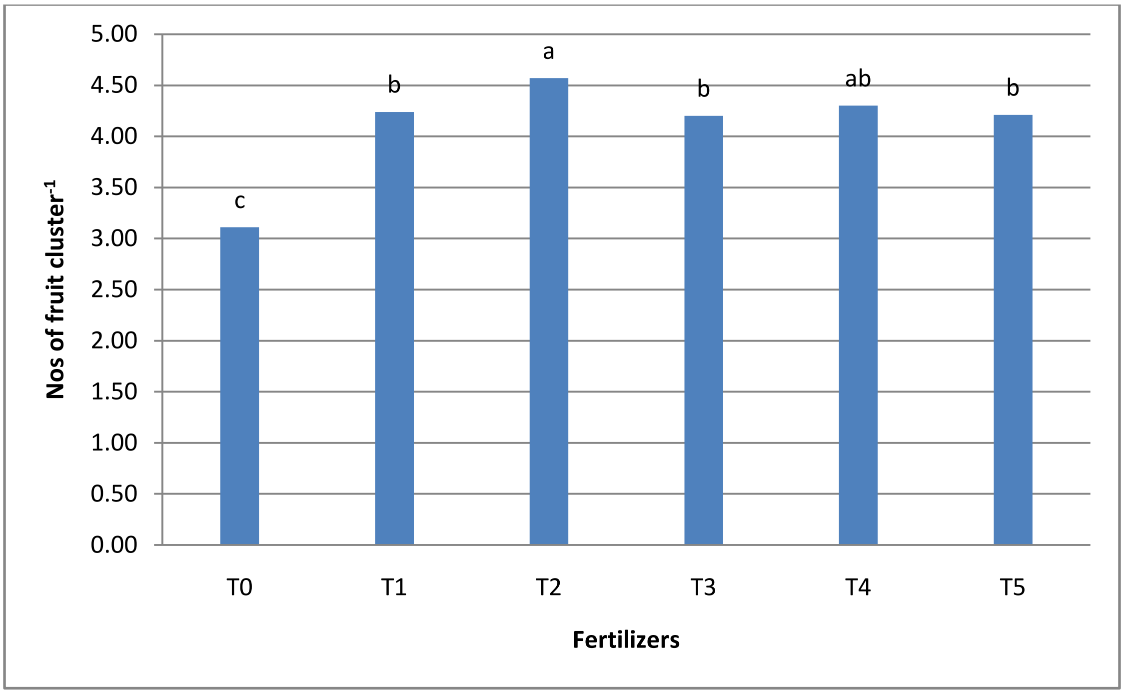

Figure 4.15. Effect of NGF with other recommended fertilizers on fruits per cluster of tomato

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

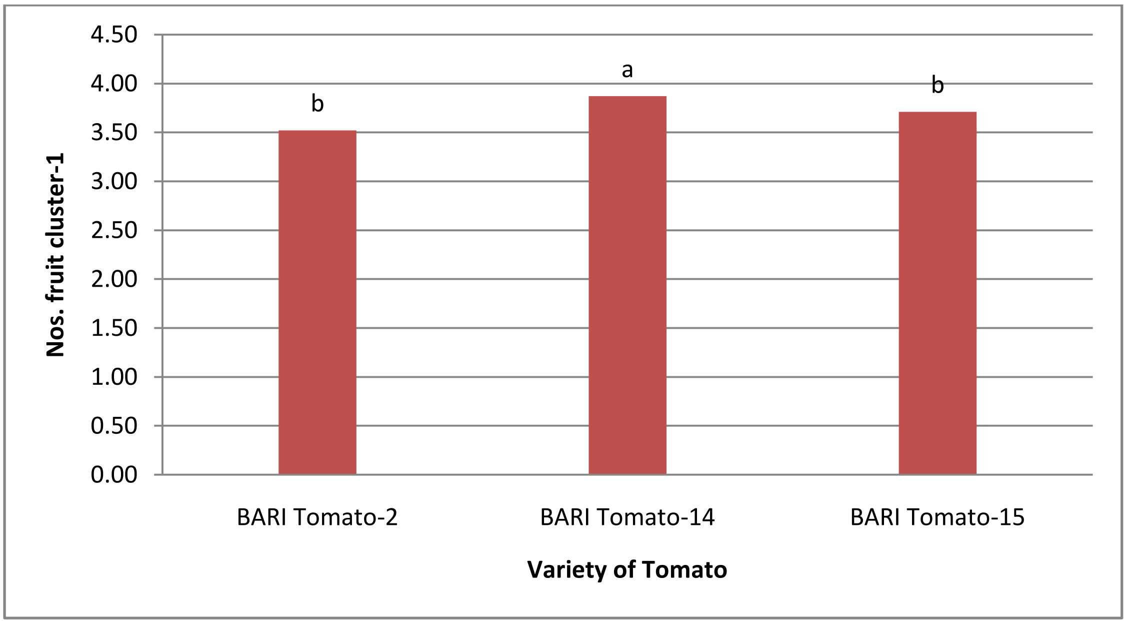

Figure 4.16. Effect of varieties on fruits per cluster of tomato

These result expressed that the number fruits per cluster of tomato progressively increased with the application of Bio-forge along with other recommended fertilizers.

Islam *et al.* (2017). studied that the effect of humic acid (HA) applied at 4.8, 9.6 and 14.4 $kg{\cdot}ha^{-1}$ on the growth and productivity of two tomato hybrids Nema 1400 and Platinium 5043. HA at 14.4 $kg{\cdot}ha^{-1}$ increased the yield characters (number of fruits per cluster, fruit number per plant and fruit weight) of Platinium 5043.

4.2.1.3.2 Effect of variety on number of fruits per cluster of tomato

Variation of number of fruits per cluster of tomato was significant due to the difference of varietal characteristics. (Appendix IV and Fig. 4.16). The maximum number of fruits per cluster was (3.87) was found in V_2 (BARI Tomato-14). The minimum number of fruits per cluster was found in V_1 (3.52) treatment which was statistically similar to V_3 (3.71) treatment.

4.2.1.3.3 Interaction effect of variety and next generation fertilizer along with NPK on number of fruits per cluster of tomato

Fruits per cluster were significant due to the effect of interaction of variety and NGF with other recommended fertilizers where fruits varied from 2.77 to 5.23 (Appendix IV and Table 4.9). The maximum fruits per cluster of 5.23 were produced from the variety BARI Tomato-14 receiving of Bio-forge along with other recommended fertilizers (T_2V_2) which was statistically similar to the treatment combination of T_4V_2 and T_4V_3. The lowest number of fruits per cluster was found in treatment combination T_0V_1.

Table 4.7 Effect of NGF along with other recommended fertilizers on plant height, cluster Plant^{-1}, fruits cluster^{-1}, fruits plant^{-1}, fruit diameter, fruit length and fruits yield of tomato

Fertilizers	Plant height (cm)	Cluster plant^{-1} (no.)	Fruits cluster^{-1} (no.)	Fruits plant^{-1} (no.)	Fruit diameter (cm)	Fruit length (cm)	Fruits yield (tha^{-1})
T_0	84.42 d	6.44 c	3.11 c	20.03 c	18.11	8.47	47.03 c
T_1	90.63 c	7.55 b	4.24 b	32.00 b	18.78	9.51	82.54 b
T_2	93.04 a	7.90 a	4.57 a	36.11 a	19.38	9.59	98.13 a
T_3	92.04 b	7.57 b	4.20 b	31.78 b	18.53	9.28	86.60 b
T_4	92.74 ab	7.88 ab	4.30 ab	33.89 ab	19.36	9.88	89.83 ab
T_5	91.38 b	7.53 b	4.21 b	31.70 b	18.91	9.67	84.55 b
Level of Significance	*	*	*	*	NS	NS	*

In a column, figures having similar letter (s) do not differ significantly
Here,

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

Table 4.8 Effect of varieties on plant height, cluster plant^{-1}, fruits cluster^{-1}, fruits plant^{-1}, fruit diameter, fruit length and fruits yield of tomato

Variety)	Plant height (cm)	Cluster plant^{-1} (no.)	Fruits cluster^{-1} (no.)	Fruits plant^{-1} (no.)	Fruit diameter (cm)	Fruit length (cm)	Fruits yield (tha^{-1})
V_1	77.27 c	8.98 b	3.52 b	31.61 b	19.94 a	9.62 a	75.93 b
V_2	98.53 a	10.12 a	3.87 a	39.11 a	20.44 a	9.09 b	98.70 a
V_3	96.83 b	8.11 b	3.71 b	30.11 b	16.65 b	9.98 a	80.20 b
Level of Significance	*	*	*	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly
Here,

V_1 = BARI Tomato 2
V_2 = BARI Tomato 14
V_3 = BARI Tomato 15

Table 4.9 Effect of interaction of fertilizers and varieties on plant height, cluster plant^{-1}, fruits cluster^{-1}, fruits plant^{-1}, fruit diameter, fruit length and fruits yield of tomato

Interaction (Fertilizer x Variety)	Plant height (cm)	Cluster plant^{-1} (no.)	Fruits cluster^{-1} (no.)	Fruits plant^{-1} (no.)	Fruit diameter (cm)	Fruit length (cm)	Fruits yield (tha^{-1})
T_0 x V_1	72.77 h	6.44 c	2.77 d	19.67 cd	16.31 c	7.79 c	40.00 d
T_0 x V_2	75.82 g	6.56 c	3.36 c	24.00 cd	16.39 c	7.99 c	53.33 cd
T_0 x V_3	78.58 f	6.33 c	3.21 c	20.00 cd	16.27 c	8.07 c	47.77 cd
T_1 x V_1	98.02 c	8.00 b	3.82 bc	33.33 bc	19.03 b	8.28 bc	62.99 bc
T_1 x V_2	96.83 d	8.22 b	3.95 bc	32.33 bc	19.14 b	8.88 bc	86.67 bc
T_1 x V_3	97.07 c	8.11 b	3.87 bc	33.00 bc	19.10 b	8.67bc	66.67 bc
T_2 x V_1	98.30 bc	8.27 b	4.33 b	34.67 bc	18.64 b	9.07 b	87.90 bc
T_2 x V_2	100.50 a	8.89 a	5.23 a	45.33 a	20.99 a	10.14a	114.43 a
T_2 x V_3	98.40 bc	8.67 ab	4.20 bc	35.80 b	19.62 ab	9.10 b	88.21 bc
T_3 x V_1	78.45 f	8.24 b	3.52 bc	33.10 bc	19.10 b	9.05 b	70.00 bc
T_3 x V_2	98.70 bc	8.28 b	3.91 bc	34.33 bc	19.12 b	9.07b	80.00 bc
T_3 x V_3	98.70 bc	8.22 b	3.50 bc	32.00 bc	19.01 b	8.53 bc	76.67 bc
T_4 x V_1	98.50 bc	8.11 b	4.33 b	27.00 bc	19.13 b	9.39 b	87.77 bc
T_4 x V_2	99.89 ab	8.78 ab	4.72 ab	39.67 ab	20.59 ab	9.80 ab	88.20 bc
T_4 x V_3	98.60 bc	8.39 b	4.50 ab	31.67 bc	19.15 b	9.07 b	88. 17 bc
T_5 x V_1	85.65 e	8.11 b	3.52 bc	31.33 bc	18.26 bc	8.35 bc	77.77 bc
T_5 x V_2	98.70 bc	8.33 b	4.20 b	34.33 bc	18.50 bc	9.01 b	84.56 bc
T_5 x V_3	78.61 f	8.22 b	4.03 bc	33.33 bc	18.28 bc	8.73 bc	84.43 bc
Level of Significance	**	*	*	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly as per DMRT
Here,

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

V_1 = BARI Tomato 2
V_2 = BARI Tomato 14
V_3 = BARI Tomato 15

4.2.1.4 Number of fruits plant^{-1} of tomato

4.2.1.4.1 Effect of NGF along with other recommended fertilizers on fruits plant^{-1} of tomato

Fruits bearing of tomato were influenced significantly by the use of next generation fertilizers (NGF) along with other recommended fertilizers (Appendix V, Table 4.7 and Fig. 4.17). The maximum number of fruits per plant (36.11) was found in the treatment T_2 receiving Bio-forge along with other recommended fertilizers which was statistically similar with the threat T_4 (33.89). The lowest number of fruits per plant (20.03) was found in T_0 control treatment. These results signify that the fruits per plant of tomato increased in applied combination of Bio-forge with other recommended fertilizers. Similar result found from Chaurasia *et al.* (2005) who applied foliar sprays of water soluble fertilizers significantly increased number of fruits, average fruit weight, fruit length, fruit diameter and yield of tomato. The similar result also obtained by Singh *et al.* (2005) who conducted an experiment to study the effects of N, P, and K at 200:100:150, 350:200:250, and 500:300:350 kg ha^{-1} on the growth and yield of tomato hybrids Rakshita, Karnataka, and Naveen.

4.2.1.4.2 Effect of variety on fruits plant^{-1} of tomato

Variation of number of fruits per plant were significant due to the effect of variety (Appendix V and Fig. 4.18). BARI Tomato-14 (V_2) was produced the highest number of fruits per plant (39.11). The lowest number of fruits per plant was found V_3: BARI Tomato-15 (30.11) which was statistically similar to treatment V_1 (31.61).

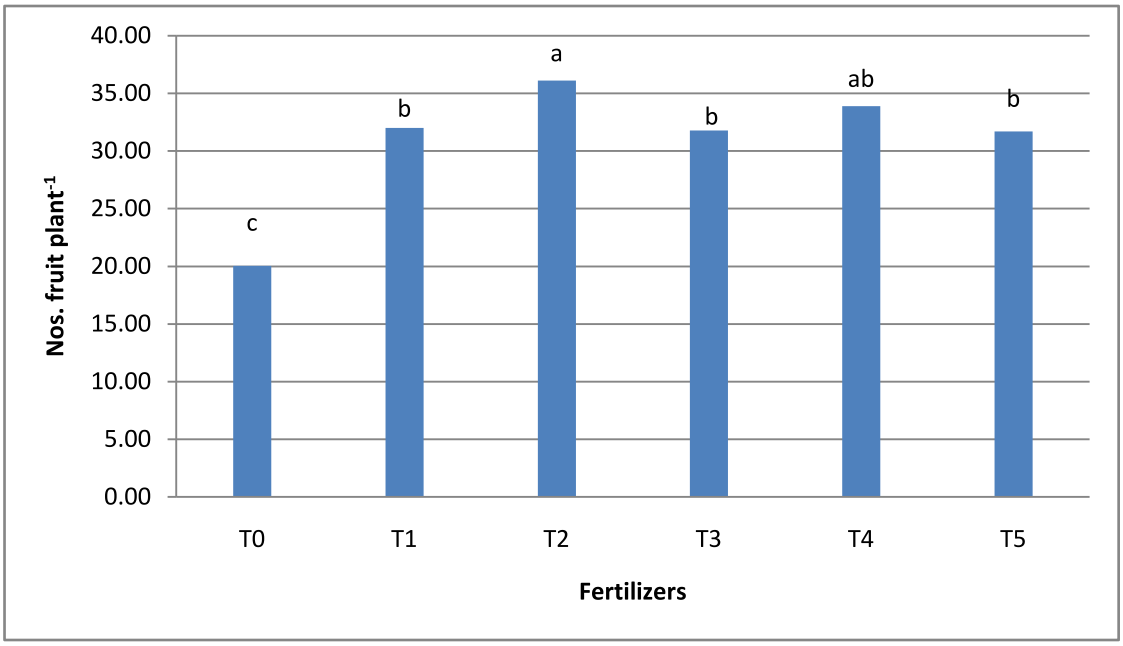

Figure 4.17. Effect of NGF along with other recommended fertilizers on number fruits plant^{-1} of tomato

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

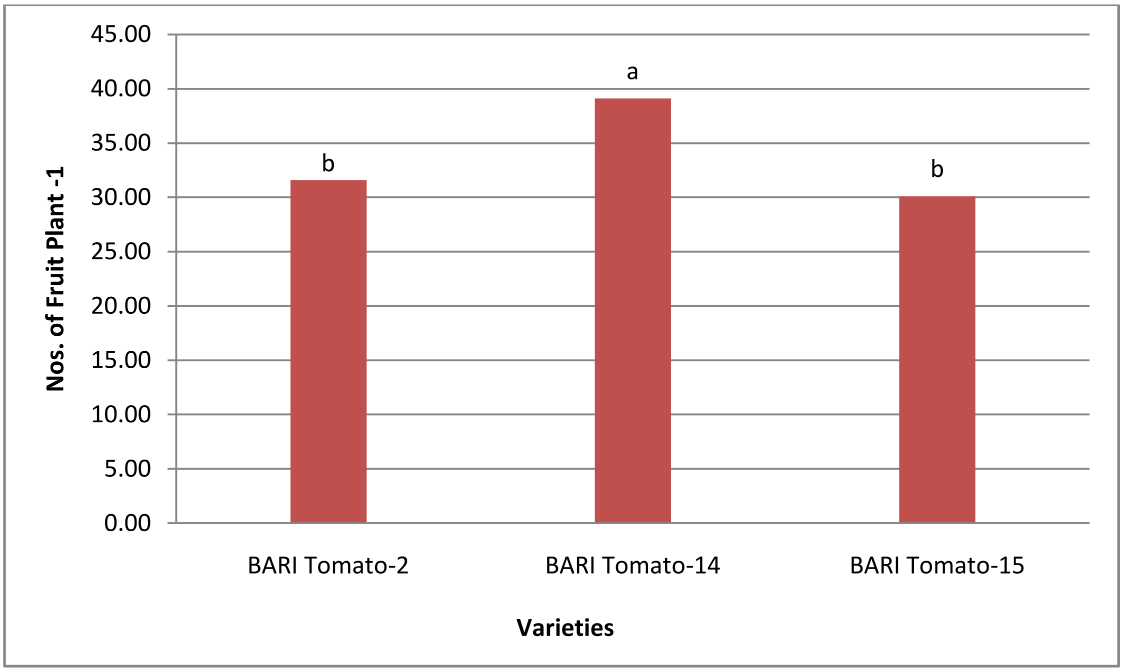

Figure 4.18. Effect of varieties on number fruits plant^{-1} of tomato

4.2.1.4.3 Effect of interaction of NGF along with other recommended fertilizers and variety on fruits plant^{-1} of tomato

Significant variation was found in number of fruits per plant due to the interaction of variety and NGF along with other recommended fertilizers where fruits per plant varied from 19.67 to 45.33 (Appendix V and Table 4.9). The maximum number of fruits per plant (45.33) was produced from the variety BARI Tomato 14 receiving of Bio-forge along with other recommended fertilizers (T_2V_2) which was statistically similar 39.80 and 39.67 with the combination of T_2V_3 and T_4V_2 respectively. The lowest number of fruits per plant (19.67) was found in the treatment combination (T_0V_1) which was statistically similar treatment combination of T_0V_2 (24.00) and T_0V_3 (20.00).

4.2.1.5 Fruit diameter of tomato

4.2.1.5.1 Effect of NGF with other recommended fertilizers on fruit diameter of tomato

There was no significant variation in fruit diameter of tomato due to the application of next generation fertilizers (NGF) along with other recommended fertilizers while fruits diameter ranges from 18.11 cm to 19.38 cm (Appendix V and Table 4.7). It was revealed that the highest fruit diameter (19.38 cm) was found from the treatment T_2 receiving Bio-forge along other recommended fertilizers. The lowest fruit diameter (18.11 cm) was found in T_0 control treatment. Chaurasia *et al.* (2005) who applied foliar sprays of water soluble fertilizers significantly increased fruit diameter of tomato.

4.2.1.5.2 Effect of variety on fruit diameter of tomato

Variation of fruit diameter was highly significant due to the effect of variety and controlled by the genetical character of tomato (Appendix V and Table 4.8).

Among the varieties, maximum fruit diameter (20.44 cm) found in the BARI Tomato-14 which was statistically similar with 19.94 (BARI Tomato-2). The lowest fruit diameter (16.65 cm) was observed in the variety BARI Tomato-15.

4.2.1.5.3 Effect of interaction of NGF along with other recommended fertilizers and variety on fruit diameter of tomato

Significant variation was found in fruit diameter of tomato due to combine effect of variety and NGF along with other recommended fertilizers where fruit diameter varied from 16.27 cm to 20.99 cm (Appendix V and Table 4.9). The maximum fruit diameter (20.99 cm) was produced from the variety BARI Tomato-14 receiving of Bio-forge along with other recommended fertilizers (T_2V_2) which was statistically similar with the treatment combination of T_2V_3 and T_4V_2. The lowest fruit diameter was found in the treatment combination (T_0V_3) which is statiscally similar with treatment combination of T_0V_1 and T_0V_2.

4.2.1.6 Fruit length of tomato

4.2.1.6.1 Effect of NGF with other recommended fertilizers on fruit length of tomato

No significant variation was found in the fruit length of tomato due to application of next generation fertilizers (NGF) along with other recommended fertilizers while fruits length ranges from 8.47 cm to 9.88 cm (Appendix V and Table 4.7). The highest fruits length of tomato (9.88 cm) was found from the treatment T_4 which were statistically similar T_2 (Bio-forge along with other recommended fertilizers). The lowest fruit length (8.47 cm) was found in T_0 control treatment.

4.2.1.6.2 Effect of variety on fruit length of tomato

Variation of fruit length of tomato was significant due to the effect of varietal characteristics (Appendix V and Table 4.8). Among the varieties, the highest fruit length (9.98 cm) was found in V_3 (BARI Tomato-15) was which was statistically similar to V_1 (BARI Tomato-2). The lowest fruit length of tomato found in V_2 BARI Tomato 14 (9.09 cm).

4.2.1.6.3 Effect of interaction NGF along with other recommended fertilizers and variety on fruit length of tomato

There was significant variation of fruit length of tomato due to the effect of interaction of variety and NGF with other recommended fertilizers where the length varied from 7.79 cm to 10.14 cm (Appendix V and Table 4.9). The highest fruit length 10.14 cm was produced from the treatment combination T_4V_2 (BARI Tomato-14 receiving of Root Feed along with other recommended fertilizers) which was statistically similar with T_2V_2 (Bio-forge with other recommended fertilizers). The lowest fruit length was found (7.79 cm) in the treatment combination which was statistically similar with treatment combination of T_0V_2 and T_0V_3.

4.2.1.7 Fruit yield of tomato

4.2.1.7.1 Effect of NGF with other recommended fertilizers on fruit yield of tomato

Fruits yield per hectare varied significantly due to effect of next generation fertilizers (NGF) along with other recommended fertilizers where fruits yield ranges from 47.03 to 98.13 t ha^{-1} (Appendix V Table-4.7 and Figure 4.19). Figure 4.19 revealed that the highest fruits yield (98.13 t ha^{-1}) was found from the treatment T_2 receiving Bio-forge along with other recommended fertilizers. The lowest number of fruits per plant (47.03 t ha^{-1}) was found in treatment control T_0. These result expressed that the fruits yield of tomato per hactere was increased in application of next generation fertilizer Bio-forge along with other recommended fertilizers.

Similar result found from Chaurasia *et al.* (2005) who applied foliar sprays of water soluble fertilizers significantly increased the yield of tomatoes. The similar result also obtained by Islam *et al.* (2017) with the application of applied humic acid (HA).

4.2.1.7.2 Effect of variety on fruit yield of tomato

There was a significant variation was found in fruits yield of tomato plant due to the effect of variety (Appendix V and Fig. 4.20). Among the varieties, the highest fruit yield of tomato 98.70 $tha^{-1}$was found in the treatment of V_2 (BARI Tomato-14). The lowest fruit yield 80.20 tha^{-1} of tomato found in treatment V_3 (BARI Tomato-15) which was statistically similar with treatment V_1 (75.93 t ha^{-1}).

4.2.1.7.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on fruit yield of tomato

The interaction effects of variety and NGF along with other recommended fertilizers on fruit yield of tomato was significant (Appendix V and Table 4.9). The highest fruits yield (114.43 tha^{-1}) was recorded from the treatment combination T_2V_2 (BARI Tomato-14 receiving of Bio-forge along with other recommended fertilizers). The lowest fruit yield (40 tha^{-1}) was found from T_0V_1 which was statistically insignificant with T_0V_2 and T_0V_3.

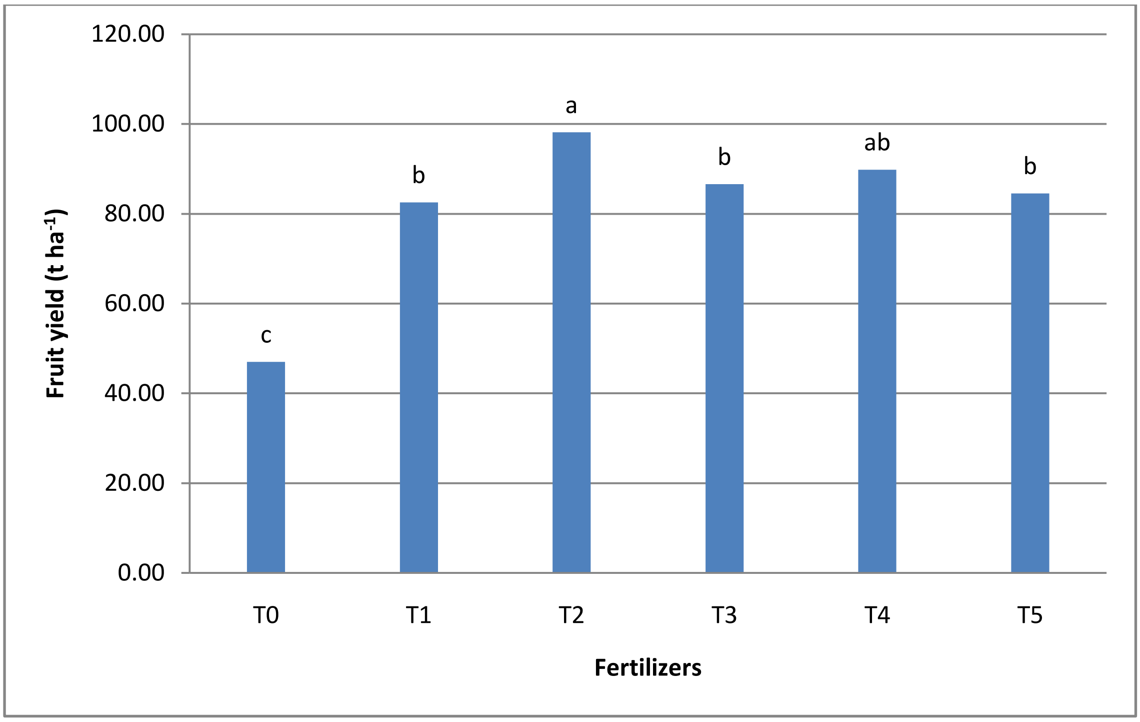

Figure 4.19 Effect of NGF along with other recommended fertilizers on fruits yield of tomato

T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

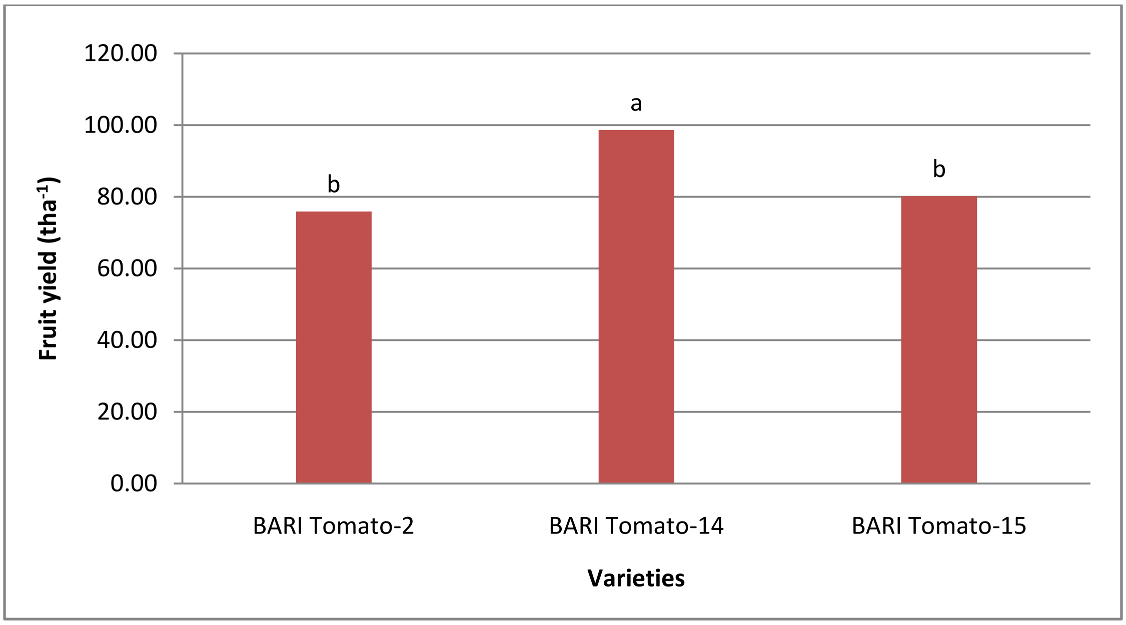

Figure 4.20 Effect of varieties on fruit yield of tomato

4.2.2 Soil chemical properties in postharvest soil of tomato crop field

4.2.2.1 Effect of NGF along with other recommended fertilizers on soil chemical properties in postharvest soil of tomato field

Soil pH

There was no significance change in pH of post harvest soil of tomato experiment field due to application of next generation fertilizers along with other recommended fertilizers where pH varied from 5.47 to 5.60 (Table 4.10 and Appendix VI) and compare to initial soil pH 5.5 (Table 3.2).

Soil organic carbon

There was no also significance change in soil organic carbon (SOC) of post harvest soil due to effect of next generation fertilizers along with other recommended fertilizers where SOC varied from 0.61% to 0.74% and compare to initial soil 0.61 (Table 4.10 and Appendix VI).

Soil nutrient NPKS

Total N content in post harvest soil showed insignificant variation due to the effect of NGF along with other recommended fertilizers where N content varied from 0.065 % to 0.080 % (Table 4.10 and Appendix VI).

Available P content in post harvest soil of tomato crop field showed significant variation due to application of NGF along with other recommended fertilizers where P content varied from 20.65 ppm to 25.23 ppm (Table 4.10 and Appendix V). The highest available P content 25.23 ppm was found in the treatment of T_4 which was statistically similar with T_2 (24.70 ppm). The lowest P content 20.65 ppm in post harvest soil was found in treatment of T_0 which was statistically similar to T_1, T_3 and T_5 treatment.

Exchangeable K content in post harvest soil showed insignificant variation due to effect of NGF along with other recommended fertilizers where K content varied 0.157 to 0.173 meq 100^{-1}g (Table 4.10 and Appendix VI).

Available S content in post harvest soil of tomato crop field showed significant variation due to application of NGF along with other recommended fertilizers where S content varied from 14.86 ppm to 10.29 ppm (Table 4.10 and Appendix VI). The highest S content 14.86 ppm was found in the treatment of T_4 which was statistically similar with treatment T_5 (12.58 ppm) and T_2 (12.50 ppm). The lowest S content in post harvest soil 10.29 ppm was found in treatment of T_0 which was statistically similar to T_1 and T_3 treatment.

4.2.2.2 Effect of variety on soil chemical properties in postharvest soil of tomato field

Soil pH and amount soil organic carbon in postharvest soil showed insignificant variation due to the effect of varieties. Soil pH varied from 5.53 to 5.56 and soil organic carbon content varied from 0.66 % to 0.71 % (Appendix VI and Table 4.11).

Total nitrogen, exchangeable K and available S content in post harvest soil was no significantly varied due to the effect of varieties (Appendix VI and Table 4.11) where total N varied (0.065 to 0.075 %), exchangeable K content varied (0.162 to 0.168 meq 100^{-1}g) and available S content varied (11.52 to 13.14 ppm)

Available P content in post harvest soil of tomato crop field showed significant variation due to effect of varieties where P content varied from 21.54 ppm to 24.24 ppm (Table 4.11 and Appendix VI). The highest P content 24.24 ppm was found in soil of the variety of V_3 which was statistically similar with V_2 (23.90 ppm). The lowest P content in post harvest soil 21.54 ppm was found in varietal treatment of V_1.

Table 4.10 Effect of NGF along with other recommended fertilizers on chemical properties of post harvested soil of tomato crop field

Treatment	pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Exchangeable K ($meq100^{-1}g$)	Available S (ppm)
T_0	5.56	0.74	0.065	20.65 c	0.169	10.29 b
T_1	5.60	0.62	0.065	22.87 bc	0.173	11.19 b
T_2	5.56	0.73	0.075	24.70 ab	0.165	12.50 ab
T_3	5.52	0.61	0.070	22.59 bc	0.161	11.20 b
T_4	5.57	0.64	0.080	25.23 a	0.157	14.86 a
T_5	5.47	0.74	0.075	22.58 bc	0.168	12.58 ab
Level of Significance	**NS**	**NS**	**NS**	*****	**NS**	*****

In a column, figures having similar letter (s) do not differ significantly
Here,
T_0 = Control (No fertilizer)
T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}
T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$
T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

Table 4.11 Effect of variety on chemical properties of post harvested soil of tomato crop field

Varieties	Soil pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Exchangeable K ($meq100^{-1}g$)	Available S (ppm)
V_1	5.54	0.66	0.065	21.54 b	0.167	12.66
V_2	5.56	0.68	0.075	23.90 a	0.162	11.52
V_3	5.53	0.71	0.070	24.24 a	0.168	13.14
Level of Significance	**NS**	**NS**	**NS**	******	**NS**	**NS**

In a column, figures having similar letter (s) do not differ significantly
Here,
V_1 = BARI Tomato 2
V_2 = BARI Tomato 14
V_3 = BARI Tomato 15

Table 4.12 Effect of interaction of fertilizers and variety on chemical properties of post harvested soil of tomato crop field

Interaction Fertilizers x Varieties	pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Exchangeable K ($meq100^{-1}g$)	Available S (ppm)
T_0 x V_1	5.60	0.78	0.055 b	25.21 ab	0.169	10.16 d
T_0 x V_2	5.43	0.75	0.065 b	25.42 ab	0.163	10.08 d
T_0 x V_3	5.63	0.78	0.065 b	25.04 ab	0.174	10.63 d
T_1 x V_1	5.60	0.74	0.070 ab	23.26 bc	0.176	11.46 cd
T_1 x V_2	5.60	0.74	0.070 ab	22.43 bc	0.164	11.52 cd
T_1 x V_3	5.60	0.79	0.070 ab	24.80 ab	0.179	11.60 cd
T_2 x V_1	5.47	0.72	0.070 ab	21.22 bc	0.163	17.19 a
T_2 x V_2	5.60	0.72	0.080 ab	26.04 a	0.163	12.57 cd
T_2 x V_3	5.60	0.77	0.070 ab	24.96 ab	0.170	14.81 bc
T_3 x V_1	5.50	0.72	0.070 ab	18.70 cd	0.161	12.04 cd
T_3 x V_2	5.63	0.78	0.070 ab	22.99 bc	0.160	11.25 cd
T_3 x V_3	5.43	0.73	0.070 ab	23.25 b	0.161	11.31 bc
T_4 x V_1	5.60	0.76	0.070 ab	19.92 bc	0.159	12.97 cd
T_4 x V_2	5.60	0.73	0.095 a	23.43 ab	0.156	12.57 d
T_4 x V_3	5.50	0.73	0.070 ab	24.40 ab	0.156	15.29 ab
T_5 x V_1	5.47	0.72	0.070 ab	20.91 bc	0.173	12.11 cd
T_5 x V_2	5.50	0.76	0.070 ab	23.12 bc	0.165	15.44 ab
T_5 x V_3	5.43	0.75	0.075 ab	22.98 bc	0.167	16.18 ab
Level of Significance	**NS**	**NS**	*	*	**NS**	*

In a column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)

T_1 = Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ kg ha^{-1}

T_2 = Bio-forge (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_3 = Wuxal Super (5.00 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

T_5 = Nitro Plus (1.20 L ha^{-1}) + Recommended $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$

4.2.2.3 Interaction effect of treatments and varieties on soil chemical properties in postharvest soil of tomato field

Analysis of variance data of the Appendix VI and Table 4.12 revealed that there was no significant variation in soil pH, organic carbon and exchangeable K in postharvest soil due to the interaction effect of NGF along with other recommended fertilizers and varieties after harvest of Tomato.

From Table 4.12, the results were found that pH in soil varied from 5.43 to 5.63, organic carbon from 0.72 % to 0.79 %, and exchangeable K varied from 0.156 to 0.179 meq100^{-1}g.

The maximum level of total N content (0.095 %) in post harvest soil was found under the treatment combination of T_4V_2. The minimum level of total N content was found from the treatment combination of T_0V_1 (0.055 %) which was statistically similar with T_0V_2 and T_0V_3 treatment combination.

The maximum level of available P content (26.04 ppm) in post harvest soil of tomato crop field was found from the treatment combination of T_2V_2. The minimum level of available P found from the interaction of T_3V_1 (18.70 ppm).

The maximum level of available S content (17.19 ppm) in post harvest soil of tomato field was found from the treatment combination of T_2V_1 which was statistically similar to T_4V_1 (15.29 ppm), T_5V_2 (15.44 ppm) and T_5V_3 (16.18 ppm). The minimum level of available S found from the interaction of T_0V_2 (10.08 ppm) which was statistical similar with T_0V_1, T_0V_3 and T_4V_2 treatment combination.

4.3 Experiment 3: Effect of next generation fertilizers on growth and yield of rice

Results obtained from the present study regarding the influence of various treatment combinations of next generation fertilizers along with other recommended fertilizer and variety on growth, yield attributes and yield of rice are presented and discussed in this chapter. The results have been presented in Tables 4.13 to 4.19 and Figures 4.21 to 4.28. All ANOVA are presented in Appendices from VII to IX. The grain yield and yield contributing characters of the rice cultivars have been presented and discussed under separate heads and sub–heads as follows:

4.3.1 Yield attributes and yields of rice

4.3.1.1 Plant height of rice

4.3.1.1.1 Effect of NGF along other recommended fertilizers on plant height of rice

Plant height was varied significantly due to the effect of next generation fertilizers (NGF) along with other recommended fertilizers while plant height ranges from 86.10 to 94.83 cm (Appendix VII, Table 1 and Fig. 4.21). The tallest plant of 94.83 cm was found from the treatment T_2 receiving Bio-forge along with other recommended fertilizers which was statistically similar with treatment T_4 (92.23 cm). The shortest plant height (86.10 cm) was found in T_0 control treatment. These result expressed that the plant height of rice increased in apply of Bio-forge along with other recommended fertilizers. Various physiological processes including cell division and cell elongation of the plant might be influenced by the application of Bio-forge along with other recommended fertilizers. These findings are in agreement with the findings of Rogaciano and Rosill (2015) who conducted a research to determine the effects of three liquid fertilizers (Nitrofert, Crop Gaint and Nutriplant AG) on the growth of glutinous corn. Findings revealed that the height of corn was not significantly affected by the supplementation of different liquid fertilizers. Shaha (2014) who reported that the different rates of cowdung with inorganic fertilizers showed significant effect on plant height. Sarkar (2014) also found that the application of 75% RD of inorganic fertilizers + 50% cowdung showed superiority on plant height. Similar result agreed by Naidu *et al*. (2013) who reported that the highest growth, yield attributes, lesser spikelet sterility and higher grain yield were obtained with the application of 100–50–50 kg ha^{-1} N, P and K.

4.3.1.1.2 Effect of variety on plant height

Plant height was significantly influenced by the effect of variety (Appendix VII and Fig. 4.22). The highest plant (98.31 cm) was found in the variety V_3 (BRRI dhan58). The lowest plant highest was found in the treatment V_2 (87.81 cm) which was statistically similar to V_1 treatment (89.06 cm). The above variation in plant height was observed due to the variation of genetic character.

Similar findings were also obtained by Islam *et al*. (2013) who found significant and genetic variation among the varieties on plant height. Mahamud *et al*. (2013), who found that the variation in plant height was indicated by the differentiation of genotypic characters and their genetic makeup also. Similar findings were also obtained by Panwar *et al*. (2012); Oka *et al*. (2012); Sritharan and Vijayalakshmi (2012); and many other scientists. Besides, the climatic and soil condition of the studied area were farvourable for better growth of BRRI dhan58 which ultimately showed highest plant height among the others two.

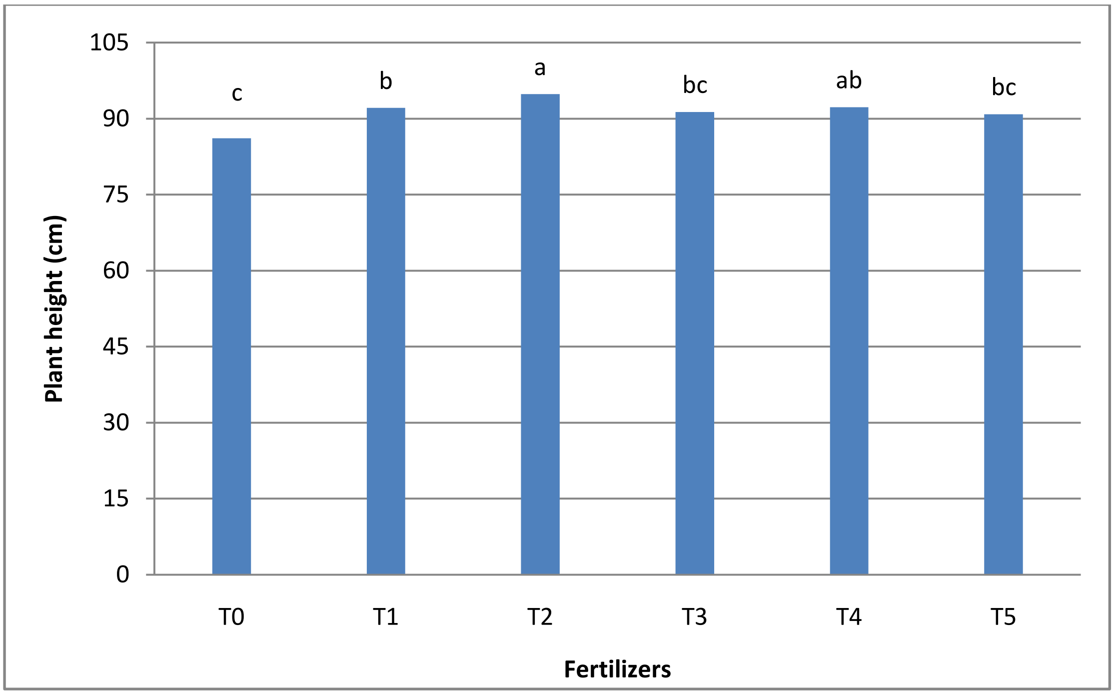

Figure 4.21 Effect of NGF along with other recommended fertilizers on plant height of rice

T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

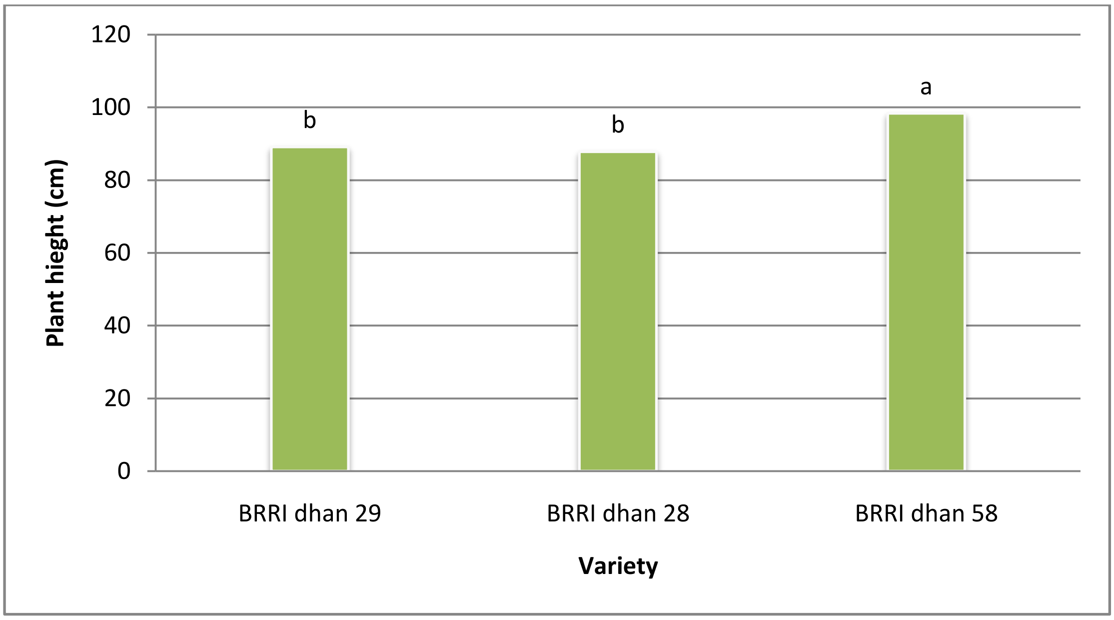

Figure 4.22 Effect of varieties on plant height of rice

4.3.1.1.3 Interaction effect of next generation fertilizer along with other recommended fertilizers and variety on plant height at vegetative stage of rice

Analysis of variance data on plant height at harvest varied significantly due to the effect of interaction of variety and NGF along with other recommended fertilizers where plant height significantly varied from 80.63 cm to 101.70 cm (Appendix VII and Table 4.15). The highest plant height (101.70 cm) was found in the treatment combination of T_2V_3 which was statistically similar with T_2V_1, T_2V_2 and T_4V_1 treatment combination. The shortest plant (80.63 cm) was found from the variety BRRI dhan28 while it did not receive any levels of fertilizer (T_0V_2) which was statistically similar to treatment combination of T_0V_3 (84.48 cm).

4.3.1.2 Number of effective tillers hill^{-1} of rice

4.3.1.2.1 Effect of NGF along with other recommended fertilizers on number of effective tillers hill^{-1} of rice

The numbers of effective tillers are an important parameter which influences yield of rice. Supply of nutrient plays a great role on production of effective tillers per hill. The NGF along with other recommended fertilizers had significant effect on increase number of effective tillers hill^{-1} (Appendix VII, Table 4.13 and Figure 4.23). The highest number of effective tillers hill^{-1} (17.33) was found in treatment T_2 having Bio-forge along with other recommended fertilizers which was statistically similar with treatment T_4 (Root feed along with other recommended fertilizers (16.78). The lowest number of effective tillers hill^{-1} (11.33) was produced in T_0 control treatment. These result revealed that Bio-forge along with other recommended fertilizers influenced to produce the more effective tillers due to the rice plant can be utilized more nutrient from the soil. Such similar performance were also obtained by Shaha (2014) who found that the cowdung levels along with BRRI recommended dose of inorganic fertilizer showed the more tillers hill^{-1} which might be due to the combination of cowdung and inorganic fertilizer increase the soil nutrient and enhance the tillering capacity.

4.3.1.2.2 Effect of varieties on number of effective tillers hill^{-1} of rice

A rice plant may produce a number of tillers during its early growth stages but not all of them become effective that do not bear panicles. So, this character is directly related to yield of rice. The significant difference of number of effective tillers hill^{-1} was found among the varieties (Appendix VII and Table 4.14). The maximum number of effective tillers hill^{-1} (16.61) was found in V_1 (BRRI dhan29) (Fig. 4.24). The lowest number of effective tillers hill^{-1} was found in treatment V_3 which was statistically similar to V_2 treatment. Result revealed that BRRI dhan29 produced maximum number of effective tillers hill^{-1} than BRRI dhan28 and BRRI dhan58 due to variation in their genetic characteristics or genetic makeup and environmental condition. Similarly, significant variation among the rice varieties regarding tillers hill^{-1}were also found by Panwar *et al*. (2012) and Alam *et al*. (2012).

4.3.1.2.3 Interaction effect of NGF along with other recommended fertilizers and variety on number of effective tillers hill^{-1} of rice

The effect of interaction between treatment and varieties was significant in respect of number of effective tillers hill^{-1} (Appendix VII and Table 4.15). The significant variation was found that the number of effective tillers varied from 10.00 to 19.67 where the maximum number of effective tillers hill^{-1} (19.67) was produced from the variety BRRI dhan29 receiving of Bio-forge along with other recommended fertilizers which was statistically insignificant with T_2V_2.

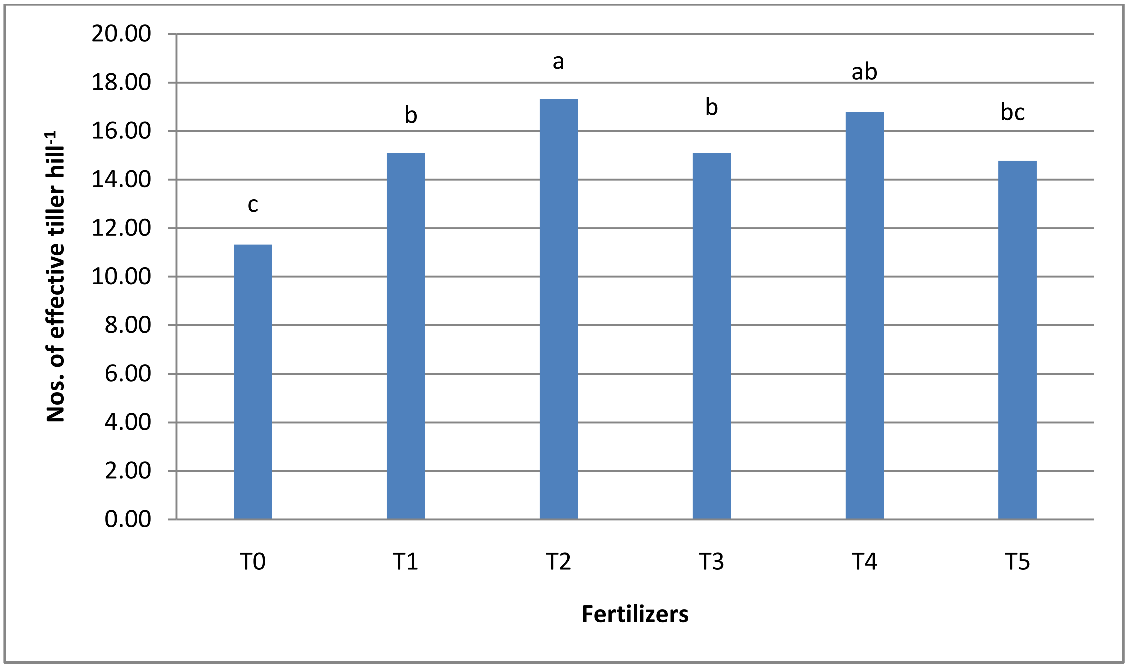

Figure 4.23 Effect of NGF along with other recommended fertilizers on effective tiller hill^{-1} of rice

T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

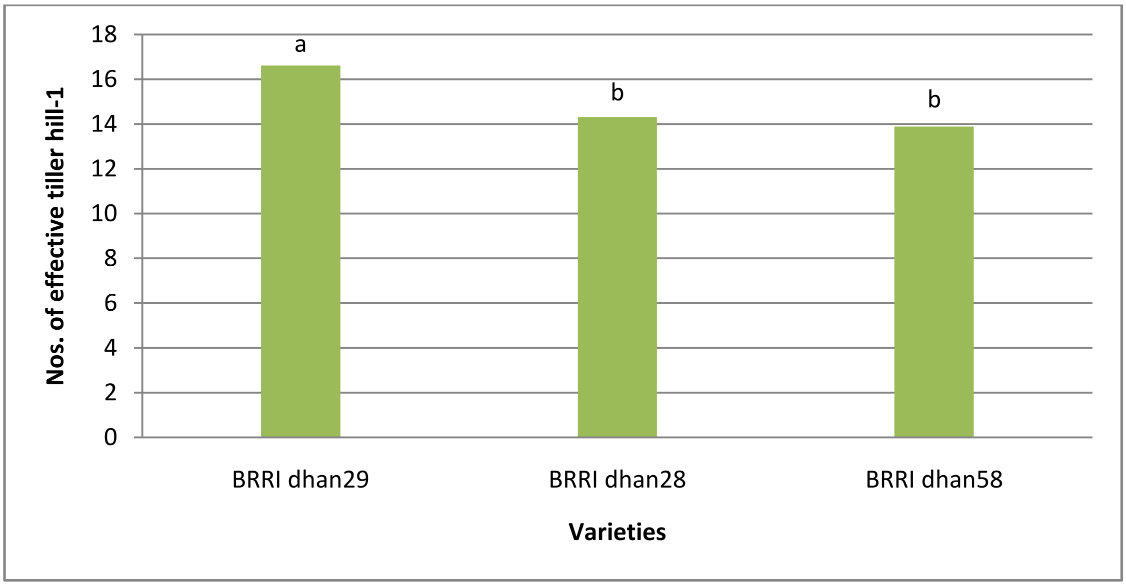

Figure 4.24 Effect of varieties on effective tiller hill^{-1} of rice

The minimum number of effective tillers $hill^{-1}$ (10.00) was produced in the treatment combination of T_0V_1 (BRRI dhan29 having no fertilizer treatment) which was statistically similar with treatment combination of T_0V_2 and T_0V_3 (Table 4.15).

4.3.1.3 Number of non-effective tillers $hill^{-1}$ of rice

4.3.1.3.1 Effect of NGF along with other recommended fertilizers on number of non-effective tillers $hill^{-1}$ of rice

Different treatments of NGF along with other recommended fertilizers showed significant variation in number of non-effective tillers $hill^{-1}$ of rice (Appendix VII & Table 4.13).The maximum number of non effective tillers $hill^{-1}$ (6.00) was observed from T_0 treatment whereas the minimum number of non-effective tillers $hill^{-1}$ (3.11) from T_2 treatment which was statistically similar (3.91 and 3.80) with T_3 and T_4 treatment.

4.3.1.3.2 Effect of varieties on non-effective tillers $hill^{-1}$ of rice

The significant difference in number of non-effective tillers $hill^{-1}$ was found among the varieties (Appendix VII and Table 4.14). The maximum number of non-effective tillers $hill^{-1}$ (4.63) was found in V_2 (BRRI dhan28) which was statistically similar to V_3 treatment. Result revealed that V_1 (BRRI dhan29) produced less number of effective tillers $hill^{-1}$ than BRRI dhan28 and BRRI dhan58.

4.3.1.3.3 Effect of interaction between variety and next generation fertilizer along with other recommended fertilizer on number of non-effective tillers $hill^{-1}$ of rice

Significant variation was found in number of non-effective tillers $hill^{-1}$ (Appendix VII and Table 4.15). The significant variation results in Table 4.15 revealed that the non-effective tillers varied from 3.33 to 7.53 where the maximum number of non effective tillers hill^{-1} (7.53) was produced from the treatment combination of T_0V_2 which was statistically similar with T_0V_1 (5.80) and T_0V_3 (6.81) combination. The minimum number of non effective tillers hill^{-1} (3.33) was produced in the treatment combination of T_2V_1 which was statistically similar with treatment combination of T_4V_1 (3.34).

4.3.1.4 Panicle length of rice

4.3.1.4.1 Effect of NGF along with other generation fertilizers on panicle length of rice

Panicle length was showed statistical variation among the NGF along with other recommended fertilizers (Appendix VII and Figure 4.25). The longest panicle (26.09 cm) was obtained from the treatment T_2 having Bio-forge along with other recommended fertilizers which was statistically similar with T_4 treatment. The shortest panicle (24.16 cm) was found in the treatment T_0. These result reveled that Bio-forge along with other recommended fertilizers had effective influence than others treatment combination to produce longest panicle. So, the above findings was agreed by the research work of Rashid *et al*. (2011); Hoshain (2010) and other researchers of the home and abroad.

4.3.1.4.2 Effect of variety on panicle length of rice

Panicle length was significantly influenced by the variety (Appendix VII, Table 4.14 and Figure 4.26). From the Fig. 4.26, it was found that the longest panicle (26.03 cm) was observed in BRRI dhan29 (V_1) and the shortest panicle (24.62 cm) was found in the treatment V_2 which was statistically similar with V_3 treatment. These results showed that there was significant difference among the cultivar might be due to its genetic variation. This result is in agreement with the findings Ali *et al*. (2014); Shiyam *et al*. (2014); Sarker *et al*. (2013) and many other scientists.

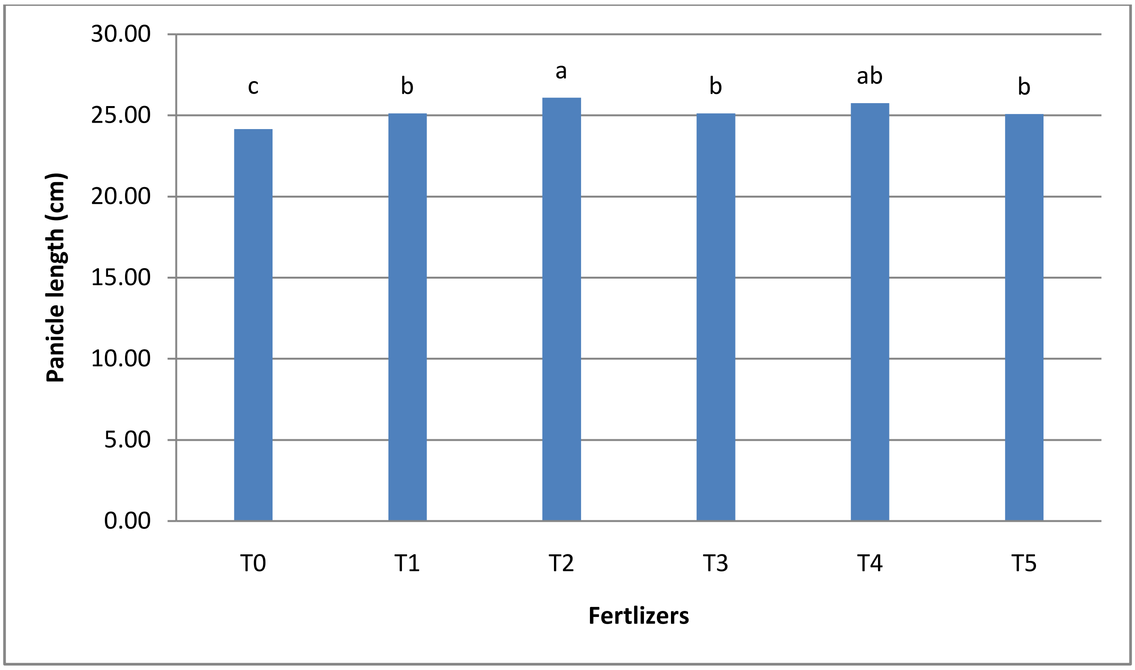

Figure 4.25. Effect of NPK along with other recommended fertilizers on panicle length of rice

T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

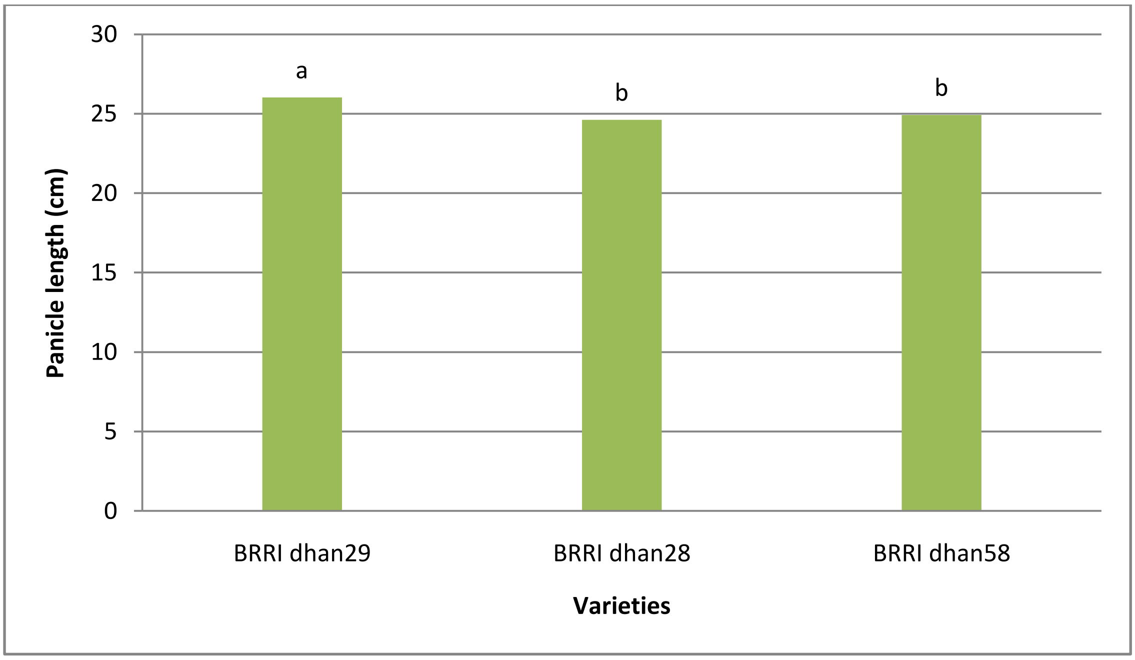

Figure 4.26. Effect of varieties on panicle length of rice

Table 4.13 Effect of NGF along with other recommended fertilizers on plant height, effective tiller hill^{-1}, non-effective tiller hill^{-1}, panicle length, filled grain panicle^{-1} and unfilled grain panicle^{-1} of rice

Treatment	Plant height (cm)	Effective tiller hill^{-1} (nos)	Non effective tiller hill^{-1} (nos)	Panicle length (cm)	Filled grain panicle^{-1} (nos)	Non-filled grain panicle^{-1} (nos
T_0	86.10 c	11.33 c	6.00 a	24.16 c	132.1 c	8.60 a
T_1	92.09 b	15.10 b	4.00 b	25.13 b	140.3 bc	6.60 b
T_2	94.83 a	17.33 a	3.11 c	26.09 a	154.9 a	5.71 bc
T_3	91.30 bc	15.10 b	3.91 bc	25.13 b	142.2 b	6.40 bc
T_4	92.23 ab	16.78 ab	3.80 bc	25.76 ab	150.9 ab	6.51 bc
T_5	90.87 bc	14.78 bc	4.11 b	25.09 b	141.9 bc	7.05 bc
Level of Significance	*	*	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

Table 4.14 Effect of variety on plant height, effective tiller hill^{-1}, non-effective tiller hill^{-1}, panicle length, filled grain panicle^{-1} and unfilled grain panicle^{-1} of rice

Varieties	Plant height (cm)	Effective tiller hill^{-1} (nos)	Non effective tiller hill^{-1} (nos)	Panicle length (cm)	Filled grain panicle^{-1} (nos)	Non-filled grain panicle^{-1} (nos
V_1	89.06 b	16.61 a	3.07 b	26.03 a	168.70 a	5.57 b
V_2	87.81 b	14.32 b	4.63 a	24.62 b	123.70 b	7.13 a
V_3	98.31 a	13.89 b	4.47 a	24.93 b	128.00 b	6.97 a
Level of Significance	*	*	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly

Here,

V_1 = BRRI dhan29
V_2 = BRRI dhan28
V_3 = BRRI dhan58

Table 4.15 Interaction of fertilizer x variety on plant height, effective tiller hill^{-1}, panicle length and filled grain panicle^{-1} of rice

Fertilizer x Varieties	Plant height (cm)	Effective tiller hill^{-1} (nos)	Non effective tiller hill^{-1} (nos)	Panicle length (cm)	Filled grain panicle^{-1} (nos)	Non-filled grain panicle^{-1} (nos
T_0 x V_1	85.91 bc	10.00 c	5.80 a	23.85 b	122.7 cd	8.50 a
T_0 x V_2	80.63 d	10.33 c	7.53 a	23.71 c	103.3 fd	10.23 a
T_0 x V_3	84.48 cd	10.12 c	6.81 a	23.73 b	119.3 cd	9.51 a
T_1 x V_1	100.30 ab	14.67 b	3.67 b	24.57 bc	164.0 b	6.37 b
T_1 x V_2	91.94 bc	14.33 b	3.70 b	24.04 bc	137.3 bc	6.40 b
T_1 x V_3	92.19 bc	14.33 b	3.71 b	24.01 bc	133.7 cd	6.41 b
T_2 x V_1	99.46 ab	19.67 a	3.33 bc	26.79 a	193. 7 a	6.03 bc
T_2 x V_2	99.49 ab	17.67 ab	3.66 b	24.50 ab	171.3 ab	6.36 b
T_2 x V_3	101.70 a	15.00 b	3.70 b	24.98 ab	174.0 ab	6.40 b
T_3 x V_1	92.20 bc	15.00 b	3.68 b	24.57 bc	161.7 bc	6.38 b
T_3 x V_2	87.87 bc	14.67 b	3.69 b	24.42 bc	123.3 cd	6.39 b
T_3 x V_3	86.53 bc	14.33 b	3.72 b	24.66 bc	132.7 cd	6.42 b
T_4 x V_1	95.66 ab	17.30 b	3.34 bc	26.96 a	129.0 cd	6.04 bc
T_4 x V_2	92.44 bc	16.80 b	3.71 b	25.01 ab	128.3 cd	6.41 b
T_4 x V_3	91.38 bc	16.31 b	3.72 b	25.31 ab	134.0 cd	6.42 b
T_5 x V_1	89.72 bc	15.00 b	3.68 b	25.36 bc	125.7 cd	6.38 b
T_5 x V_2	87.24 bc	14.33 b	3.70 b	24.14 bc	124.7 cd	6.40 b
T_5 x V_3	88.81 bc	13.33 b	3.69 b	24.19 bc	147.3 bc	6.39 b
Level of Significance	*	*	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 L.ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

V_1 = BRRI dhan29
V_2 = BRRI dhan28
V_3 = BRRI dhan58

4.3.1.4.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on panicle length of rice

The analysis of variance data of the Appendix VII and Table 4.15 showed that significance variation was found in panicle length of yield character due to treatment combination. From the obtained result in Table 4.15 it was found that the length of panicle numerical varied from 23.71 to 26.96 cm. The longest panicle (26.96 cm) was recorded from the variety BRRI dhan29 containing Root Feed (T_4V_1) which was statistically similar with T_2V_1, T_2V_2, T_2V_3, T_4V_2 and T_4V_3 while shortest panicle (23.71 cm) was obtained from the variety BRRI dhan28 with the treatment combination of T_0V_2 (Table 4.15).

4.3.1.5 Filled grain panicle^{-1} of rice

4.3.1.5.1 Effect of NGF along with other recommended fertilizers on filled grain panicle^{-1} of rice

Number of filled grains panicle^{-1} was varied due to the effect of treatment of NGF along with other recommended fertilizers (Appendix VII and Figure 4.27). So, the maximum number of filled grains panicle^{-1} (154.90) was recorded in treatment T_2 which was statistically similar with T_4 treatment (150.90). On the other hand, the minimum number of filled grains panicle^{-1} (132.1) was produced from the treatment T_0 control. Similarly, Rashid *et al.* (2011) also found significant variation on the production of grains panicle^{-1} due to the effect of urea– nitrogen, cowdung, poultry manure and urban wastes produced the maximum number of filled grains panicle^{-1}. This was also supported by the findings of Hoshain (2010) who also found significant variation due to the effect of organic (cowdung) and inorganic (nitrogen) fertilizer where the highest number of grain panicle^{-1} was obtained from the combination of 6 t ha^{-1} cowdung + 120 kg N ha^{-1}.

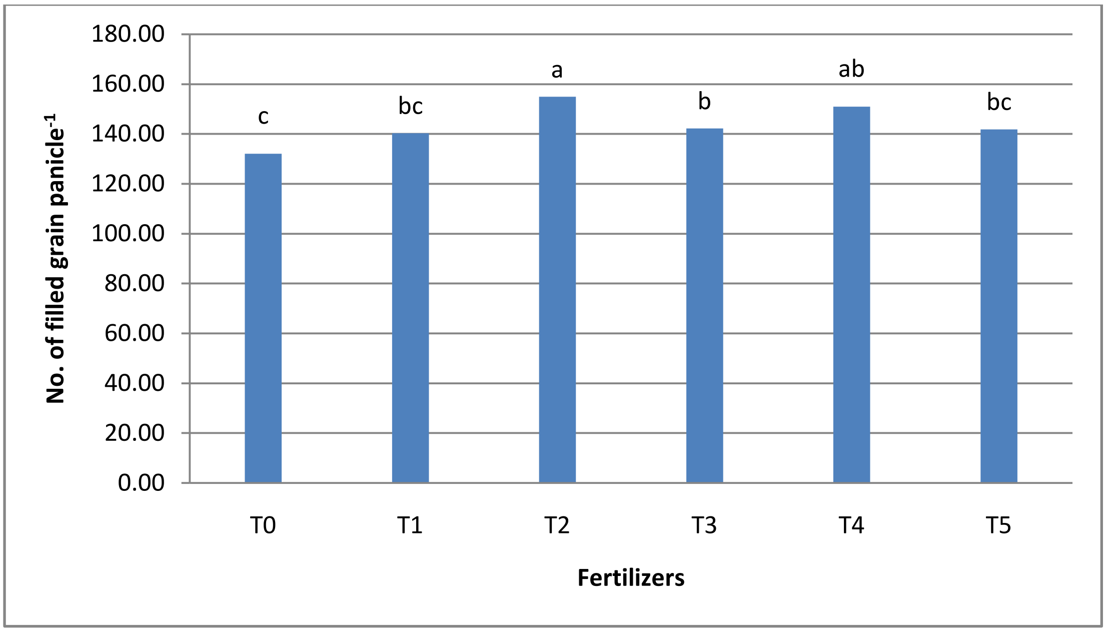

Figure 4.27 Effect of NGF along with other recommended fertilizers on filled grain panicle $^{-1}$ of rice

T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

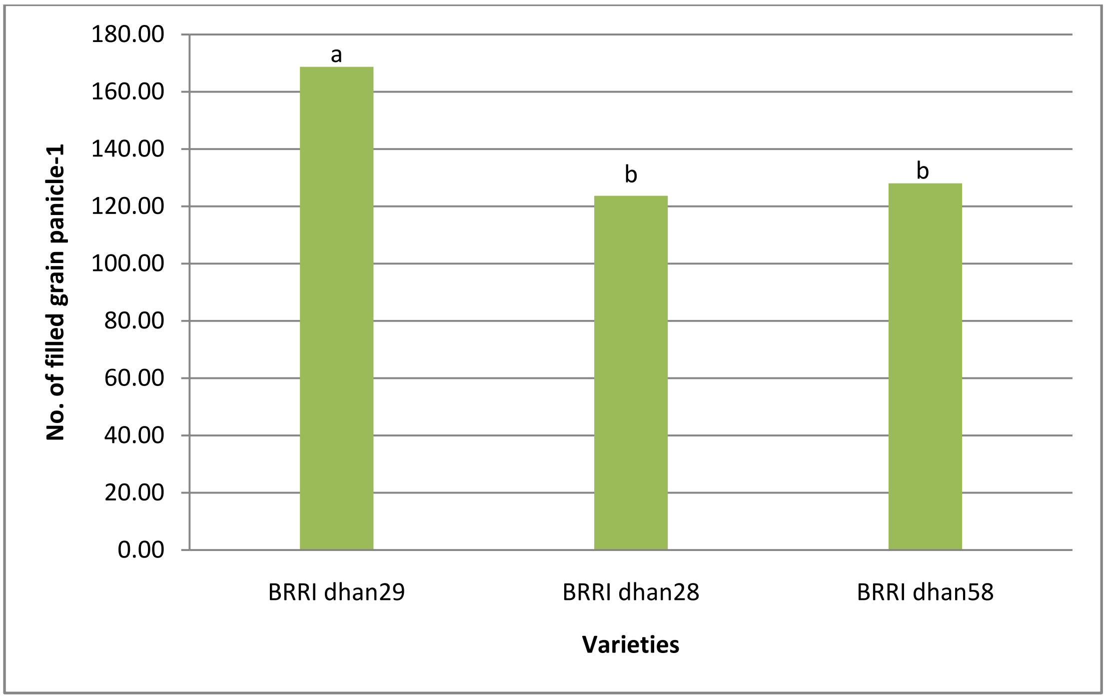

Figure 4.28 Effect of varieties on filled grain panicle $^{-1}$ of rice

4.3.1.5.2 Effect of variety on filled grain panicle^{-1} of rice

Number of filled grains panicle^{-1} was significantly influenced by the effect of variety (Appendix VII and Figure 28). The maximum number of filled grains panicle^{-1} (168.7) in the treatment V_1 (BRRI dhan29). The minimum number of filled grain panicle^{-1} (123.70) as found in the treatment V_2 which was statistically similar with V_3. Filled grains panicle^{-1} is the most important yield attribute, the increasing grains panicle^{-1} significantly increased the grain yield for any crops. These result also revealed that the different variety observed the variation in filled grains hill^{-1} due to their genetic makeup. Such the similar above findings of the present study was also found by Uddin *et al*. (2011) who reported the significant differences were found in filled grains panicle^{-1} while BRRI dhan 44 produced highest and Lalchicon produced the lowest. Similarly, Shiyam *et al*. (2014); Sarker *et al*. (2013); Islam *et al*. (2013); Mahamud *et al*. (2013) and many other scientist of the country and abroad also agreed the present findings.

4.3.1.5.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on filled grain panicle^{-1} of rice

Number of filled grains panicle^{-1} was influenced by the effect of combination of treatment and varieties (Appendix VII and Table 4.15). The number of filled grains panicle^{-1} significantly varied from 103.3 to 193.70 (Table 4.15). From the Table 4.15, it was found that the maximum number of filled grains panicle^{-1} was produced from the variety BRRI dhan29 receiving of Bio-forge along with other recommended fertilizers (T_2V_1) which was statistically similar to T_2V_2 and T_2V_3 treatment combination. On the other hand, the minimum number of filled grains panicle^{-1} (103.3) was obtained from the treatment combination of T_0V_2 (Table 4.15).

4.3.1.6 Unfilled grain panicle^{-1} of rice

4.3.1.6.1 Effect of NGF along with other recommended fertilizers on unfilled grain panicle^{-1} of rice

Number of unfilled grains panicle^{-1} was varied due to the effect of treatment of NGF along with other recommended fertilizers (Appendix VII and Table 4.13). So, the maximum number of unfilled grains panicle^{-1} (8.60) was recorded in treatment T_0. On the other hand, the minimum number of unfilled grains panicle^{-1} (5.71) was produced from the treatment T_2.

4.3.1.6.2 Effect of variety on unfilled grain panicle^{-1} of rice

Number of filled grains panicle^{-1} was significantly influenced by the effect of variety (Appendix VII and Table 4.14). The maximum number of unfilled grains panicle^{-1} (7.13) in the treatment V_2 (BRRI dhan28) which was statistically similar to treatment V_3. The minimum number of unfilled grain panicle^{-1} (5.57) as found in the treatment V_1 (BRRI Dhan29).

4.3.1.6.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on unfilled grain panicle^{-1} of rice

Number of unfilled grains panicle^{-1} was influenced by the effect of combination of treatment and varieties (Appendix VII and Table 4.15). The number of unfilled grains panicle^{-1} significantly varied from 6.03 to 10.23 (Table 4.15). From the Table 4.15, it was found that the maximum number of unfilled grains panicle^{-1} (10.23) was produced from the variety BRRI dhan28 with control treatment T_0

(T_0V_2) which was statistically similar to T_0V_1 and T_0V_3 treatment combination. On the other hand, the minimum number of unfilled grains panicle^{-1} (6.03) was obtained from the treatment combination of T_2V_1 which was statistically similar to all other combination except three control combinations.

4.3.1.7 Thousand grain weight of rice

4.3.1.7.1 Effect of NPK along with other recommended fertilizers on thousand grain weight

The different NGF along with other recommended fertilizers showed insignificant effect on 1000-grain weight (25.60 g) (Appendix VIII and Table 4.16). Among the treatments, maximum 1000-grain weight was found in T_1, T_3 and T_4 treatment. On the other hand, control treatment (T_0) produced the lowest (23.90 g) 1000-grain weight (Table 4.16). These result indicated that grain size increase insignificantly with the application of NGF along with other recommended fertilizers. The significant variation in 1000-grain weight were also found by Fakhrul *et al*., (2013) who also conducted their study with the application of inorganic (RDF) + organic (PM) manures where T_5 (50% RDCF + 4 ton PM ha^{-1}) showed the highest 1000 grain weight. The similar results were also obtained by Rashid *et al*. (2011) who studied on the effect of urea-nitrogen, cowdung, poultry manure and urban wastes where N @ 50 kg ha^{-1}+ PM @ 50 kg ha^{-1} produced the highest weight of 1000-grains (29.30 g) of BRRI dhan29..

4.3.1.7.2 Effect of variety on thousand grain weight of rice

The significant variation in 1000–grain weight might be due to genetic makeup of particular genotype and sink strength. The results were revealed that the variety BRRI dhan29 (28.6 g) had more efficient to produce larger sizes grain than BRRI dhan28 (23.2 g) and BRRI dhan54 (23.6) (Appendix VIII and Table 4.17). Ali *et* *al*. (2014) found similar result and they reported that 1000-grain weight differed significantly among the varieties, which was also supported by Hossain *et al*. (2008).

Shiyam *et al*. (2014); Islam *et al*. (2013); and many scientists of the home and abroad were also found significant variation in 1000-grain weight due to the variation in genetic makeup of the variety. The findings of the present study are also agreed to the findings of Oka *et al*. (2012); Alam *et al*. (2012).

4.3.1.7.3 Interaction effect of variety and next generation fertilizer along with NPK on thousand grain weight of rice

The effect of interaction significant varieties and NGF along with other recommended fertilizers was found in 1000-grain weight (Appendix VIII and Table 4.18). However, the maximum 1000-grain weight (30.00g) was found in the treatment combination of T_2V_1 which was statistically insignificant with the treatment combinations in T_2V_2, T_2V_3, T_4V_1, T_4V_2 and T_4V_3. On the other hand, BRRI dhan28 showed the lowest weight of 1000-grain (22.69 g) while it did not received any fertilizer levels (T_0) and it was very close with T_0V_1 and T_0V_3 treatment combinations.

4.3.1.8 Grain Yield of rice

4.3.1.8.1 Effect of NGF along with other recommended fertilizers on grain yield of rice

A significant variation was found for the character of grain yield of rice due to the effect of NGF along with other recommended fertilizers (Appendix VIII and Table 4.16). Among the treatments, Bio-forge along with other recommended fertilizers (T_2) produced significantly the highest grain yield (7.81 t ha^{-1}) which was statistically similar with T_4 treatment. The lowest yield of grain (2.53 t ha^{-1}) was found in the treatment T_0. This result was revealed that Bio-forge and Root feed along with other recommended fertilizers showed the highest grain yield which might be due to the more effective tillers $hill^{-1}$, longest panicle, more grains $panicle^{-1}$ and larger grain. The above findings indicated that the two treatments (T_2 and T_4) would be the ideal for getting the higher grain yield. Similarly, organic + inorganic fertilizer application on *bor*o rice were also conducted by Shaha (2014); Sarkar (2014); Liza *et al*. (2014); Hasan (2014); Islam *et al*. (2013) and many other researchers. All of them were found significant variation on grain yield due to the application of organic (cowdung) - inorganic (N) fertilizer. Shaha (2014) found highest grain yield (5.62 t ha^{-1}) in cowdung 7.5 t ha^{-1} + inorganic fertilizers; Sarkar (2014) found highest grain yield in 75% RD of inorganic fertilizers + 50% cowdung (5 t ha^{-1}); Hoshain (2010) found highest grain yield (6.13 t ha^{-1}) in combination of 6 t ha^{-1} cowdung + 120 kg N ha^{-1}.

4.3.1.8.2 Effect of variety on grain yield of rice

There was a significant difference between the varieties in grain yield of rice (Appendix VIII). Among the varieties, BRRI dhan29 (V_1) produced the highest grain yield (8.35 t ha^{-1}). The lowest grain yield was found in the varietal treatment V_2 (5.82 t ha^{-1}) (Table 4.17). The yield was higher in BRRI dhan 29 due to the production of taller plant, more effective tillers, longest panicle, more grains $panicle^{-1}$ as well as larger sizes grains. Ali *et al*. (2014); Shiyam *et al*. (2014) and many workers reported that the varieties which produced higher number of effective tillers $hill^{-1}$ and higher number of filled grains $panicle^{-1}$ also showed higher grain yield ha^{-1}. Similar results were also reported by Hossain *et al*. (2014a and 2014b); Islam *et al*. (2013); Mahmud *et al*. (2012) in rice. This variation in grain yield was also found due to their genetic difference between the varieties while Sohel *et al*. (2009) reported the same observation in his study.

4.3.1.8.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on grain yield of rice

Grain yield was significantly influenced by the interaction effect of varieties and the application of next generation fertilizer along with other recommended fertilizers (Appendix VIII and Table 4.18). From the Table 4.18, it was found that the grain yield was significantly varied from 2.75 to 8.61 t ha^{-1} while the treatment combination T_2V_1 (BRRI dhan29 receiving of that Bio-forge along with other recommended fertilizers) showed the highest grain yield (8.61 t ha^{-1}). BRRI dhan 58 showed the lowest grain yield (2.75 t ha^{-1}) while it was cultivated without fertilizers under treatment T_0. This result revealed that the growth of BRRI dhan 29 had highly efficient in Bio-forge along with other recommended fertilizers. Similarly, Sarkar (2014) found that the highest grain yield was found in BRRI dhan 34 coupled with 75% RD of inorganic fertilizers + 50% cowdung.

4.3.1.9 Straw yield of rice

4.3.1.9.1 Effect of NGF along with other recommended fertilizers on straw yield of rice

Straw yield was significantly influenced by the effect of NGF along with other recommended fertilizers (Appendix VIII and 4.16). Among the treatments, Bio-forge along with other recommended fertilizers produced significantly the highest yield of straw (7.87 t ha^{-1}) which was statistically similar with treatment T_4 (7.30 t ha^{-1}).

Table 4.16 Effect of NGF along with other recommended fertilizers on the thousand seed weight, grain yield, straw yield, biological yield and harvest index of rice

Fertilizer	1000 seed weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
T_0	23.90	2.53 c	6.31 c	8.84 c	28.61 c
T_1	25.60	6.45 b	7.51 b	13.96 cd	46.20 b
T_2	25.60	7.81 a	7.87 a	15.68 a	49.81 a
T_3	24.90	6.42 b	7.45 b	13.87 cd	46.29 ab
T_4	25.60	6.90 ab	7.30 ab	14.20 bc	48.59 ab
T_5	24.70	6.80 b	7.40 b	14.20 bc	47.88 ab
Level of Significance	**NS**	**	**	**	**

In a column, figures having similar letter (s) do not differ significantly

Here,
T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

Table 4.17 Effect of variety on the thousand seed weight, grain yield, straw yield, biological yield and harvest index of rice

Treatment	1000 seed weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
V_1	28.6 a	8.35 a	8.66 a	17.01 a	49.09 a
V_2	23.2 b	5.82 c	7.25 b	13.07 b	44.53 b
V_3	23.6 b	6.96 b	7.34 b	14.30 b	48.67 b
Level of Significance	**	**	**	**	**

In a column, figures having similar letter (s) do not differ significantly

Here
V_1 = BRRI dhan 29
V_2 = BRRI dhan 28
V_3 = BRRI dhan 58

Table 4.18 Effect of interaction of NGF along with other recommended fertilizers and varieties on the thousand seed weight, grain yield, straw yield, biological yield and harvest index of rice

Fertilizer x Variety	1000 seed weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (tha^{-1})	Harvest index (%)
T_0 x V_1	22.70 c	2.88 e-g	7.52 b-c	10.40 ef	27.69 e
T_0 x V_2	22.69 c	2.96 g	5.76 e	8.72 f	33.94 e
T_0 x V_3	22.71 c	2.75 h	5.66 e	8.41 f	32.70 e
T_1 x V_1	24.00 bc	6.58 d-f	6.81 cd	13.39 cd	49.14 b
T_1 x V_2	23.70 bc	6.31 d-g	7.51 b-d	13.82 cd	45.66 cd
T_1 x V_3	23.30 bc	7.38 b-f	7.51 b-d	14.89 bc	49.56 ab
T_2 x V_1	30.00 a	8.61 a	8.81a-c	17.42 ab	49.43 ab
T_2 x V_2	29.30 ab	8.01 bc	9.19 a	17.02 ab	47.06 bc
T_2 x V_3	29.90 ab	8.00 bc	8.49 de	16.49 ab	48.51 bc
T_3 x V_1	23.30 bc	7.46 b-e	8.53 a-c	17.02 ab	49.88 a
T_3 x V_2	24.31 bc	6.59 d-f	7.53 ab	14.12 cd	46.67 c
T_3 x V_3	24.40 bc	7.40 b-f	8.25 b-d	15.65 bc	47.28 bc
T_4 x V_1	29.30 ab	8.00 bc	9.30 a	17.69 a	46.24 bc
T_4 x V_2	29.00 ab	8.01 bc	7.59 a-c	15.69 bc	51.95 a
T_4 x V_3	28.30 ab	7.77 bc	7.78 b-d	15.55 bc	49.97 a
T_5 x V_1	24.10 bc	5.59 fg	8.59 a-c	16.66 ab	48.44 bc
T_5 x V_2	24.30 bc	6.88 c-f	8.32 a-c	15.20 bc	45.26 cd
T_5 x V_3	24.00 bc	6.98 c-f	7.35 cd	14.33 c	48.71 ab
Level of Significance	*	*	*	*	*

In a column, figures having similar letter (s) do not differ significantly

Here,
T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

V_1 = BRRI dhan 29
V_2 = BRRI dhan 28
V_3 = BRRI dhan 58

The lowest yield of straw (6.31 t ha^{-1}) was found in the treatment T_0. This result revealed that Bio-forge and Root feed showed the greater effect on straw yield which might be due to the higher plant height, effective tillers $hill^{-1}$ and longest panicle. Similar trend of the effect of organic (Cowdung) and inorganic (Urea) fertilizer on straw yield was also reported by Shaha (2014) who also conducted his study with the effect of organic + inorganic fertilizer. Similarly, Liza *et al*. (2014) also found that the treatment T_6 (50% RFD + residual effect of CD 2.5 t ha^{-1}, PM 1.5 t ha^{-1}, and Com. 2.5 t ha^{-1}) produced the highest straw yield (7.24 t ha^{-1}). Hasan (2014); Islam *et al*. (2013); Rahman *et al* (2009) and other scientists also found similar results with the present study where the entire researcher conducted their studied by the effect of organic + inorganic fertilizer.

4.3.1.9.2 Effect of variety on straw yield of rice

There was a significant difference between the varieties in respect of straw yield (Appendix VIII and Table 4.17). Between the varieties, BRRI dhan29 produced the highest straw yield (8.66 tha^{-1}) than other two varieties BRRI dhan28 (7.25 tha^{-1}) and BRRI dhan54 (7.34 tha^{-1}) (Table 4.17). The straw yield was higher in BRRI dhan29 and than that of others two might be attributed to the production of taller plant, more effective tillers and longest panicle. Uddin *et al*. (2011) reported that the BRRI dhan44 produced significantly higher straw yield against the lowest by Lalchicon. This might be due to varietal differences and also the variation in plant height. Similarly, the findings of the present was also agreed by the researchers of Mahamud *et al*. (2013); Panwar *et al*. (2012); Mia and Shamsuddin (2011).

4.3.1.9.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on straw yield of rice

Straw yield was significantly influenced by the interaction effect of varieties and the application of NGF along with other recommended fertilizers (Appendix II and Table 4.18). The treatment T_4V_1 showed the highest straw yield (9.30 t ha^{-1}) which was very close with the treatment combination T_2V_2 (9.19 t ha^{-1}). BRRI dhan58 showed the lowest straw yield (5.66 tha^{-1}) under T_0 treatment which was statistically similar with T_0V_2 treatment combination. This result revealed that the growth of BRRI dhan29 had highly efficient in Root feed along with other recommended fertilizers for getting the tallest plant, maximum effective tillers $hill^{-1}$ and longest panicle which resulting the higher straw yield.

4.3.1.10 Biological yield of rice

4.3.1.10.1 Effect of NGF along with other recommended fertilizers on biological yield of rice

Biological yield was significantly influenced by the effect of NGF along with other recommended fertilizers (Appendix VIII and 4.16). Among the treatments, Bio-forge along with other recommended fertilizers produced significantly the highest biological yield (15.68 t ha^{-1}). The lowest biological yield (10.84 t ha^{-1}) was found in the treatment T_0.

4.3.1.10.2 Effect of variety on biological yield of rice

There was a significant difference between the varieties in respect of biological yield (Appendix VIII and Table 4.17). Between the varieties, BRRI dhan29 produced the higher biological yield (17.01 t ha^{-1}) than other two varieties BRRI dhan28 and BRRI dhan54 (13.07 and 14.30 tha^{-1}, respectively (Table 4.17). The biological yield was higher in BRRI dhan29 and that of others two might be attributed to the production of taller plant, more effective tillers and longest panicle and grain yield.

4.3.1.10.3 Interaction effect of variety and next generation fertilizer along with other recommended fertilizers on biological yield of rice

Biological yield was significantly influenced by the interaction effect of varieties and the application of NGF along with other recommended fertilizers (Appendix II and Table 4.18). The treatment T_4V_1 showed the highest biological yield (17.69 t ha^{-1}). BRRI dhan58 showed the lowest biological yield (8.41tha^{-1}) under T_0 treatment which was statistically similar with T_0V_2 treatment combination. This result revealed that the growth of BRRI dhan29 had highly efficient in Root feed along with other recommended fertilizers for getting the tallest plant, maximum effective tillers $hill^{-1}$, longest panicle and grain yield which resulting the higher biological yield.

4.3.1.11 Harvest Index of rice

4.3.1.11.1 Effect of NGF other recommended fertilizers on harvest index of rice

A significant variation was found due to different treatment of NGF along with other recommended fertilizers regarding harvest index (Appendix II and Table 4.16). Table 4.16 shows that the highest harvest index (49.81%) was recorded in T_2 treatment having Bio-forge along with other recommended fertilizers while it was statistically similar to T_3 (46.29%), T_4 (48.59%) and T_5 (47.88%) treatments. On the other hand, control treatment T_0 showed the lowest harvest index (28.61%).

4.3.1.11.2 Effect of variety on harvest index of rice

Harvest index (HI) was very significant due to the effect of varieties (Appendix VIII and Table 4.17). However, the ranges of HI were 44.53% to 49.09%. The highest harvest index (49.09%) was found in the varietal treatment V_1 and the lowest harvest index (44.53%) found in V_2 treatment which was statistical similar with V_3 treatment. Such variation in genetic makeup of the varieties regarding HI were also found by Yao *et al*. (2012); Sritharan and Vijayalakshmi (2012); Islam (2011); Baset Mia and Shamsuddin (2011) any another many scientist.

4.3.1.11.3 Interaction effect of variety and next generation fertilizer other recommended fertilizers on harvest index of rice

Harvest index (HI) was very significant due to the effect of treatment combination of varieties and NGF along with other recommended fertilizers (Appendix VIII and Table 4.18). However, the ranges of HI were 27.69% to 51.95%. The highest harvest index (51.95%) was found in the treatment combination of T_4V_2 which was statistically similar with treatment combinations of T_4V_3, T_1V_3 and T_2V_1. The lowest harvest index (27.69%) found in the treatment combination of T_0V_1 which was statistically similar with the treatment combination of T_0V_2 and T_0V_3.

4.3.2 Chemical properties in postharvest soil of rice cop field

4.3.2.1 Effect of NGF along with other recommended fertilizers on soil chemical properties in postharvest soil of rice field

Soil pH

There was no significance change in pH of post harvest soil of rice experiment field due to application of next generation fertilizers along with other recommended fertilizers where pH varied from 6.89 to 7.02 (Table 4.19) and compare to initial soil pH 6.8 (Table 3.2).

Soil Organic Carbon

There was also no significant change in soil organic carbon (SOC) of post harvest soil of rice field due to effect of next generation fertilizers along with other recommended fertilizers where SOC varied from 0.73 to 0.77 (Table 4.19) and compare to initial soil 0.68 (Table 4.19).

Soil Nutrient NPKS

Total N content in post harvest soil of rice showed significant variation due to the effect of NGF along with other recommended fertilizers where N content varied from 0.045% to 0.073 % (Table 4.19 and Appendix IX). The highest total N content (0.073 %) was found in the treatment of T_4 which was statistically similar with treatment of T_5 and T_2. The lowest total N content (0.045%) was found in the treatment of T_3.

Available P content in post harvest soil of rice crop field showed significant variation due to application of NGF along with other recommended fertilizers where P content varied from 16.09 ppm to 19.60 ppm (Table 4.90 and Appendix IX). The highest P content 19.60 ppm was found in the treatment of T_4 which was statistically similar with treatment T_2, T_3 and T_0. The lowest P content in post harvest soil 16.09 ppm was found in treatment of T_1.

Exchangeable K content in post harvest soil showed insignificant variation due to effect of NGF along with other recommended fertilizers where K content varied 0.160 to 0.171 meq 100^{-1}g (Table 4.19 and Appendix IX).

Available S content in post harvest soil of rice field showed significant variation due to application of NGF along with other recommended fertilizers where S content varied from 8.23 ppm to 12.41 ppm (Table 4.10 and Appendix V). The highest S content 12.41 ppm was found in the treatment of T_2 which was statistically similar with $T_{0,}$ T_3 and T_4. The lowest S content in post harvest soil 8.23 ppm was found in treatment of T_5 which was statistically similar to T_1 treatment.

From the result of Rongting *et al.* (2017) conducted pot experiment, the liquid organic fertilizers significantly promoted root and aboveground growth of chrysanthemum by 10.2–77.8% and 10.7–33.3%, respectively, compared with the chemical fertilizer. The order of growth promotion was: L1 (shrimp extracts) > L2 (plant decomposition) > L4 (seaweed extracts)/L5 (fish extracts) > L3 (vermicompost). The shrimp extract treatment significantly increased the nutrient contents and altered the soil's functional microbial community at the rhizospheric level compared with the chemical fertilizer treatment.

Akhila *e. al.* 2017 conducted an experiment with foliar application of different levels of seaweed extract and enriched banana psuedostem sap on different varieties of green gram (*Vigna radiata*) and result was revealed that non-significant effect on all the soil property tested due to liquid fertilizer except available N.

4.3.2.2 Effect of variety on soil chemical properties in postharvest soil of rice field

pH in postharvest soil showed no significant variation due to the effect of varieties. Soil pH was varied from 6.91 to 6.99 (Appendix IX and Table 4.20).

Soil organic carbon in postharvest soil showed significant variation due to effect of varieties. Soil organic carbon varied from 0.74 to 0.79 %.

Total N content in postharvest soil showed significant variation due to effect of varieties. Total N content was varied from 0.050 to 0.069%.

Available P content, exchangeable K and available S content in post harvest soil showed insignificant variation due to the effect of varieties (Appendix IX and Table 4.20) where available P content varied (17.18 to 18.48 ppm), exchangeable K content varied (0.165 to 0.169 meq 100^{-1}g) and available S content varied (10.00 to 10.47 ppm)

4.3.2.3 Interaction effect of treatments and varieties on soil chemical properties in postharvest soil of rice field

Analysis of variance data of the Appendix IX and Table 4.21 revealed that there was no significant variation in soil pH, organic carbon and exchangeable K in postharvest soil due to the effect of interaction of NGF along with other recommended fertilizers and varieties in soil of post harvest soil of rice field. From Table 4.12, the results were found that pH in soil varied (6.73 to 7.20), organic carbon (0.69 % to 0.80%), and exchangeable K varied (0.156 to 0.178 meq100^{-1}g).

The maximum level of total N content (0.093 %) in post harvest soil of rice field was found from the treatment combination of T_5V_2. The minimum level of total N found from the interaction of T_0V_1 (0.040 %) which was statistically similar with T_0V_2 and T_0V_3.

Table 4.19 Effect of NGF with other recommended fertilizers on chemical properties of post harvested soil of rice crop field

Fertilizer	pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Available K ($meq100^{-1}g$)	Available S (ppm)
T_0	6.90	0.73	0.054 bc	17.75 ab	0.160	10.57 ab
T_1	6.89	0.74	0.051 bc	16.09 b	0.164	8.913 b
T_2	6.99	0.74	0.062 ab	17.46 ab	0.171	12.41 a
T_3	6.94	0.75	0.045 c	18.31 ab	0.165	10.49 ab
T_4	6.97	0.77	0.073 a	19.60 a	0.168	10.82 ab
T_5	7.02	0.77	0.070 a	19.07 ab	0.171	8.232 b
Level of Significance	**NS**	**NS**	*	*	**NS**	*

In column, figures having similar letter (s) do not differ significantly
Here,
T_0 = Control (No fertilizer)
T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}
T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2
T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

Table 4.20 Effect of variety on chemical properties of post harvested soil of rice crop field

Varieties	pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Available K ($meq100^{-1}g$)	Available S (ppm)
V_1	6.96	0.74 b	0.050 b	17.18	0.169	10.47
V_2	6.99	0.79 a	0.069 a	18.48	0.165	10.24
V_3	6.91	0.72 b	0.058 b	18.48	0.165	10.00
Level of Significance	**NS**	**	**	**NS**	**NS**	**NS**

In a column, figures having similar letter (s) do not differ significantly
Here,
V_1 = BRRI dhan29
V_2 = BRRI dhan28
V_3 = BRRI dhan58

Table 4.21 Effect of interaction of fertilizers and variety on chemical properties of post harvested soil of rice crop field

Interaction Treatment x Varieties	pH	Organic carbon (%)	Total N (%)	Available P (ppm)	Available K ($meq100^{-1}g$)	Available S (ppm)
T_0 x V_1	7.07	0.72	0.040 d	13.75 c	0.188	6.973 c
T_0 x V_2	6.90	0.77	0.087 d	15.75 b-c	0.159	7.593 bc
T_0 x V_3	6.73	0.69	0.043 d	15.10 bc	0.168	9.370 a-c
T_1 x V_1	6.80	0.74	0.055 cd	17.78 a-c	0.169	12.20 ab
T_1 x V_2	6.93	0.79	0.055 cd	18.79 a-c	0.168	11.70 a-c
T_1 x V_3	6.93	0.69	0.056 cd	20.36 ab	0.156	8.070 a-c
T_2 x V_1	6.97	0.74	0.050 cd	18.90 abc	0.178	12.68 a
T_2 x V_2	7.20	0.79	0.075 a-c	23.20 a	0.168	12.92 a
T_2 x V_3	6.80	0.69	0.062 b-d	18.24 a-c	0.168	11.64 a-c
T_3 x V_1	6.90	0.74	0.055 cd	19.01 a-c	0.159	10.80 a-c
T_3 x V_2	6.93	0.79	0.05 cd	16.13 bc	0.168	11.32 a-c
T_3 x V_3	7.00	0.71	0.046 cd	19.81 a-c	0.168	9.340 a-c
T_4 x V_1	6.97	0.77	0.088 cd	18.53 a-c	0.168	11.51 a-c
T_4 x V_2	7.03	0.78	0.088 ab	17.15 a-c	0.168	10.57 a-c
T_4 x V_3	6.90	0.76	0.068 a-d	23.12 a	0.168	10.37 a-c
T_5 x V_1	7.03	0.72	0.06 b-d	15.15 bc	0.158	8.687 a-c
T_5 x V_2	6.93	0.80	0.093 a	15.24 bc	0.159	8.417 a-c
T_5 x V_3	7.10	0.79	0.065 a-d	18.85 a-c	0.164	10.13 a-c
Level of Significance	**NS**	**NS**	*****	*****	**NS**	*****

In a column, figures having similar letter (s) do not differ significantly

Here,

T_0 = Control (No fertilizer)

T_1 = Recommended N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}

T_2 = Bio-forge (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_3 = Wuxal Super (5.00 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_4 = Root Feed (1.20 kg ha^{-1}) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

T_5 = Nitro Plus (1.20 $L.ha^{-1}$) + Recommended N_{140} P_{20} K_{60} S_{18} Zn_2

V_1 = BRRI dhan29
V_2 = BRRI dhan28
V_3 = BRRI dhan58

The maximum level of available P content (23.20 ppm) in post harvest soil of rice crop field was found from the treatment combination of T_2V_2. The minimum level of available P found from the treatment combination of T_0V_1 (13.75 ppm).

The maximum level of available S content (12.92 ppm) in post harvest soil of tomato field was found from the treatment combination of T_2V2 which was statistically similar to treatment combination T_2V_1 (12.68 ppm). The minimum level of available S found from the treatment combination of T_0V_1 (6.973 ppm).

CHAPTER V

SUMMARY AND CONCLUSION

Bangladesh is agriculture based country. The main purpose of agriculture is to provide food for the increasing population. Fertilizer is the main inputs for increasing crop yields. Before 1950, farmers applied first generation fertilizers such as cow dung, bone meal, farmyard manure (FYM), mustard oil cake and fish meal. Then second generation inorganic fertilizer started to use with the import of ammonium sulphate, phosphates and muriate of potash for "grow more food to meet the country's food shortage". Fertilizer consumption began to increase rapidly with the introduction of HYV rice. Now-a-days food security has become a major concern in world wide. Double food production is needed in the world to feed for increasing population. The most significant issue climate change also severe threat in agricultural sector and food security and resulting crop yields may be reduced up to 30 per cent. Moreover, agricultural land per day goes to urbanization and homestead area expansion in rural area. For this reason the net cropped area of the country is decreasing on the other hand the cropping intensity is increasing over times. This result affected in soil nutrient losing which was reflected in more nutrient deficiencies exhibited by the crops. The soil fertility is dynamic. It changes depending on intensive use of the land; nutrients are added and removed through crops. The farmers of Bangladesh could not harvest additional yield advantage of crops due to lack of knowledge in using of next generation fertilizers along with other recommended fertilizers. Even though some farmers are following recommended fertilizer dose under IPNS basis but still some hidden hunger is remaining in plants. As a result the farmer are not getting desired yield of the crops. In developed countries, they are using Next Generation Fertilizer along with inorganic fertilizer done under INM or IPNS basis and increasing crops yield as well as keeping soil health & environmental sustainable. *Next generation fertilizer* means nutritional mixed fertilizers applied by spraying to provide total nutritional requirements for crops / plants without compromising on productivity while protecting ecology and also address "*First Generation*" & "*Second Generation*" fertilizer.

Considering the above facts, objectives of the research study were (i) to study the effect of available Next Generation Fertilizers along with other recommended fertilizers on growth and yield of different crops (maize, tomato and rice); (ii) to observe the residual effect of Next Generation Fertilizers on chemical properties of post harvested soils; and (iii) to evaluate the potentiality of existing Next Generation Fertilizer technologies for better crop growth and maximizing yield.

To fulfill these objectives, the investigation was carried out with three separate experiments during the period from March 2014 to June 2015 at the field experimental plot of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh; Summary of the research works is presented experiment wise as follows:

Under the first experiment, the effect of next generation fertilizers along with other recommended fertilizers on growth, yield attributes and kernel yield of maize and the residual effect of next generation fertilizers on the chemical properties of post harvested soils were investigated. In this experiment, eight treatments including control *viz.* T_0 = Control (No fertilizer), T_1 = recommended dose N_{250} P_{50} K_{100} S_{25} Zn_2 B_1, T_2 = American NPK + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1, T_3 = Bio-forge + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 ,T_4 = Wuxal + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1, $\mathbf{T_5}$ = Peak + $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$, T_6 = Root Feed + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 & T_7 = Nitro Plus + N_{250} P_{50} K_{100} S_{25} Zn_2 B_1 and three maize varieties namely V_1 = BARI Hybrid Bhutta-5 , V_2 = BARI Hybrid Bhutta-6 & V_3 = BARI Hybrid Bhutta-9.

Considering growth, yield attributes and kernel yield of maize, due to the effect of interaction of treatment NPK with next generation fertilizer and variety where plant height at harvest was varied significantly due to the interaction effect of next generation fertilizers with other recommended fertilizers and maize varieties. Plant height was varied from 127.0 cm to 157.8 cm. Cob numbers at harvest showed insignificant variation due to the effect of interaction of treatment combination of next generation fertilizer with other recommended fertilizers and variety. Cob length and weight at harvest varied significantly due to the effect of interaction of treatment next generation fertilizer and variety where cob length varied from 20.20 cm to 23.67 cm. and cob weight varied from 91.25 to 153.75 g. 100- kernel weight at harvest statistically significant due to the effect of interaction of treatment next generation fertilizer along with other recommended fertilizers and variety where 100- kernel weight varied from 24.59 to 28.05 g (Table 4.3).

Kernel yield of maize at harvest significantly varied due to the effect of interaction effect of treatment next generation fertilizer with other recommended fertilizers and variety where kernel yield varied from 1.97 to 5.95 t ha^{-1} (Table 4.3). The highest kernel yield of 5.95 t ha^{-1} was found from the variety BARI Hybrid Bhutta-9 receiving Bio-forge along with other recommended fertilizers of (T_3V_3) which was statistically similar with T_6V_3 treatment combination. The lowest kernel yield of 1.97 t ha^{-1} was found from the variety BARI Hybrid Bhutta-5 which did not receive any levels of next generation fertilizer along with other recommended fertilizers (T_0V_1) which was statistically similar with T_0V_2 and T_0V_3 treatment combinations.

Considering soil chemical properties in postharvest soil of maize field, there was no significant variation for soil pH, organic carbon and nutrient content except available S in postharvest soil due to the effect of interaction of NGF along with other recommended fertilizers and varieties in soil of post harvest soil of maize (Table 4.6) The maximum level of available S content (18.99 ppm) in post harvest soil was found from the treatment combination of T_3V_1 which was statistically similar to T_6V_1 (15.51 ppm). The minimum level of available S found from the interaction of T_0V_1 (9.64 ppm)

Under the second studies, the effect of next generation fertilizers along with other recommended fertilizers on growth and yield attributes of tomato, and the residual effect of next generation fertilizers on the chemical properties of post harvested soils were evaluated. In this experiment, six treatments including control *viz.* T_0 = Control (No fertilizer), T_1 = recommended dose $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ $kgha^{-1}$, T_2 = Bio-forge + $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$, T_3 =Wuxal Super + $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$, T_4 = Root Feed + $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$, T_5 = Nitro Plus + $N_{140}P_{35}K_{75}S_{15}Zn_2B_1$ and three tomato varieties namely V_1 = BARI Tomato-2, V_2 = BARI Tomato-14 & V_3 = BARI Tomato-15.

Considering the growth, yield attributes and fruit yield of tomato, plant height of tomato was significantly varied due to the effect of interaction of variety and NGF along with other recommended fertilizers where plant height varied from 72.77 cm to 100.50cm. Number of clusters per plant was significantly varied due to the effect of interaction of variety and NGF with other recommended fertilizers where number of cluster varied from 6.44 to 8.89. Fruits per cluster were significant due to the effect of interaction of variety and NGF with other recommended fertilizers where fruits varied from 2.77 to 5.23. There was a significant variation found in fruits per plant due to the effect of interaction of variety and NGF along with other recommended fertilizers where fruits per plant were varied from 19.67 to 45.33 (Table 4.9). The maximum number of fruits per plant (45.33) was produced from the variety BARI Tomato-14 receiving of Bio-forge along with other recommended fertilizers (T_2V_2) which was statistically similar 39.80 and 39.67 with the combination of T_2V_3 and T_4V_2, respectively.

There was a significant variation found in fruit yield of tomato due to the effect of interaction of variety and NGF along with other recommended fertilizers where fruit yield varied from 40.00 to 114.43 tha^{-1} (Table 4.9). The highest fruits yield (114.43) was produced from the treatment combination T_2V_2 (BARI Tomato-14 receiving of Bio-forge along with other recommended fertilizers).

Considering the soil chemical properties of postharvest soil of tomato field, the results revealed that there was no significant variation in soil pH, organic carbon and exchangeable K in postharvest soil due to the interaction effect of NGF along with other recommended fertilizers and varieties after harvest of tomato. The results also revealed that there was a significant variation in total N content available P and available S in postharvest soil due to the interaction effect of NGF along with other recommended fertilizers and varieties after harvest of tomato. The maximum level of total N content (0.095 %) in post harvest soil was found under the treatment combination of T_4V_2. The maximum level of available P content (26.04 ppm) in post harvest soil of tomato crop field was found from the treatment combination of T_2V_2. The maximum level of available S content (17.19 ppm) in post harvest soil of tomato field was found from the treatment combination of T_2V_1 which was statistically similar to treatment combination of T_4V_1 (15.29 ppm), T_5V_2 (15.44 ppm) and T_5V_3 (16.18 ppm).

Under the third studies, the effect of next generation fertilizers along with other recommended fertilizers on growth and yield attributes of rice, and the residual effect of next generation fertilizers on the chemical properties of post harvested soils were evaluated. In this experiment, six treatments including control *viz* T_0 = Control (No fertilizer), T_1 = recommended dose N_{140} P_{20} K_{60} S_{18} Zn_2 kg ha^{-1}, T_2 = Bio-forge + N_{140} P_{20} K_{60} S_{18} Zn_2, T_3 = Wuxal Super + N_{140} P_{20} K_{60} S_{18} Zn_2, T_4 = Root Feed + N_{140} P_{20} K_{60} S_{18} Zn_2, T_5 = Nitro Plus + N_{140} P_{20} K_{60} S_{18} Zn_2 and three rice varieties namely V_1 = BRRI dhan29, V_2 = BRRI dhan28 & V_3 = BRRI dhan58.

Under evaluation of the growth yield attributes and grain yield of rice, plant height at harvest varied significantly due to the effect of interaction of variety and NGF along with other recommended fertilizers where plant height varied significantly from 80.63 cm to 101.70 cm (Table 4.15).

The effect of interaction between treatment and varieties was significant in respect of number of effective tillers $hill^{-1}$. The significant variation was found that the number of effective tillers varied from 10.00 to 19.67 where the maximum number of effective tillers $hill^{-1}$ (19.67) was produced from the variety BRRI dhan29 receiving of Bio-forge along with other recommended fertilizers which was statistically insignificant with T_2V_2. Also significant variation was found in number of non-effective tillers $hill^{-1}$. Significance variation was found in panicle length of yield character due to treatment combination where length of panicle varied from 23.71 to 26.96 cm. The longest panicle (26.96 cm) was recorded from the variety BRRI dhan29 containing Root Feed (T_4V_1) which was statistically similar with T_2V_1, T_2V_2, T_2V_3, T_4V_2 and T_4V_3 while shortest panicle (23.71 cm) was obtained from the variety BRRI dhan28 with the treatment combination of T_0V_2 (Table 4.15).

Number of filled grains $panicle^{-1}$ was influenced by the effect of combination of treatment and varieties (Table 4.15). The number of filled grains $panicle^{-1}$ significantly varied from 103.3 to 193.70. It was found that the maximum number of filled grains $panicle^{-1}$ was produced from the variety BRRI dhan29 receiving of Bio-forge along with other recommended fertilizers (T_2V_1) which was statistically similar to T_2V_2 and T_2V_3 treatment combination.

The effect of interaction significant varieties and NGF along with other recommended fertilizers was found in 1000-grain weight (Table 4.18). However, the maximum 1000-grain weight (30.00g) was found in the treatment combination of T_2V_1 which was statistically insignificant with the treatment combinations in T_2V_2, T_2V_3, T_4V_1, T_4V_2 and T_4V_3.

Grain yield was significantly influenced by the interaction effect of varieties and the application of next generation fertilizer along with other recommended fertilizers (Table 4.18). The grain yield was significantly varied from 2.75 to 8.61 t ha^{-1} while the treatment combination T_2V_1 (BRRI dhan29 receiving of that Bio-forge along with other recommended fertilizers) showed the highest grain yield (8.61 t ha^{-1}). BRRI dhan 58 showed the lowest grain yield (2.75 t ha^{-1}) while it was cultivated without fertilizers under treatment T_0. This result revealed that the growth of BRRI dhan29 had highly efficient in Bio-forge along with other recommended fertilizers.

Straw yield was significantly influenced by the interaction effect of varieties and the application of NGF along with other recommended fertilizers. Biological yield was significantly influenced by the interaction effect of varieties and the application of NGF along with other recommended fertilizers (Table 4.18). The treatment combination T_4V_1 showed the highest biological yield (17.30 t ha^{-1}).

Harvest Index (HI) was very significant due to the effect of treatment combination of varieties and NGF along with other recommended fertilizers (Table 4.18). However, the ranges of HI were 27.69% to 51.95%. The highest harvest index (51.95%) was found in the treatment combination of T_4V_2 (Root feed and BRRI dhan28) which was statistically similar with treatment combinations of T_4V_3, T_1V_3 and T_2V_1.

Considering the soil chemical properties of postharvest soil of rice field, the results were revealed that no significant variation in soil pH, organic carbon and exchangeable K in postharvest soil due to the effect of interaction of NGF along with other recommended fertilizers and varieties in soil of post harvest soil of rice field (Table 4.21). The results also showed that significant variation in total N content, available P content and S content in postharvest soil due to the effect of interaction of NGF along with other recommended fertilizers and varieties in soil of post harvest soil of rice field. The maximum level of total N content (0.093%) in post harvest soil of rice field was found from the treatment combination of T_5V_2. The minimum level of total N found from the interaction of T_0V_1 (0.040 %) which was statistically similar with T_0V_2 and T_0V_3. The maximum level of available P content (23.20 ppm) in post harvest soil of rice crop field was found from the treatment combination of T_2V_2. The minimum level of available P found from the treatment combination of T_0V_1 (13.75 ppm). The maximum level of available S content (12.92 ppm) in post harvest soil of tomato field was found from the treatment combination of T_2V2 which was statistically similar to treatment combination T_2V_1 (12.68 ppm). The minimum level of available S found from the treatment combination of T_0V_1 (6.973 ppm).

From the study of three experiments finally it can be concluded that the next generation fertilizers along with other recommended fertilizers had varying degree of integrated effects on crops viz. maize, tomato and rice. In case of maize crop, the interaction of fertilizers and variety, among the next generation fertilizers, T_3 = Bio-forge (1.20 L ha^{-1}) + recommended dose $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$ performed the best compared to other fertilizer treatments of the study in aspect of growth and yield contributing characters mainly plant height, cob length, cob weight, 100-kernel weight and kernel yield (5.95 tha^{-1}) and similar result showed by T_6 = Root Feed (1.20 kg ha^{-1}) + recommended dose $N_{250}P_{50}K_{100}S_{25}Zn_2B_1$, produce 5.12 tha^{-1} kernel yield. Among the varieties BARI Hybrid Bhutta-9 performed the best compared to other two varietal treatments of the study in aspect of yield contributing characters, kernel yield and nutrient management of maize.

In case of tomato crop, the interaction of fertilizers and variety, among the next generation fertilizers, T_2 = Bio-forge (1.20 L ha^{-1}) + recommended dose N_{140} P_{35} K_{75} S_{15} Zn_2 B_1 kg ha^{-1} performed the best compared to other fertilizer treatments of the study in aspect of growth and yield contributing characters mainly plant height, flower cluster $plant^{-1}$, number of fruits $cluster^{-1}$, fruit $plant^{-1}$ and fruits yield (114.43 tha^{-1}). Among the varieties BARI Tomato-14 performed the best compared to other two varieties of the study in aspect of yield contributing characters, fruit yield and nutrient management of tomato.

In case of rice crop, the interaction of fertilizers and variety, among the next generation fertilizers, T_2 = Bio-forge (1.20 L.ha^{-1}) + recommended dose N_{140} P_{20} K_{60} S_{18} Zn_2 performed the best compared to other fertilizers treatments of the study in aspect of growth and yield contributing characters mainly plant height, effective tiller $hill^{-1}$, panicle length, filled grain $panicle^{-1}$, 1000 seed weight, harvest index and grain yield (8.61 tha^{-1}). Among the varieties BRRI dhan29 performed the best compare to other treatments of the study in aspect of yield contributing characters and yield of rice.

From above discussion, next generation fertilizers viz. Bio-forge and Root feed would be ideal for better crop growth and yield.

CHAPTER VI

REFERENCS

Ahmed, R. (1987). Structure, dynamics and related policy issues of fertilizer subsidy in Bangladesh. pp. 281-380.

Akhila, K., Kaswala, A., Priyanka, R. and Dubey, P.K. (2017). Effect of liquid fertilizers on nutrient uptake and soil properties of the green gram (*Vigna radiata*) crop under organic farming. *The Pharma Innov. Int. J.* **6** (11): 224-228.

Alam, M.S., Baki, M.A., Sultana, M.S., Ali, K.J. and Islam, M.S. (2012). Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant *aman* rice. *Int. J. Agric. Agric Res.* **2**(12): 10-15.

Ali, H.J., Khalid, N.A. and Kadhum, M.H. (2016). Effect of spraying extracts concentration of three organic fertilizers on growth and yield of maize (*Zea mays* L.). *Mesopotamia Env. J.* Special Issue **B**: 131-137.

Ali, M.P., Reza, S., Yousef, A. and Babak, S. (2012). Comparison of the effect of liquid humic fertilizers on yield of maize genotypes in Ardabil region. African J. Biotech. **11**(21): 4810-4814.

Amali, P.E. and Namo, O.A.T. (2015). Effect of time of fertilizer application on growth and yield of maize (*Zea mays* L.) in Jos - plateau environment. *Global J. Agric Sci*.**14** (1): 1-9.

Amin, M.E.M.H. (2011). Effect of different nitrogen sources on growth, yield and quality of fodder maize (*Zea mays* L.). J. Saudi Society Agric. Sci. **10** (1): 17-23.

Anonymous (2007). The Daily Amader Shomoy, Nov. 17, 2007. p.3.

Anonymous. (1998a). Annual Report for 1997-98. Technical report on hybrid rice Aalok 6201. Agronomy Division, Bangladesh Institute of Nuclear Agriculture, Mymensingh. pp. 1-16.

Anonymous. (1998b). Technical report on hybrid rice Aalok 6201. Department of Soil Science, BAU, Mymensingh. pp. 1-7.

Anonymous. (2004). Workshop on testing of rice knowledge bank. The Bangladesh Observer. [Online available at: www.bangladeshobserveronline.com/new / 2004 / 07/18/national.htm].

Asghar, A., Ali A., Syed, W.H., Asif, M., Khaliq, T. and Abid, A.A. (2010). Growth and yield of maize (*Zea mays L.*) cultivars affected by NPK application in different proportion. *Pakistan J. Sci.* **62**(4): 111-114.

Baset Mia, M.A. (2017). Digital herbarium of crop plant. Department of Crop Botany, Bangabandhu Sheikh Mujibur Rahman Agricultural University. Salna, Gazipur. http://dhcrop.bsmrau.net.

Baset Mia, M.A. and Shamsuddin, Z.H. (2011). Physio–morphological appraisal of aromatic fine rice (*Oryza sativa* L.) in relation to yield potential. *Int. J. Bot.* **7**(3): 223-229.

Bhuiyan, N.I. (1998). Soil research in Bangladesh: Past, Present and Future. In: proc: Soil Research and Education in Bangladesh. BAU, Mymenshing. pp. 6-11.

Black, C.A., Evans, D.D., White, J.L., Ensminger, L.E., Clark, F.E. and Dinauer, R. C. (eds.). (1965). Methods of soil analysis. Am. Soc. Agron. Monogr . No. 9, Madison. p. 1572 (in 2 parts).

Bremner, J.M. and Mulvaney, C.S. (1982). Nitrogen–Total. In methods of soil Analysis Part 2. Edited by A.L. Page, R.H. Miller and D.R. Keeney. pp. 595–624. American Soc. for Agron., Inc. and Soil Science Soc., American Inc., Madison, Wisconsin.

Chaurasia, S.N.S., Singh, K.P. and Mathura, R. (2005). Effect of foliar application of water soluble fertilizers on growth, yield, and quality of tomato (*Lycopersicon esculentum* L.) SriLankan J. Agric. Sci. **42**: 66-70.

Climate Change Cell. (2007). Climate Change and Bangladesh (Dhaka: Climate Change Cell, Department of Environment, Government of the People's Republic of Bangladesh, with support from Comprehensive Disaster Management Program of the Government of the People’s Republic of Bangladesh and its development partners, UNDP and DFID). http://www.climatechangecellbd.org

EPBS (1958). The Provincial Statistical Board and Bureau of Commercial Industrial Intelligence. Statistical Abstract for East Pakistan, Dacca, p. 517.

Fakhrul, I., Asaduzzaman M.K., Fazle B.A.S.M., Hosain, M.T. and Sabikun N. (2013). Effect of fertilizer and manure on the growth, yield and grain nutrient concentration of *boro* rice (*Oryza sativa* L.) under different water management practices. *The Agriculturists*. **11**: 44-51.

Fertilizer Recommended Guide (2012). Bangladesh Agricultural Research Council, Farmgate, Dhaka. www.barc.gov.bd.

Gardner, F. P., Pearce, R. B. and Mitchell, R. L. (1985). Physiology of crop plants. Lowa. St. Univ. Press. pp. 112-114.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedure for agricultural research. 2nd ed. John Wiley and Sons. New York. p. 64.

Hasan, M.N. (2014). Effect of USG with cowdung on nitrogen use efficiency of rice and nitrogen dynamics in porewater. MS Thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh. pp. 1-66.

Hoshain, S. (2010). Effect of cowdung and nitrogen (urea) on growth, yield and yield contributing characters of aromatic rice cv. BRRI dhan50. MS Thesis. Department of Agronomy, Bangladesh Agricultural University, Mymensingh. pp. 4-20.

Hossain M. (1987). Fertilizer consumption, pricing and food grain production in Bangladesh. In: 1987. Fertilizer pricing policy in Bangladesh (Bruce Stone, *ed*.). IFPRI, Washington D.C.

Hossain, M.B., Islam, M.O. and Hasanuzzaman, M. (2008). Influence of different nitrogen levels on the performance of four aromatic rice cultivars. *Int. J. Agric. Biol.* **10**: 693-696.

Hunter, A. H. (1984). Soil fertility analytical service in Bangladesh. Consultancy report BARC, Dhaka.

Idris, A. E., Obid, S A. and Ahmed, B. E. A. M. (2016). Effect of bio-fertilizer on growth and yield of two maize (*Zea mays* L.) Cultivars at Shambat, Sudan. *Scholars J. of Agric. and Vet. Sci*. **3**(4):313-317.

IFDC. (2011). International Fertilizer Development Corporation. Research on the next generation of fertilizers presented by Amit Roy, IFRC Presented at the Syngenta foundation for sustainable agriculture, Switzerland.

Islam, L. M. Y. A., Youssef, A. A., Yousry T. M. A. and Hassan M. A. M. M. (2017). Effect of humic acid on growth and productivity of tomato plants under heat stress. *J. Hort. Res*. Online publication. www.degruyter.com.

Islam, M.R., Akther, M. Afroz, H. and Bilkis, S. (2013). Effect of nitrogen from organic and inorganic sources on the yield and nitrogen use efficiency of BRRI dhan28. *Bangladesh J. Prog. Sci. Technol.* **11**(2): 179-184.

Liza, M.M.J., Islam, M.R., Jahiruddin, M., Hasan, M.M., Alam, M.A., Shamsuzzaman, S.M. and Samsuri, A.W. (2014). Residual effects of organic manures with different levels of chemical fertilizers on rice. *Life Sci. J.***11** (12): 6-12.

Mahamud, J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted aman rice varieties influenced by seedling densities per hill. *Int. J. Sust. Agric.* **5**(1): 16-24.

Maulana, Z., Zaitun, Z. and Jumini, J. (2015). The effect of bio-liquid fertilizer application on the growth and yield of two variety of maize (*Zea mays L.*). Proceedings of The 5th Annual International Conference Syiah Kuala University (AIC Unsyiah) 2015 In conjunction with The 8th International Conference of Chemical Engineering on Science and Applications (ChESA) 2015 September 9-11, 2015, Banda Aceh, Indonesia. pp. 224-227.

Muthaura, C., Muna, M.M., Zingore, S., Kihara, J., and Muthamia, J. (2017). Effect of application of different nutrients on growth and yield parameters of maize (*Zea mays*), case of Kandara Murang'a County. *ARPN J. Agric Biol. Sci*. **12** (1):19-33.

Naidu, G.J., Rao, K.T. and Rao, A.U. (2013). Performance of rice under sri as influenced by effect of graded nutrient levels and time of nitrogen application. *Int. J. Adv. Biol.Res.* **3**(4): 572-575.

Oka, A.O., Ubi, B.E. and Efisue, A.A. (2012). A Comparative Study on Local and Newly Introduced Rice Varieties in Ebonyi State of Nigeria based on Selected Agronomic Characteristics. *Int. J. Agric. Forest.***2**(1): 11-17.

Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L.A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate, U.S. *Dept. Agric. Circ*., p. 929.

Page, A.L., Miller, R.H. and Keeney, D.R. (1982). Methods of analysis part 2, Chemical and Microbiological Properties, Second Edition American Society of Agronomy, Inc., Soil Science Society of American Inc. Madson, Wisconsin, USA. pp. 403-430.

Panwar, C.S., Vishwakarma, S.K. and Verma, N. (2012). Comparative performance of different rice varieties in relation to growth and yield. *Bioinfolet*. **9**(4A): 631-632.

Quasem, M.A. (1978). Fertilizer use in Bangladesh: 1965-66 to 1975-76. Bangladesh Institute of Development Studies, Dhaka, (BIDS Research Report Series No. 25). p. 37.

Rahman, M.S., Islam, M.R., Rahman, M.M. and Hossain, M.I. (2009). Effect of cowdung, poultry manure and urea on the yield and nutrient uptake of BRRI dhan29. Bangladesh Res. Pub. J. **2**(2): 552-558.

Rashid, M.M.U., Solaiman, A.R.M., Jahiruddin, M., Karim, A.J.M.S., Islam, M.S. and Nasim, A.S.B.M. (2011). Effect of urea nitrogen, cowdung, poultry manure and urban wastes on yield and yield components of *Boro* rice. *Int. J. Agric. Environ. Biotech.* **4**(1): 9-13.

Rogaciano, D.D.J. and Rosill, A.C. (2015). Effect of different liquid fertilizers on yield and economic analysis of glutinous corn (*Zea mays* L.) *Int. J. Multidis. Res. Dev.* **2**(2): 558-562.

Rongting, J., Gangqiang, D., Weiming, S. and Ju, M. (2017). Effects of liquid organic fertilizers on plant growth and rhizosphere soil characteristics of chrysanthemum. *Sustainability*. **9**: 841.

Russel, D.F. (1986). MSTAT-C Package programme. Crop and Soil Science Department, Michigan State University, USA.

Sarkar, S.K. (2014). Effect of nutrient management on growth, yield and quality of aromatic fine rice. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh. pp. 1-119.

Sarker, B.C., Zahan, M., Majumder, U.K., Islam, M.A. and Roy, B. (2013). Growth and yield potential of some local and high yielding *Boro* rice cultivars. *J. Agroforest. Environ.* **7**(1): 107-110.

Shaha, U. (2014). Integrated use of cowdung and inorganic fertilizer on the performance of modern varieties of transplanted aman rice. MS Thesis, Department of Agronomy, Bangladesh Agricultural University, Mymensingh, Bangladesh. pp. 1-70.

Shiyam, J.O., Binang, W.B. and Ittah, M.A. (2014). Evaluation of growth and yield attributes of some lowland Chinese hybrid rice (*Oryza sativa* L.) varieties in the Coastal Humid Forest Zone of Nigeria. *J. Agric. Vet. Sci.* **7**(2): 70-73.

Singh, A.K., Gupta, M.J., Srivastava, R. and Behara, T.K. (2005). Effect of NPK levels on growth and yield of tomato hybrids under multi-span polyhouse. *Indian J. Hort.* **62**(1): 91-93.

Sohel, M.A.T., Siddique, M.A.B., Asaduzzaman, M., Alam, M.N. and Karim, M.M. (2009). Varietal performance of transplant *aman* rice under different hill densities. *Bangladesh J. Agric. Res.* **34**(1): 33-39.

Souri, M.K., Sooraki, F.Y. and Masoud, M. (2017). Growth and quality of cucumber, tomato, and green bean under foliar and soil applications of an amino chelate fertilizer. *Hortic. Environ. Biotechnol*. **58**(6):530-536.

Sritharan, N. and Vijayalakshmi, C. (2012). Physiological basis of rice genotypes under aerobic condition. *Plant Archives.* **12**(1): 209-214.

Sutharsanr, S. and Rajendran M. (2017). Influence of liquid organic fertilizer on growth and yield of maize *(Zea mays L.). Agrieast* **2010** (9): 11-16.

Tandon, H.L.S. and Narayan P. (1990). Fertilizers in Indian Agriculture: Past, present, and future, 1950-2000. Development and Consultation Organization (New Delhi, *India*).

Uddin, M.J., Ahmed, S., Harun-or-Rashid, M., Hasan, M.A. and Asaduzzaman, M. (2013). Effect of spacing on the yield and yield attributes of transplanted aman rice cultivars in medium lowland ecosystem of Bangladesh. *J. Agric. Res.* **49**(4): 465-476.

United Nations (2009). Food production must double by 2050 to meet demand from world's growing population, innovative strategies needed to combat hunger. Sixty-fourth General Assembly, Second Committee GA/EF/3242, Panel Discussion (AM). 9 October 2009. http://www.un.org

Woldesenbet, M. and Haileyesus, A. (2016). Effect of nitrogen fertilizer on growth, yield and yield components of maize (*Zea mays* L.) in Decha District, Southwestern Ethiopia. *International J. Res. Ggranthaalayah*. **4**(2): 95-100.

Yao, F., Huang, I., Cui, K., Nie, L., Xiang, I, Liu, X., Wu, W., Chen, M. and Peng, S. (2012). Agronomic performance of high–yielding rice variety grown under alternate wetting and drying irrigation. *Field Crops Res.* **126**: 16-22.

Yihenew, G.S. (2015). The effect of N fertilizer rates on agronomic parameters, yield components and yields of maize grown on Alfisols of North-western Ethiopia. *Environ. Sys. Res.***4**:21.

APPENDICES

Appendix I. Mean square of plant height, no. of cob and cob length of maize

Source of variation	Degrees of freedom	Mean square		
		Plant height	Number of cobs	Cob length
Replication	2	210.753	115.792	4.636
Factor A (NGF + NPKSZnB)	7	493.190**	11.204NS	4.608*
Factor B (Varieties)	2	16.151*	63.542NS	1.891 *
AB	14	45.853*	10.431NS	1.683 *
Error	46	51.395	27.603	1.741

*, **= Significant at 5% and 1%, respectively level of probability and NS= non significant

Appendix II. Mean square of single weight of cob without husk (g), 100 kernel weight and grain yield of maize

Source of variation	Degrees of freedom	Mean square		
		Cob weight	100-kernel weight	Kernel yield
Replication	2	0.795	0.795	0.281
Factor A (NGF + NPKSZnB)	7	0.253 *	0.253 *	0.178 *
Factor B (Varieties)	2	1.555**	1.555 *	0.301*
AB	14	0.138 *	0.138 *	0.085 *
Error	46	0.192	0.192	0.100

*, **= Significant at 5% and 1%, respectively level of probability

Appendix III. Mean square of pH, organic carbon, total N, available P, exchangeable K and available S in postharvest soil of maize crop field

Source of variation	Degree of freedom	Mean square					
		pH	Organic carbon	Total N	Available P	Exchangeable K	Available S
Replication	2	0.077	0.016	0.000	23.540	0.000	68.298
Factor A (NGF + NPKSZnB)	7	0.126 ^{NS}	0.011 ^{NS}	0.000 ^{NS}	2.240 ^{NS}	0.000 ^{NS}	7.396 ^{NS}
Factor B (Varieties)	2	0.094 ^{NS}	0.005 ^{NS}	0.000 ^{NS}	2.026 ^{NS}	0.000 ^{NS}	10.203 ^{NS}
AB	14	0.049 ^{NS}	0.004 ^{NS}	0.000 ^{NS}	2.531 ^{NS}	0.000 ^{NS}	16.570 *
Error	46	0.045	0.002	0.000	3.154	0.000	8.536

* = Significant at 5% level of probability and NS= non significant

Appendix IV. Mean square of plant height, flower cluster plant^{-1}, fruits cluster^{-1} of tomato

Source of variation	Degrees of freedom	Mean square		
		Plant height	Flower cluster plant^{-1}	Fruits cluster^{-1}
Replication	3	1.18	0.098	0.136
Factor A (NGF + NPKSZnB)	5	96.36*	6.749*	1.985*
Factor B (Varieties)	2	2513.37*	0.063*	3.327*
AB	10	12.80**	0.019*	0.619*
Error	34	0.79	0.031	0.286

*, **= Significant at 5% and 1%, respectively level of probability

Appendix V. Mean square of fruits plant^{-1}, fruit diameter, fruit length, fruit field of tomato

Source of variation	Degrees of freedom	Mean square			
		Fruits plant^{-1}	Fruit diameter	Fruit length	Fruit yield
Replication	3	68.06	1.60	1.018	24.57
Factor A (NGF + NPKSZnB)	5	79.46*	1.00 NS	0.36 NS	382.59*
Factor B (Varieties)	2	418.50*	76.48*	3.58*	237.57*
AB	10	92.32 *	1.50 *	0.22 *	43.02 *
Error	34	32.33	1.15	0.38	20.87

* = Significant at 5% level of probability and NS= non significant

Appendix VI. Mean square of soil pH, organic carbon, total N, available P, available K and available S in postharvest soil of tomato crop field

Source of variation	Degrees of freedom	Mean square					
		pH	Organic carbon	Total N	Available P	Exchangeable K	Available S
Replication	3	0.005	0.008	0.000	24.477	0.001	27.850
Factor A (NGF + NPKSZnB)	5	0.019 NS	0.035 NS	0.001 NS	17.991*	0.000 NS	32.623*
Factor B (Varieties)	2	0.004 NS	0.011 NS	0.002 NS	39.057**	0.000 NS	12.424 NS
AB	10	0.019 NS	0.022 NS	0.000 *	3.726 *	0.000 NS	9.804 *
Error	34	0.013	0.002	0.001	5.009	0.001	9.303

*, **= Significant at 5% and 1%, respectively level of probability and NS= non significant

Appendix VII. Mean square of plant height, nos. effective tillers hill^{-1}, panicle length, nos. effective grain panicle^{-1} of rice

Source of variation	Degrees of freedom	Mean square			
		Plant height	Nos. effective tillers hill^{-1}	Panicle length	Nos. effective grain panicle^{-1}
Replication	3	61.80	36.74	2.84	1373.13
Factor A (NGF + NPKSZn)	5	89.70*	41.01*	0.99 *	531.62 *
Factor B (Varieties)	2	592.59*	33.46 *	9.80*	10978.35*
AB	10	17.08 *	7.59 *	0.27 *	333.15 *
Error	34	32.98	11.29	1.90	313.58

*= Significant at 5% level of probability

Appendix VIII. Mean square of 1000- grain weight, grain yield, straw yield, harvest index of rice

Source of variation	Degrees of freedom	Mean square			
		1000 grain weight	Grain yield	Straw yield	Harvest Index
Replication	3	0.001	0.015	0.012	0.01
Factor A (NGF + NPKSZn)	5	0.000 NS	0.139**	0.046**	0.09**
Factor B (Varieties)	2	0.016**	0.290**	0.112**	0.20**
AB	10	0.000 *	0.007 *	0.006 *	0.01 *
Error	34	0.001	0.009	0.005	0.01

*, **= Significant at 5% and 1%, respectively level of probability and NS= non significant

Appendix IX. Mean square of soil pH, organic carbon, total N, available P, exchangeable K and available S in postharvest soil of rice crop field

Source of variation	Degrees of freedom	Mean square					
		pH	Organic carbon	Total N	Available P	Exchangeable K	Available S
Replication	3	0.104	0.020	0.000	37.657	0.000	29.588
Factor A (NGF + NPKSZn)	5	0.024 NS	0.002 NS	0.004*	13.980 *	0.000NS	19.816*
Factor B (Varieties)	2	0.027 NS	0.022**	0.007**	10.019 NS	0.000 NS	1.006 NS
AB	10	0.047 NS	0.002 NS	0.001 *	26.136*	0.000 NS	6.076 *
Error	34	0.042	0.004	0.001	9.904	0.001	6.418

*, **= Significant at 5% and 1%, respectively level of probability and NS= non significant