ZINC BIOFORTIFICATION OF MAIZE (*Zea mays* L.) AND INTEGRATED NUTRIENT MANAGEMENT IN FOOTHILL CONDITION OF NAGALAND

Thesis
submitted to

NAGALAND UNIVERSITY

in partial fulfillment of requirements for the Degree
of
DOCTOR OF PHILOSOPHY
in
AGRONOMY
by

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2022

Dedicated to my beloved Parents

DECLARATION

I, **Z. Kawikhonliu**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form the basis of the award of any previous degree to me or to the best of my knowledge to anybody else, and that the thesis had not been submitted by me for any research degree in any other university/institute.

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CERTIFICATE – I

This is to certify that the thesis entitled "**Zinc Biofortification of Maize (*Zea mays* L.) and Integrated Nutrient Management in Foothill condition of Nagaland"** submitted to Nagaland University in partial fulfilment of the requirements for the award of degree of Doctor of Philosophy in the discipline of Agronomy, the record of research work carried out by Ms. Z. Kawikhonliu, Registration No. 818/2018, under my personal supervision and guidance.

The results of the investigation reported in the thesis have not been submitted for any other degree or diploma. The assistance of all kinds received by the student has been duly acknowledged.

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This is to certify that the thesis entitled "**Zinc Biofortification of Maize (*Zea mays* L.) and Integrated Nutrient Management in Foothill condition of Nagaland**" submitted by Ms. Z. Kawikhonliu, Admission No. Ph-161/14, Registration No. 818/2018, to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agronomy has been examined by the Advisory Board and External examiner on ………………............

The performance of the student has been found **Satisfactory/Unsatisfactory.**

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Date: **(Z. KAWIKHONLIU)**
Place:

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

%	-	Per cent
/	-	Per
:	-	Ratio
@	-	At the rate of
₹	-	Rupees
AAS	-	Atomic absorption spectroscopy
C.D	-	Critical difference
C.V	-	Coefficient of variance
cm	-	Centimeter
cm^2	-	Square centimeters
DAS	-	Days after sowing
ESS	-	Error mean sum of square
et al.	-	And others
Fig.	-	Figure
FYM	-	Farm Yard Manure
g	-	Gram
g^{-1}	-	per gram
g^{-1} Plant	-	gram per plant
ha	-	Hectare
ha-1	-	Per hectare
i.e.	-	That is
ICAR	-	Indian Council of Agriculture Research
K	-	Potassium
K_2O	-	Potassium oxide
kg	-	Kilogram
km	-	Kilometre
L.	-	Linnaeus
m	-	Meter
m^{-2}	-	Square metre
m^{-2}	-	Per square meter
Max.	-	Maximum
mg	-	Milligram

mm	-	Millimeter
MOP	-	Murate of Potash
mt	-	Metric ton
N	-	Nitrogen
No.	-	Number
NS	-	Non-significant
^{o}	-	Degree
^{o}C	-	Degree Celsius
P	-	Phosphorus
P_2O_5	-	Phosphorus pentaoxide
pH	-	Puissance de hydrogen
q		Quintal
R	-	Range
R1-3	-	Replication
RBD	-	Randomized Block Design
RDF	-	Recommended dose of fertilizer
S	-	Significant
S. Ed	-	Standard error of mean difference
S. Em	-	Standard error of mean
Sl No.	-	Serial number
SSP	-	Single Superphosphate
t	-	ton
T	-	Treatment
Temp.	-	Temperature
viz.	-	Namely
Zn	-	Zinc
$ZnSO_4$	-	Zinc sulphate

Abstract

The experiment entitled "Zinc Biofortification of Maize (*Zea mays* L.) and Integrated nutrient management in Foothill condition of Nagaland" was conducted during the kharif season of 2016 and 2017 in the Agronomy experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Medziphema Campus, Nagaland. The experimental field was laid out in Split–Split plot design with three replications. The treatment consists of three factors each of them with three levels. The main plot factors consist three level of organic manures *i.e.*, M_1 (10 t ha^{-1} FYM), M_2 (4 t ha^{-1} PM) and M_3 (2 t ha^{-1} VC); three level of subplot factor with three level fertilizer i.e., F_1 (0% RDF), F_2 (50% RDF) and F_3 (100% RDF); lastly sub – subplot factors with three level of Zinc *i.e.*, Z_1 (0 kg ha^{-1}), Z_2 (15 kg ha^{-1}) and Z_3 (30 kg ha^{-1}). HQPM-1 hybrid was tested in the experiment.

Among different sources of organic manure poultry manure recorded significantly better results in almost all the growth, yield and yield attributing characters. Whereas, among the fertilizer level, 100% RDF dominated in producing significantly better results in growth, yield and yield attributing characters. Highest levels of Zinc *i.e.* 30 kg ha^{-1} recorded highest value in all the growth and yield and yield attributing characters. But it was found to be at par with Zinc application at the rate of 15 kg ha^{-1} in all the characters recorded except for dry matter.

Combine application of poultry manure @ 4 t ha^{-1} with fertilizer @ 100% RDF (M_2F_2) recorded maximum yield (3486.39 kg ha^{-1}), dry matter accumulation (234.70 g $plant^{-1}$) and took lesser days to attain 50% silking (56.39) in maize. While the interaction between dose of fertilizers and Zinc application showed significant effect on dry matter accumulation (242.16 g $plant^{-1}$), CGR (4.36 g m^{-2} day^{-1}) and yield (4104.83 kg ha^{-1}). Where, the highest values were recorded with the treatments receiving 100% RDF in combination with 30 kg ha^{-1} Zinc application.

In case of quality parameters under study application of poultry manure @ 4 t ha^{-1} (M_2) significantly improved the quality status of the maize grain and stover in comparison with FYM and Vermicompost. With regard to the dose of fertilizers, maize plants supplied with 100% RDF (F_3) resulted in improved quality maize grains,

which in turn resulted in remunerative returns. Among the different levels of Zinc tried, application of 30 kg ha^{-1} of Zinc to the HQPM-1 maize registered highest increase in the quality parameters when compared to the other control *i.e.* 0 kg ha^{-1} Zinc.

Only fertilizer levels and Zinc application could exert significant influence on nitrogen content and uptake, phosphorus content and uptake; zinc content and uptake; protein and carbohydrate content in the HQPM-1 maize. The treatment combination involving 100% RDF and 30 kg ha^{-1} Zinc exerted the best results among all the combinations.

Among the soil physico-chemical parameters under study the organic carbon content responded significantly to the application of various sources of organic manure. Where poultry manure positively increased organic carbon content of the soil.

Total cost of cultivation in production of Maize was found varied among the different treatments and the highest cost of cultivation (₹54223.5 ha^{-1}) was recorded in T_{27} ($M_3F_3Z_3$) while the lowest was observed in T_1 ($M_1F_1Z_1$). Highest gross return was obtained from the T_{18} ($M_2F_3Z_3$) during both the years as well as in pooled data, while the lowest gross income was obtained from T_{21} ($M_2F_1Z_3$). Maximum net return during both the year as well as in the pooled data was recorded in T_{18} ($M_2F_3Z_3$). The pooled maximum benefit cost ration (B:C) was recorded in T_8 ($M_1F_3Z_2$).

From this field investigation application of poultry manure @ 4t ha^{-1} + 100% RDF + zinc @ 30 kg ha^{-1} ($M_2F_3Z_3$) is recommended in order to achieve higher grain yield, grain quality and to sustain the quality of soil as well as maximize the monetary returns of the farmers in foothill condition of Nagaland.

Keywords: Integrated Nutrient Management, Zinc biofortification, HQMP-1, Maize

CHAPTER I

INTRODUCTION

INTRODUCTION

Human being requires at least 22 mineral elements for their wellbeing. These can be supplied by an appropriate diet. However, it is estimated that over 60% of the world's 6 billion people are deficient in iron (Fe), over 30% are zinc (Zn), 30% are iodine (I) and 15% selenium (Se). In addition, calcium (Ca), magnesium (Mg) and copper (Cu) deficiencies are common in many developed and developing countries. This situation is attributed to crop production in areas with low mineral Phyto availability and consumption of crops with inherently low tissue mineral concentrations, compounded by a lack of fish or animal products in the diet. Currently, mineral malnutrition is considered to be among the most serious global challenges to humankind. However, such occurrence is avoidable. Mineral malnutrition can be addressed through dietary diversification, mineral supplementation, food fortification and/or increasing mineral concentrations in edible crops (biofortification). Due to their detrimental effects on both food production and human health in many regions of the world, iron and zinc deficiencies have drawn increased attention (Cakmak *et al*., 2010).

Zinc (Zn) deficiency is occurring in both crops and humans (White and Zasoski, 1999). Zinc deficiency in soil reduces not only the grain yield, but also the nutritional quality of grain (Cakmak, 2008) and ultimately nutritional quality of human diet. Zinc is now recognized as the fifth major nutrient deficiency after Protein-Calorie, Iron, Vitamin A and Iodine (Prasad, 2003; Hotz and Brown, 2004). Millions of hectares of cropland are affected by Zn deficiency and approximately one third of the human population suffers from inadequate intake of Zn. Zn plays a key role in physical growth and development, the functioning of the immune system, reproductive health, sensory function and neurobehavioral development in humans (Hotz and Brown, 2004). In plants, enzymes either containing or activated by Zn are involved in carbohydrate metabolism, protein synthesis, maintenance of the integrity of cellular membrane, regulation of auxin synthesis and pollen formation (Marschner, 1995). Zn is also required for the regulation and maintenance of the gene expression required for the tolerance of environmental stresses in plants, such as high light intensity and high temperature (Cakmak, 2000).

Though Zn is needed in trace amount but are no way micro in their role; rather play a major role in enhancing the macronutrient efficiency as Zn is highly essential for better utilization of macronutrients. Absence of one atom of Zn would impair the biochemical advantages arising from the presence of 3333 atoms of N, 833 atoms of K, 200 atoms of P and 100 atoms of Sulphur (Shukla *et al*., 2009). This shows a strong interactive relationship among essential plant nutrients. If zinc deficiency is not diagnosed and rectified timely, the problem will become alarming in the years to come because land has been cultivated more intensively to have additional production to meet the requirement of increasing population.

In spite of considerable primary success, indiscriminate use of chemical fertilizers has often led to deterioration of overall soil health of the country leading to a stagnation of food grain production in recent years inspite of consistent increment in fertilizer use. This stagnation in agricultural productivity is often attributed to degradation of soil due to various biotic and abiotic stresses inflicted on soil due to high input agriculture. With a view to sustain the soil health and to maintain thereby the productivity levels of agricultural soils more emphasis is now being paid on integration of organic inputs with mineral sources of nutrition. Use of such organic materials not only increase the nutrient status of the agricultural soils but also help improve various physical, chemical and biological properties of soils leading to betterment of soil quality and also to increased fertilizer use efficiency. Farmyard manure, Vermicompost, Poultry manure, Biofertilizer etc. are some organic manures which are rapidly emerging as an important source of organic inputs produced from various organic wastes and some useful microorganisms. They play a vital role in improving availability of zinc and other nutrient by direct contribution as well as indirectly by influencing chemical transformation reaction and microbial activity.

Maize (*Zea mays* L.) is the third most important cereal after wheat and rice. The crop is commonly cultivated in the tropics and warm sub-tropics for food, livestock and industrial uses. In India maize is an important food, fodder and industrial crop grown both commercially and at subsistence level. Maize is used for the production of indigenous and commercial food products that are relished for their unique and distinctive flavors. It is eaten fresh or milled into flour and serves as a valuable ingredient for baby food, cookies, biscuits, livestock's feed and variety of beverages.

In Nagaland and other parts of North East Hill Region, Maize is the second largest producing cereal crop next to rice. The entire region has high potential for large scale production with improved management practices. The area and production of Maize for the year 2012-2013 under Nagaland was 68,670 ha and 1,34,650 metric tonnes respectively (Anonymous, 2014). The climatic condition of the foothill of Nagaland is humid sub-tropical with an average rainfall of 200 – 250 cm. Temperature ranges from 20^0C to 35^0C during summer and rarely below 8^0C in winter. Relative humidity ranges from 75% to 85% and soil are sandy loam in nature.

Maize grown on Zinc deficient soils is therefore often deficient in Zn and other essential micronutrients. However, application of Zn-containing mineral fertilizers along with the organic manure in cereal crops (maize) may contribute towards improved soil health, yields and grain quality. This will enhance the nutritional status of smallholder communities in maize-based farming systems. Agronomic biofortification through inorganic and organic manure could be a cost-effective strategy to enhance nutrition and soil fertility in these communities given that the majority of farmers often do not have the financial capacity to purchase high cost fertilizer and other Zn-rich foods including meat.

Keeping in view of these important points, the present research work was under taken to study Zinc Biofortification of Maize (*Zea mays* L.) and Integrated nutrient management under foothill condition of Nagaland, with the following objectives:

1. To find out the effect of Zinc levels on growth, yield and quality of maize.
2. To find out the suitable source of organic manure and level of Recommended dose of fertilizer.
3. To find out the interaction effect and economics of the treatment combinations.

CHAPTER II

REVIEW OF LITERATURE

REVIEW OF LITERATURE

In this chapter attempt has been made to review the advances of earlier scientific research work on Zinc biofortification of maize and integrated nutrient management. Based on the objectives involved in the experiment the available literatures pertaining to these aspects inside and outside of the country are briefly described in this chapter.

2.1. Farm yard manure

2.1.1. Effect of Farm yard manure on growth and yield of maize

Gajri *et al.* (1994) conducted a field experiment in maize for 3 year and found that application of 0-15 t farmyard manure/ha improved root growth, water extraction and grain yield in loamy sand soils.

Khan *et al.* (2000) reported that application of 0, 5, 10 and 15 t FYM ha^{-1} recorded 4640, 4990, 5260 and 5910 kg ha^{-1} and 5053, 5200 and 5338 kg ha^{-1} with the application of 0, 60, 90 kg N ha^{-1} respectively. While, the highest yield of 6650 kg ha^{-1} was given by the combination of 15 t FYM and 90 Kg ha^{-1}.

Nair (2000) reported that application of FYM (10 to 20 t ha^{-1}) shows significantly higher growth attributes of maize over RDF (120:40:30 kg NPK ha^{-1}) and control (no fertilizer and FYM application).

Debele *et al.* (2001) concluded that application of enriched FYM either at 4 or 8 t ha^{-1} significantly improved the grain yield of maize by 32.6 and 22.4% over the respective levels of conventional FYM. It was also recorded that grain yield with 4 t of enriched FYM was significantly superior to 8 t ha^{-1} of conventional FYM.

Kumar and Puri (2001) recorded 20.55 and 35.65% more grain and stover yield of maize respectively with FYM at 15 t ha^{-1} over conventional method.

Parmar and Sharma (2001) reported that application of FYM @ 15t ha^{-1} increased the grain and straw yield of maize and wheat crops in Maize – Wheat sequence cropping system.

Singh *et al.* (2005b) found that application of 10 t FYM ha^{-1} significantly increase plant height by 10.26% and dry matter accumulation per plant by 18.36%. it was also found that application of 100% RDF increased plant height by 8.17% and dry matter accumulation per plant by 12.90%.

Balyan *et al.* (2006) revealed that application of 10 t FYM ha^{-1} result in significant increase of the plant height (10.26 per cent) and dry matter per plant (18.36 per cent) *i.e.* 200.8 cm and 224.98 g $plant^{-1}$, respectively compared to without FYM application.

Ghanbahadur and Chandankar (2008) conducted a field experiment on the effect of two levels of FYM, three level of NPK and tow levels of plant density on maize hybrid Pro-Agro-4640. Higher grain yield of 55.38 q ha^{-1} was obtained with FYM at 5 t ha^{-1}.

Bhat *et al.* (2013) conducted a field trial comprising of three factors *viz.* cropping sequence, three farmyard manure rates and three frequencies, laid in split plot design replicated thrice and reported that the FYM rates increases the growth characters and yield attributes and the grain yield of maize shows significant improvement with FYM application upto 20 t ha^{-1} while stover yield increased significantly upto 30 t ha^{-1}

2.1.2. Effect of Farm yard manure on nutrient uptake and soil properties

Babu and Reddy (2000) reported that application of Farm yard manure @ 10 t ha^{-1} results in greater accumulation of available N, P and K in soil and grain and stover yield of maize than control where manures are not applied.

Swarup and Yaduvanshi (2000) reported that comparatively organic fertilizer treatment such as FYM and green manure gives significantly higher soil organic carbon, available P, K, Zn and Mn than inorganic fertilizer treatments.

Debele *et al.* (2001) revealed that grain and stover yield of maize and NPK uptake by the crop were significantly higher with enriched FYM over conventional manure. It was also observed that interaction effects of 4 and 8 t enriched FYM ha^{-1}

with 112.5 or 150 kg nitrogen ha^{-1} on grain yield, nutrient uptake and soil NPK status were significantly superior.

2.2. Vermicompost

2.2.1. Effect of vermicompost on growth and yield of maize

Chandrashekara *et al.* (2000) reported that there is significant increase in grain yield of maize in vermicompost (16%) and FYM (14%) treated plot when compared to no manure treated plots.

Jayaprakash *et al.* (2003) conducted a field trial and found that the grain yield of maize was significantly affected by the application of organic manure. Application of vermicompost gives highest grain yield. It was also observed that higher straw yield was obtained with organic treatment compared to no organic treatment.

Sudha and Chandini (2003) reported that using vermicompost @ 5 t ha^{-1} as organic manure had positive influence on growth and yield attributes of rice, resulted in better grain and straw yield along with the NPK dose of 105: 52.5: 52.5 kg ha^{-1} supplied through inorganic sources.

Omraj *et. al*. (2007) conducted experiment and found that application of 1.5 t vermicompost ha^{-1} gives significantly higher grain and stover yield, nutrient content, uptake and protein content of maize than 1.0, 0.5 t ha^{-1} and control.

Milosev *et al.* (2010) reported that with the increased doses of vermicompost and nitrogen positively influence the grain yield per plant and mass of 1000 grain. The highest grain yield was observed with 600g of vermicompost and 1.5g of nitrogen.

Kalantari *et al.* (2011) conducted a pot experiment and reported that the nutrient concentration increased with the use of organic fertilizers and Hoagland solution, the best plant growth was observed in 3% vermicompost + sulphate and 3% vermicompost treatment.

Bhartiya and Singh (2012) in their experiment observed that with application of vermicompost and other animal dung, heavy metals were found in the earthworm body and in the soil before and after harvesting of the crop. They also observed the concentration of the heavy metal to the maize seeds can be controlled by use of vermicompost and *Eisenia fetida* from the experimental field.

Gaikwad *et al.* (2012) reported that through the application of humic acid through vermicompost wash as foliar spray of 400 ppm followed by 350 ppm increased the plant height, dry weight of plant, leaf area, 100 grain weight (g), number of grains per cob.

Shariati *et al.* (2013) reported that through the treatment of vermicompost and vermicompost + perlite + bentolite some growth parameter of maize including phosphorus in the soil and shoot and Zinc in the shoots.

2.2.2. Effect of Vermicompost on nutrient uptake and soil properties

Venkatesh (1995) reported that application of vermicompost as organic fertilizer decreases the pH of soil and increase the organic carbon and available N, P, K and DTPA extractable Fe, Mn, Zn, Cu contents of soil.

Jadhav *et al.* (1997) reported that uptake of major and secondary nutrients such as N, P, K, Ca and Mg are increased in rice with application of vermicompost and maximum nitrogen uptake was recorded by the conjunctive use of urea 75 kg ha^{-1} plus vermicompost at 25 kg ha^{-1}.

Barik *et al.* 2006 from their experiment reveal that residual available nitrogen, phosphorus, potassium and organic carbon in soil was significantly higher under vermicompost treated plot, either alone or in combination with NPK fertilizer, compared to initial soil status.

Omraj *et al.* (2007) revealed that application of 1.5 t ha^{-1} vermicompost recorded highest total nutrient uptake by maize crop *i.e.* nitrogen (153.56 kg ha^{-1}), phosphorus (32.04 kg ha^{-1}), potassium (38.71 kg ha^{-1}) and protein content of maize as compared to 1.0, 0.5 t ha^{-1} and control.

2.3. Poultry manure

2.3.1. Effect of poultry manure on growth and yield of maize

Madhavi *et al.* (1995) reported that application of poultry manure at rates ranging from 1 to 4.5 t ha^{-1} significantly increased plant height, dry matter, nutrient uptake, cob weight, 1000 grain weight and stover yield of maize.

Obi and Ebo (1995) concluded that application of poultry manure @ 10 t ha^{-1} significantly increased the grain yield of maize over FYM @ 10 t ha^{-1}.

Chandrashekara *et al.* (2000) reported that application of poultry manure 10 t ha^{-1} results in significantly higher plant height (187. 5 cm), longer cobs (14.35 cm), Stem diameter (15.6 cm) and higher cob weight (170.5 g cob^{-1}) compared to lower level of poultry manure (2.5 t ha^{-1}) and FYM (10 t ha^{-1}).

Channabasavana *et al.* (2002) a flied trial was conducted comprising of the following treatment: 5 level of poultry manure (0, 1, 2, 3, 4 t ha^{-1}), 10 t farm yard manure ha^{-1}, and 3 levels of NPK (50, 75 and 100% RDF (150:75:37.5 kg NPK ha^{-1}) and the result reveal that application of poultry manure @1 t ha^{-1} recorded significant higher seed yield (5046 kg ha^{-1}) which was at par with application of FYM @ 10 t ha^{-1} (4749 kg ha^{-1}) over the control (4117 kg ha^{-1}). Increasing poultry manure from 2 to 4 t ha^{-1} did not increased the seed yield whereas increasing fertilizer level from 50 to 100% NPK increase the seed yield significantly.

Nagaraj *et al.* (2004) conducted an experiment and found that application of Poultry manure @ 5 t ha^{-1} significantly increased the grain yield (51.52 q ha^{-1}) among different organic manures. The next best treatment was application of FYM @ 10 t ha^{-1} (45.73 kg ha^{-1}) which was found to be at par with the incorporation of green leaf manures @ 5 t ha^{-1} (44.82 q ha^{-1}).

Amakinde and Ayoola (2009) in their experiment found that maize supplied with Nitrogen-fortified poultry droppings showed significantly higher growth. It gave higher plant height and leaf area that were comparable with organic fertilizer.

Ezeibekwe *et al.* (2009) reported that poultry manure encouraged early flowering, fruiting and highest vegetative growth and fruit biomass/dry weight in maize plant when compared with urea and control in Nigeria condition.

Farhad *et al.* (2009) reported that in maize plant application of 12 t ha^{-1} poultry manure gives maximum values for plant height, number of rows per cob, number of grains per row, 1000-grain weight, grain yield, biological yield and harvest index.

Akongwubel *et al.* (2012) observed that poultry manure at the rate of 20 t ha^{-1} gave the highest maize plant height, stem diameter and number of leaves per plant in Nigeria.

Okonmah (2012) observed that the response of maize plant in terms of plant height, leaf area, number of leaves, plant girth and yield components was highest with the application of poultry manure at the rate of 12 kg ha^{-1} at Asaba agro- ecological zone, Nigeria.

Okoroafor *et al.* (2013) conducted a field experiment and found that application of poultry dropping gave maximum growth and yield of maize as compared to other treatment.

2.3.2. Effect of poultry manure on nutrient uptake and soil properties

Toor and Bishnoi (1996) found that applying manure alone or in combination with inorganic sources improved nutrient status of soil. They also revealed that poultry manure was more effective than farm yard manure for available N and P but sources were equally effective for available K.

Dubey and Verma (1999) recorded highest increase in available Potassium where 100% poultry manure was applied. Highest net returns and benefit: cost ratio was obtained from application of 50% NPK + 50% poultry.

Lamani *et al.* (2000) revealed that application of poultry manure resulted in higher soil organic matter content (0.79%) when compared to control (0.67%) but it was on par with FYM (0.77%) and vermicompost (0.78%).

Keelara (2001) found that application of poultry manure at 6t ha^{-1} along with RDF resulted in maximum nitrogen and Potassium uptake. Highest residual nitrogen (210.03 kg ha^{-1}) and potassium (230.25 kg ha^{-1}) was also reported with this treatment.

Channabasavana *et al.* (2002) recorded that application of poultry manure at 4 t ha^{-1} with 75% NPK gives highest seed yield (5583 kg ha^{-1}), followed by poultry manure at 1 t ha^{-1} and 100% NPK (5573 kg ha^{-1}).

Kaur *et al.* (2005). Reported that application of FYM, Poultry manure and sugarcane filter cake alone or combination with chemical fertilizers results in improved soil organic carbon, Total NPK status.

2.4. Zinc

2.4.1. Effect of zinc on growth and yield of maize

Khan *et al.* (2014) reported that Maximum values for plant height at maturity (225 cm), cob diameter (4.29 cm), number of grains per cob (415), biological yield (20.15 tons ha^{-1}), grain yield (7.42 tons ha^{-1}) and seed protein content (8.96%) were recorded where 15 kg ha^{-1} $ZnSO_4$ + 15 kg ha^{-1} $MnSO_4$ was applied.

Azab (2015) in his experimental studies revealed that combined application of Zn (15%) and NPK fertilizer significantly improved cob length, cob girth, number of rows and grain yield as compared to only NPK treatment.

Amanullah *et al.* (2016) after conducting field experiment for two years at Peshawar, Pakistan revealed that yield attributes such as 1000 grain weight, number of grains per ear and grain yield of maize was increased when 0.2% of Zn was applied.

Mohsin *et al.* (2014) reported that maize hybrid Pioneer 30-Y-87, with combined application of Zn as seed priming (2.0%) and foliar spray (2.0%), significantly improved plant height, cob length, cob diameter, 1000-grain weight, biological yield, grain yield and harvest index. These results suggested that combined application of Zn as seed priming (2.0%) and foliar spray (2.0%) can improve the performance of maize hybrids.

Preetha and Stalin (2014) conducted a field experiment and the results revealed that the highest plant height, thousand grain weight, cob yield, stover and grain yield were recorded in the treatment with 7.50 kg Zn ha^{-1} in soil having low initial Zn status, 5.00 kg Zn ha^{-1} in soil having medium and high initial Zn status respectively. Thus, the highest grain yields of 7.42, 7.45 and 7.56 t ha^{-1} were obtained with application of 7.50, and 5.00 kg Zn ha^{-1} in soil with low initial Zn and medium and high initial Zn respectively, the yield increased being 39.08, 33.15 and 28.84% over NPK control. The results of the study clearly indicate that there was a significant response to the applied Zn in soil having severe Zn deficiency, while the soil having adequate Zn status also showed comparatively better and there was a decline or no response to the applied Zn at higher levels in soil having high zinc status.

Raskar *et al.* (2012) revealed that application of 5 kg Zn ha^{-1} significantly increased shelling percentage grain yield cob^{-1}, grain yield and stover yield in compared to control in Vadodara, Gujarat condition.

Shivay and Prasad (2014) conducted a field study at New Delhi, India and found that combine application of Zinc through soil + foliar (in 2 sprays at tasselling and initiation of flowering) produced significantly more grain and stover yield.

2.4.2. Effect of organic manure and zinc application on uptake of zinc and other nutrient:

Abunyewa and Mercer-Quarshie (2004) investigated the effect of magnesium and Zinc on maize production in the semi-arid zone of west Africa and found that as a result of Zn application maize grain yield ranged between 0.9 and 3.2 t ha^{-1} representing 84 to 108% increase in the three-year period.

Venkatesh *et al.* (2004) reported that application of FYM resulted in significant increase of zinc concentration and Fe, Mn, Zn and Cu uptake while application of liming resulted in significant reduction in available Mn and Zn content of soil.

Galavi *et al.* (2011) reported that micronutrients foliar application and biological and chemical phosphorus fertilizers had a significant influence on dry matter accumulation. Grain yield, 1000-seed weight and protein content of grain, were significantly affected by micronutrients and phosphorus fertilizers treatments.

Sarwar *et al.* (2012) conducted field experiment a result reveal that Maximum maize grain yield, *viz.* 5.18 t ha^{-1} was obtained with 75% + 25% (CF + FYM) and 4 kg Zn ha^{-1}. Zinc application also enhanced maize grain yield by 12% over treatment where no Zn was applied *i.e.* 4.08 t/ha. The study also revealed that substitution of 25 or 50% N with FYM + 4 kg Zn ha^{-1} performed better than 100% N fertilizer alone, with respect to leaf area index, grain and straw yield, soil organic matter content and nutrient uptake.

Aduloju and Abdulmalik (2013) conducted an experiment to determine the effect of zinc (Zn) and NPK fertilizers on the Zn and P content of maize ear-leaf, the P and Zn interactions with the application of Zn as $ZnS0_4$ and P as NPK 15-15-15 in maize plant and the Zn and P uptake at ear-leaf stage in the maize plant. Top soils from three identified profiles in a top sequence were sampled for general characterization and zinc contents. Results obtained showed that the soils were high in pH, total N, K and all measured exchangeable cations, but low in P and Zn. The applied fertilizer (NPK), had significant ($P<0.05$) effects on the root and shoot dry matter yield of maize plants grown on the soils at the lowest part of the slope (Profile C) only. There was a linear positive correlation ($r = 0.072$) between NPK and Zn in the ear-leaves of plant grown on profile B (mid - slope).

Afzal *et al.* (2013) conducted a field experiment to evaluate the role of seed priming with Zinc in improving the performance of maize hybrids and the result revealed that priming technique of Zinc gave higher values in almost all the physiological and yield parameters. The maximum grain yield (5.35 t ha^{-1}), biological yield (16.69 t ha^{-1}) were found in priming with $ZnSO_4$ @ 1.5% in maize hybrid.

Khalid *et al.* (2013) carried out a field trail on maize hybrid response to assorted chelated and nonchelated foliar applied Zinc rates and the result showed that application of Zinc Ch: EDTA at 180g Zn ha^{-1} has pronounced effect on growth, yield and quality related attributes than other treatments.

Menzeke *et al.* (2014) reported that under combined application of mineral NPK, Zn and leaf litter, maize grain gave highest Zn concentration up to 35 mg kg^{-1}.

Mohsin *et al.* (2014) reported that maize hybrid DK-919, with combined application of Zn as seed priming (2.0%) and foliar spray (2.0%) produced significantly more grain zinc content (mg kg^{-1}).

Shivay and Prasad (2014) reported that combined application of Zinc through soil and foliar (in 2 sprays at tasselling and initiation of flowering) recorded the highest Zn concentration in corn grain as well as in stover, with the treatments falling in the following order: combined > foliar > soil through Zn-coated urea > soil.

2.5. Integrated nutrient management

2.5.1. Effect of Integrated nutrient management on growth and yield of maize

Abrol *et. al*. (2007) conducted an experiment at Rakh Diandar, Jammu and revealed that application of 100% RDF (NPK: 60-40-20 kg ha^{-1}) + ZnSO4 @ 20 kg ha^{-1} significantly increases the yield of maize to the tune of 120% over control.

Ashoka *et. al*. (2009) reported that corn weight and corn yield were significantly improved with the application of RDF (150-75-45 kg NPK ha^{-1}) + $ZnSO_4$ @ 25 kg ha^{-1} over RDF alone.

Ashoka and Sunitha (2011) reported that application of 100% RDF (150-60-40 kg NPK ha^{-1}) +25 kg $ZnSO_4$ resulted in significant higher baby corn yield over RDF (150- 60- 40 kg NPK ha^{-1}) alone.

Boochi and Tano (1994) reported that application of organic manure increased the size of plant and promote early ripening of maize cobs but no cumulative effects were not observed on the growth of maize by combine application of highest rate of organic manure and urea.

Chandrashekara *et al.* (2000) revealed that application of poultry manure @ 10 t ha^{-1} + RDF (150:75:37.5 kg NPK ha^{-1}) recorded higher grain yield of maize (50.8 q ha^{-1}) and fodder (74.4 q ha^{-1}) over vermicompost @ 2.5 t ha^{-1} + 100% RDF.

Kumar and Bohra (2014) reported that application of 125% RDF over 100% RDF resulted in significant growth in green leaves, dry matter per plant, crop growth rate.

Dey (2000) confirmed from his field experiment that higher grain and straw yields (3640 and 9488 kg ha^{-1}) were obtained with 100% N, P, K +10 t FYM ha^{-1}, which were at par with yields obtained with 75% and 50% of fertilizers rates combined with 10 t FYM ha^{-1}.

Sahoo and Panda (2000) conducted a field experiment and found that application of $N:P_2O_5$: K_2O @ 80:40:40 kg ha^{-1} increased the grain yield from 2323 to 3036 kg ha^{-1} and 1420 to 3424 kg ha^{-1} in the subsequent year and it was also reported that application of inorganic fertilizer at the same rate + FYM increased the grain yield to 3269 and 3661 kg ha^{-1}, respectively.

Murali and Shetty (2001) reported that combined application of vermicompost @ 5 t ha^{-1} and NPK at 150:75:75 kg ha^{-1} had recorded significantly higher grain yield (4070 kg ha^{-1}) as compared to no vermicompost application (4070 kg ha^{-1}).

Nanjappa *et al.* (2001) reported that application of 50 or 75% recommended dose of fertilizer with 12 t FYM ha^{-1} or 2.7 t ha^{-1} vermicompost results in higher productivity of maize compared to application of either only inorganic fertilizer or organic sources. He also concluded that Integrated nutrient management resulted in better uptake and less loss of nutrients from the soil.

Deshmukh *et al.* (2002) found that application of compost @ 4 t ha^{-1} + 30% RDN (20 kg N ha^{-1}) could realize 63 to 67% of maize yield over 100% RDF (150: 75: 37.5 kg NPK ha^{-1} alone).

Abraham and Lal (2003) reported that use of farm compost along with poultry manure or vermicompost in combination with inorganic fertilizer showed synergistic effects on the growth on the growth and yield of the crops.

Basavaraj and Manjunath (2003) conducted a field experiment and found that significantly higher grain yield of maize (56.02 q ha^{-1}) was recorded with the application of poultry manure (1 t ha^{-1}) + 100% RDF (150: 75: 37.5 kg NPK ha^{-1})

when compared to FYM (5 t ha^{-1}) + RDF or vermicompost (2 t ha^{-1}) + RDF and control.

Jayaprakash *et al.* (2004) conducted a field trial where the treatment consists of three levels of organic manures *viz.* no organic manure, FYM @10 t ha^{-1}, VC @ 2 t ha^{-1} as main plot and under sub plot five level of inorganic fertilizers *viz.* 100, 125, 150, 175 and 200 % RDF were applied and the result reveal that there was significant increase in available nitrogen where vermicompost was applied over FYM and no organic treatment. It was also reported that application of vermicompost @ 2 t ha^{-1} recorded significantly higher P content as compared to other treatment.

Venkatesh *et al.* (2004) recorded that application of 60 kg P_2O_5 with 5 t FYM and 2 t lime ha^{-1} resulted in significant increase in yield, test weight, P uptake and PUE by maize and also with the application of lime and FYM along with P reduced the different forms of acidity and the exchangeable acidity registered a decline up to 72% on liming.

Chandankar *et al.* (2005) evaluated the effect of Farm Yard Manure @ 0-5 tha^{-1}, N:P:K @ 90:45:22.5, 120:60:30 and 150:75:37.5 kg ha^{-1} and plant density and reported that application of farm yard manure increased the plant height and highest NPK rate shows 34.1 % higher grain yield over the lowest yield and low plant density produce the taller plants with broad heavier ears.

Kumar *et al.* (2005) showed that application of 10 tonnes per ha of FYM with100% NPK found to increase the grain yield in maize and it was closely following by 100% NPK.

Barik *et al.* (2006) reported that with the application of 50% of recommended dose of NPK fertilizers with 10 t ha^{-1} vermicompost, significantly higher grain and straw yields were obtained when compared with 100% of NPK fertilizer. However, the values were statistically at par between 50 and 75% of recommended dose of NPK + vermicompost and always shows higher grain yield and straw yield of Kharif rice than similar combination of NPK and FYM.

Laxminarayana (2006) recorded highest organic carbon (8.0 g kg^{-1}) when 100% NPK + FYM @ 15 t ha^{-1} was applied followed by 100% NPK + poultry manure @ 5t ha^{-1} (8.0 g kg^{-1}) and 100% NPK +pig manure @ 5t ha^{-1} (7.6 g kg^{-1}).

Lourduraj (2006) after conducting a field trial on determining the optimum quantity of vermicompost for maize production under different levels of NPK fertilizer application and reported that with the application of 100% recommended NPK along with 5.0 t ha^{-1} of vermicompost was the optimum combination on plant height and dry matter production.

Choudhary *et al.* (2007) revealed that application vermicompost @ 10 t ha^{-1} + 120 kg N ha^{-1} through urea gave highest nitrogen content in grain and straw followed by FYM @ 15 t ha^{-1} + 120 N ha^{-1} through urea and were higher than other combination of organic manure and fertilizer.

Mucheru-Muna *et al.* (2007) investigated the effects of different soil-incorporated organic manure and mineral fertilizer inputs on maize yield and soil chemical properties over seven seasons and found that tithonia treatment (with or without half recommended rate of mineral fertilizer) gave the highest yield while the control treat gave the lowest yield.

Pandey *et al.* (2007) conducted an experiment and found that application of inorganic fertilizer level of 100, 60 and 40 kg ha^{-1} N, P_2O_5 and K_2O along with 10 t FYM ha^{-1} gave the grain yield and B:C ratio comparable to that of 100, 60 and 40 kg ha^{-1} N P_2O_5 and K_2O + FYM +25 kg $ZnSO_4$ ha^{-1} or 150, 75 and 60 kg ha^{-1} N, P_2O_5 and K_2O + FYM.

Pawar and Patil (2007) conducted a field experiment and found that the combined application of vermicompost *viz.* 2.5 and 5.0 t ha^{-1} and fertilizer *viz.,* 50, 75, and 100% RDF increases the yield of maize. Maximum grain yield of maize was obtained due to combined application of vermicompost of 5 t ha^{-1} and 100% recommended dose of fertilizer.

Naik *et al.* (2012) conducted a field experiment to study the effect of farm yard manure and biodigester liquid manure on growth and yield of maize (*Zea mays* L) and reported that application of FYM @ 12.5 t ha^{-1} + biodigester liquid manure equivalent @ 150 kg N ha^{-1} recorded significant increase in growth attributing characters like plant height (187.0 cm), number of leaves per plant (12.30), leaf area (4118.2 cm^2 per plant), leaf area index per plant (1.78), leaf duration (68.5 days) and dry matter accumulation (360.8 g per plant) and yield attributing characters grain weight per cob (15.1 g), cob length 17.0 cm), grain yield (55.1 q ha^{-1}) and stover yield (108.9 q ha^{-1}) compared with remaining treatment.

Bekeko (2014) reported that application of 4 t ha^{-1} FYM and 75, 60 kg ha^{-1} N and P increased maize yield (5.1 t ha^{-1} in 2009 to 8.15 t ha^{-1} in 2010) and harvest index (33 to 58%) at Chiro, Ethopia.

Mukherjee (2014) reported that application of FYM @ 2.5 t ha^{-1} + vermicompost @1.25 t ha^{-1} + forest litter @ 2.5 t ha^{-1} recorded higher grain and stover yield which were at par with application of vermicompost @ 2.5 t ha^{-1} + forest litter @5 t ha^{-1} and was superior to rest of the treatment. Application of organic manure also record maximum net returns (₹ 17.6 x 103 ha^{-1}) and benefit cost ratio (2.4) where FYM @ 2.5 t ha^{-1} + vermicompost @ 1.25 t ha^{-1} + forest litter @ 2.5 t ha^{-1}.

Priya *et al.* (2014) in a field study conducted at Udaipur the result shows that the growth of maize crop at different stages and harvest shows maximum Leaf area index, Dry matter accumulation and Crop growth rate. It is also confirmed that the highest maize grain and Stover yield were obtained by applying 100% NPK +FYM 10t ha^{-1} followed by 150% NPK.

Sanjivkumar (2014) after an experimental study on use of organic and inorganic fertilizer on the soil fertility status of Entic Haplustart in maize that treatment receiving vermicompost@ 5t ha^{-1} with 75 percent recommended dose of fertilizer RDF show superior over other treatment.

Jangir *et al.* (2015) found that there was increase in plant height, ear height, number of leaves and test weight with increase in P and Zn doses but beyond 60 kg P and 10 kg Zn ha^{-1} there was decrease in root dry weight.

Imranuddin and Khalil (2017) reported that days to maturity and biological yield of maize were significantly enhanced with increment of N, P, K and Zn and maximum biological yield was recorded at N (250 kg N ha^{-1}), P (175 kg P ha^{-1}) and

Zn (15 kg Zn ha^{-1}) across both years. The dry matter was higher with 250 kg N ha^{-1}, 75 kg P ha^{-1} and 15 kg Zn ha^{-1}.

Singh *et al.* (2017) reported that application of 75% RDF + vermicompost 5t/ha + FYM (5t ha^{-1}) + azotobacter gave best result in term of growth character like Plant height, Dry matter accumulation, Leaf area Index and also shows positive influence in yield parameter like cob per plant, cob length, number of grains per cob, number of grains per row, shelling percentage, seed index, grain yield, biological yield and harvest index.

Tomar *et al.* 2017. Reported that combination of 100% NPK + 5 t FYM + azotobactor + PSB recorded higher mean growth attributes *viz.* plant height, LAI at 60 DAS and dry weight per plant.

Wanniang and Singh (2017) conducted an experiment in Umiam Meghalaya and found that treatments 75 % RDF + 5 t FYM ha^{-1}, 50 % RDF + 7.5 t FYM ha^{-1}, 100 % RDF ha^{-1} and 75 % RDF + 2.5 t FYM ha^{-1} recorded significantly higher values of plant height, CGR, leaf area and dry matter accumulation over 50 % RDF + 5 t FYM ha^{-1} and control treatments. As for Number of days taken to attain the stages of 50% tasselling treatment 75 % RDF + 5 t FYM ha^{-1} took significantly lesser number of days for these stages than other treatment combinations.

Wailare and Kesarwani (2017) conducted and observed that the growth parameter, Plant height and Leaf area and yield parameter *viz.* Number of grains per cob, Cob weight per plant, Test weight and Stover Yield were significantly higher under Integrated nutrient management of Poultry or Farmyard manure and recommended dose of fertilizer (RDF) which are statistically on par but comparatively higher than 100% RDF.

Kumar *et al.* (2018) conducted an experiment in Faizabad, U.P. and found that maximum grain yield of maize was recorded with application of 75% NPK+ FYM @ 6t ha^{1} + $ZnSO_4$ @25 kg ha^{-1} as soil application + $FeSO_4$ @ 10 kg ha^{-1} as soil application.

Raman and Suganya (2018) in their experiment which was conducted in Annamalainagar, Tamil Nadu observed that the growth components of hybrid maize *viz.* Plant height, Leaf area index, Dry matter production and yield component such as Cob length, Cob diameter, number of grains per cob, 100 grain weight, grain yield, Stover yield and harvest index were favourably influenced with 100% RDF+ Press mud compost @ 5t ha^{-1}. From the experiment they concluded that 100% RDF+ Press mud compost @ 5t ha^{-1} in hybrid maize will be appropriate for Integrated nutrient management.

2.5.2. Effect of Integrated nutrient management on nutrient uptake and soil properties

Verma (1991) reported that application of FYM @ 5.0 to 10.0 t ha^{-1} and application of fertilizer @ 50 to 100% of recommended doses of N, P and K increased the nutrient content in maize grown on clayey soil.

Das *et al.* (1992) revealed that when poultry manure @ 5 t ha^{-1} along with SSP are applied there was an increase in the uptake of Ca, Mg and K along with soil organic carbonic content.

Pawar (1996) reported that application of vermicompost @ 5.0 t ha^{-1} and 100% RDF recorded highest available N content of soil (261.96 kg ha^{-1}) and it was significantly superior to all other treatment combinations.

Tompe and More (1996) recorded bulk density was highest (1.19 and 1.24 g cm^{-3}) in control where as it was lowest (1.10 g cm^{-3} and 1.15 g cm^{-3}) with treatment 15 t press mud cake ha^{-1}.

Reddy and Reddy (1999) recorded significantly increase in the available macronutrients (N, P and K) with integrated use of manure and fertilizers. It was also confirmed that nutrient availability was highest in treatments with poultry manure, closely followed by vermicompost, biogas slurry and farm yard manure.

Basavaraj and Manjunath (2003) confirmed that application of poultry manure (1 t ha^{-1}) + recommended N and K has significantly higher P uptake (57.48 kg ha^{-1}) over no manure application.

Jayaprakash *et al.* (2004) conducted a field trial where the treatment consists of three levels of organic manures *viz.* no organic manure, FYM @ 10 t ha^{-1}, VC @ 2 t ha^{-1} as main plot and under sub plot five level of inorganic fertilizers *viz.* 100, 125, 150, 175 and 200 % RDF were applied and the result reveal that there was significant increase in available nitrogen where vermicompost was applied over FYM and no organic treatment. It was also reported that application of vermicompost @ 2 t ha^{-1} recorded significantly higher P content as compared to other treatment.

Venkatesh *et al*. (2004) reported that application of FYM resulted in significant increase of zinc concentration and Fe, Mn, Zn and Cu uptake while application of liming resulted in significant reduction in available Mn and Zn content of soil.

Guggari *et al.* (2007) observed that there is an increase in organic carbon (0.3 to 0.42%) in the treatments where organic manures or crop residues were integrated with inorganic fertilizers alone (0.32%).

Mucheru-Muna *et al*. 2007 revealed that after 2 years of trial, total soil carbon and nitrogen content were improved with the application of organic residue and manure in particular improve soil calcium content.

Galavi *et al.* (2011) reported that Grain phosphorus and zinc concentration were significantly increased by micronutrients and phosphorus fertilizers treatments.

Sarwar *et al*. (2012) reported that Highest N uptake, *viz.* 98.7 kg ha^{-1} was observed with 50% + 50% (CF + FYM) and 8 kg Zn ha^{-1} application. Similarly, maximum Zn uptake, *viz.* 250.7 g ha^{-1} was observed with 75% + 25 % (CF + FYM) and 4 kg Zn ha^{-1} application.

Menzeke *et al*. (2014) reported that under combined application of mineral N, P, K, Zn and leaf litter, maize grain gave highest Zn concentration up to 35 mg kg^{-1}.

Sanjivkumar (2014) observed that application of vermicompost @ 5 t ha^{-1} + 75 percent RDF increase the Crude protein (16.67%) and Starch (81.34%) content in maize crop.

Jangir *et al.* 2015 reported that phosphorus and zinc uptake also increased with increasing P and Zn level upto 60 kg ha^{-1} and 15 kg ha^{-1} respectively. It is also observed that P and Zn application had synergistic impact on protein, lysine and tryptophan content of grain where maximum contents were found with the highest doses of P and Zn.

Tomar *et al.* 2017. The result of the trial revealed that combination of 100% NPK + 5t FYM + azotobactor +PSB recorded higher mean quality parameter *viz.* protein content (8.38 %) and protein yield (445.4 kg ha^{-1}), total nutrient uptake.

Wailare and Kesarwani (2017) reported that post-harvest soil physic- chemical properties like organic carbon and available nitrogen were significantly improved under 5t PM + 50% RDF. Whereas soil available phosphorus was recorded maximum under 5t PM + 100% RDF compared to control and rest of the treatments combination.

Kumar and Salakinkop (2018) revealed that among the interactions treatment combination involving seed treatment, soil application of FYM enriched $ZnSO_4$ and $FeSO_4$ each @ 15 kg ha^{-1} and foliar spray recorded the higher grain yield, Stover yield and yield parameter *viz.* cob length, cob weight, grain weight per cob, number of grain per cob and test weight and also higher values in growth parameter *viz.* plant height, leaf area index and dry matter production compared to no seed, soil and foliar application of Zn and Fe.

2.5.3. Effect of Integrated nutrient management on economics of maize cultivation

Chandrashekara *et al.* (2000) reported that the treatment consists of poultry manure @ 10 t ha^{-1} along with 100% RDF gave significantly higher net returns by producing higher grain and stover yield than the other organic manures and only chemical fertilizers.

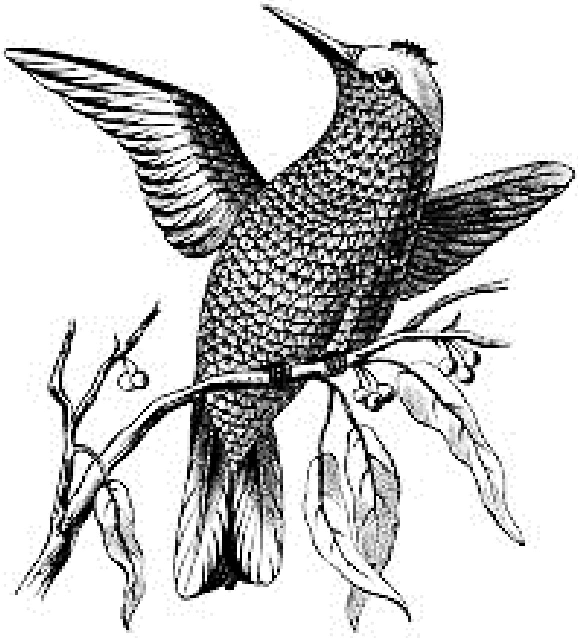
Channabasavana *et al.* (2002) concluded that application of poultry manure @ 1 t ha^{-1} with 75% was on par with 100% NPK indicating a saving of 25% NPK.

Mucheru-Muna *et al.* (2007) conducted an experiment on effects of different soil-incorporated organic and mineral fertilizer inputs on maize yield and the result of the economic analysis indicated that on average across the seven seasons, tithonia with half recommended rate of mineral fertilizer treatment recorded the highest net benefit while the control recorded the lowest.

Sanjivkumar (2014) observed that application of vermicompost @ 5 t ha^{-1} + 75 percent RDF increase the Crude protein (16.67%) and Starch (81.34%) content in maize crop.

The result of the trial revealed that combination of 100% NPK + 5t ha^{-1} FYM + azotobactor +PSB recorded higher mean quality parameter *viz.* Protein content (8.38 %) and Protein yield (445.4 kg ha^{-1}), total nutrient uptake (Tomar *et al.,* 2017).

Wailare and Kesarwani (2017) reported that post-harvest soil physic- chemical properties like Organic carbon and available Nitrogen were significantly improved under 5t ha^{-1} PM + 50% RDF. Whereas, soil available Phosphorus was recorded maximum under 5t ha^{-1} PM + 100% RDF compared to control and rest of the treatment combinations.



CHAPTER III

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment entitled **"Zinc Biofortification of maize (*Zea mays* L.) and Integrated nutrient management in Foothill condition of Nagaland"** were conducted during the kharif season of 2016 and 2017 in the Agronomy experimental farm of School of Agricultural Sciences and Rural Development (SASRD), Nagaland, Medziphema Campus, Nagaland. The details of the materials used and methods adopted during the course of investigated have been discussed in this chapter.

3.1. General information

3.1.1. Geographical location of the experimental field

The experiment was conducted at the experimental farm situated at Medziphema, in foot hill situation of Nagaland with the geographical location at about 25^0 $45^/$ $43^{//}$ North latitude and 95^0 $53^/$ $4^{//}$ east longitude and altitude of 310 meters above mean sea level.

3.1.2. Climatic condition

The climatic condition of the Medziphema is sub- tropical. The rainy season usually stars by May and extends upto September. Climatic conditions of the experimental site also exhibit high humidity and moderate temperature with medium to high rainfall. The mean temperature ranges from 21^0C to 31^0C during summer and rarely goes below 8^0C in winter due to high atmospheric humidity. The average rainfall varies between 2000-2500 mm starting from April to March remains comparatively dry.

The meteorological data of weather parameters viz., temperature, rainfall, relative humidity and sunshine hours for the period of experimentation form July to October during the year 2016 and 2017 were obtained from meteorological observatory, ICAR and are presented in Table 1 and illustrated in Fig 1.

3.1.2.1. Temperature

The data shows that the monthly mean maximum temperature during the period of experiment varied from 32.68^{0}C to 33.53^{0}C in the year 2016 and 31.70^{0}C to 31.82^{0}C in the year 2017. The highest maximum temperature was observed in the month of August (33.53^{0}C) 2016 and September (31.82^{0}C) 2017 while lowest minimum temperature was recorded during September (23.98^{0}C) 2016 and June (24.07^{0}C) 2017.

3.1.2.2. Relative Humidity

The average relative humidity recorded during the growing period is ranging from maximum of 93.48% in the month of September 2016 and 95.04% in the month of September 2017 to a minimum of 68.80% in the month of June 2016 and 72.23% in the month of 2017.

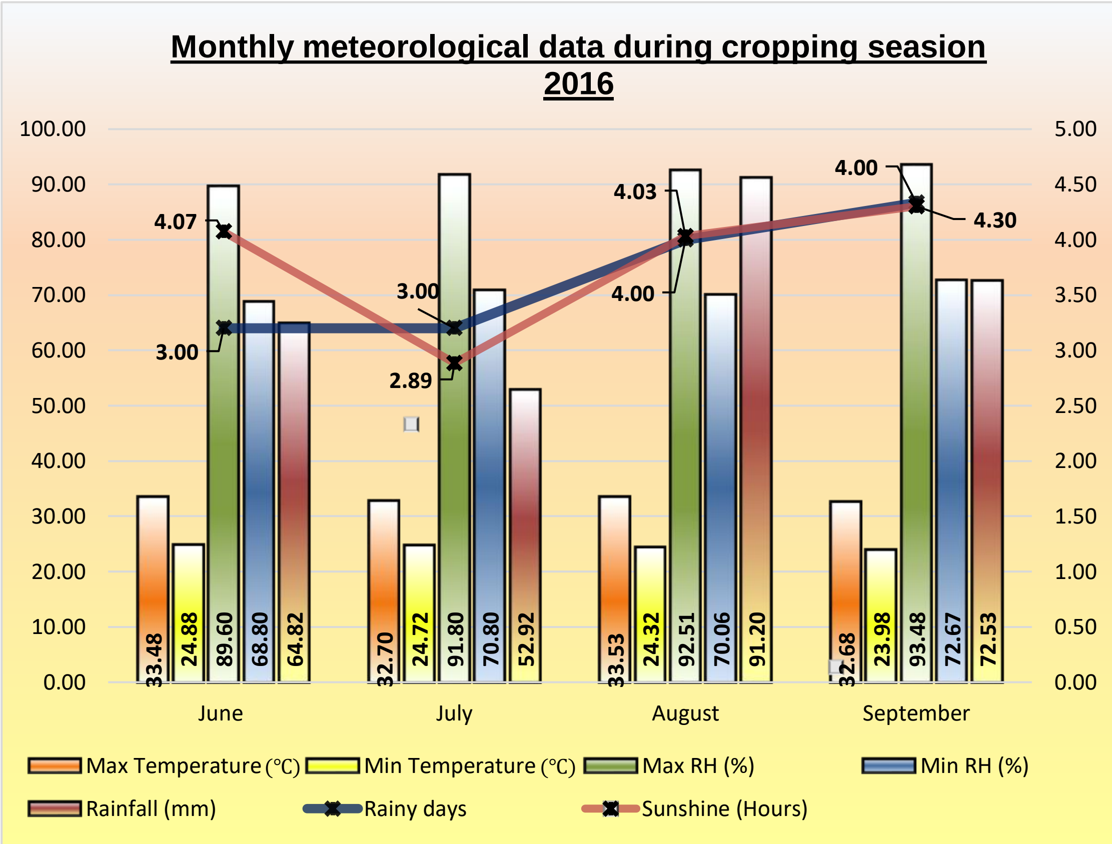
3.1.2.3. Rainfall

The total rain fall received during the two consecutive crop growing period of maize was recorded to be 281.47 mm in the year 2016 and 334.79 mm in the year 2017.

Table 3.1: Meteorological data during the period of experimentation (2016-2017)

Year / Parameters	2016				2017			
	June	**July**	**August**	**September**	**June**	**July**	**August**	**September**
Max Temperature (°C)	33.48	32.70	33.53	32.68	31.81	31.70	31.78	31.82
Min Temperature (°C)	24.88	24.72	24.32	23.98	24.07	24.62	24.62	24.53
Max RH (%)	89.60	91.80	92.51	93.48	93.03	93.19	93.89	95.04
Min RH (%)	68.80	70.80	70.06	72.67	74.11	73.81	72.23	73.61
Rainfall (mm)	64.82	52.92	91.20	72.53	88.52	94.25	100.14	51.88
Rainy days	3.00	3.00	4.00	4.00	4.00	5.00	3.00	2.00
Sunshine (Hours)	4.07	2.89	4.03	4.30	3.42	3.24	3.50	4.59

Sources: ICAR, Research complex for NEH Region, Nagaland centre, Jharnapani, Nagaland.



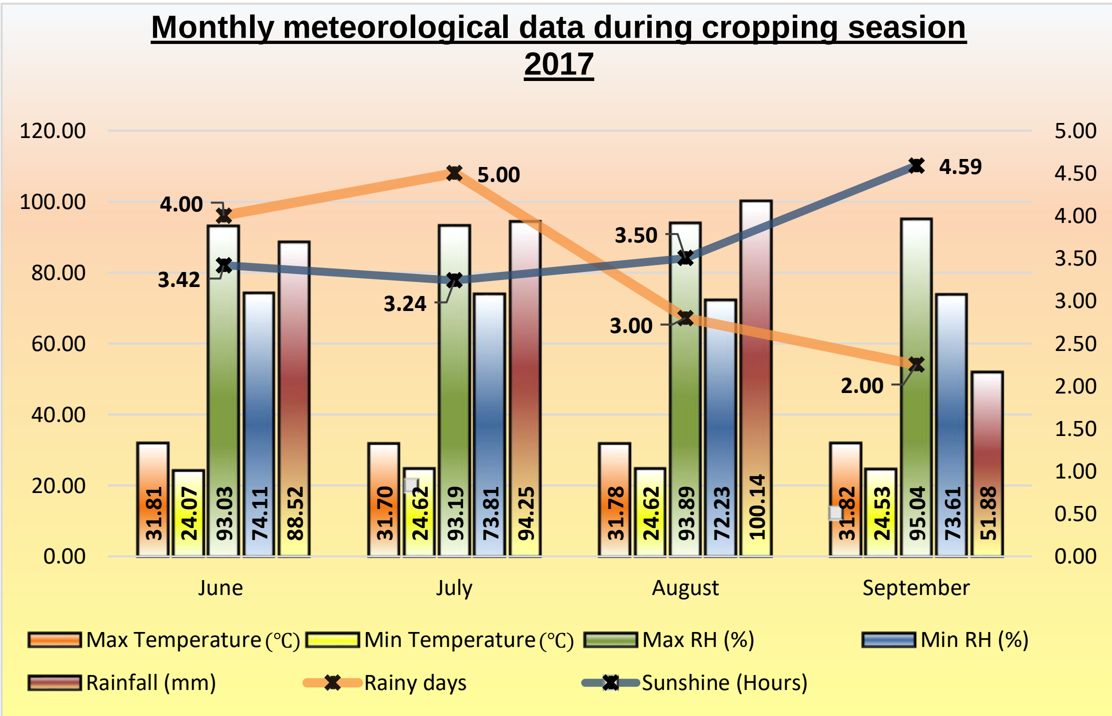


Fig 3.1: Meteorological data during the period of experiment

3.1.3. Soil condition of the experimental site

Soil samples from the study area were analysed prior to experimentation. Representative soil samples were collected with the help of soil auger from the top 20 cm soil layer depth from several spots of experimental site. Mechanical and chemical analysis were done to determine the physico-chemical properties of the soil. The results thus obtained are interpreted in Table 3.2.

Table 3.2: Mechanical and chemical analysis of soil.

Sl.No.	**Particulars**	**Value**	**Interpretation**	**Methods adopted**
A.	**Mechanical composition**			
1.	Sand (%)	49.6	Sandy clay loam	Bouyoucos Hydrometer method (Chopra and Kanwar, 1976)
2.	Silt (%)	28.3		
3.	Clay (%)	22.1		
4.	Bulk density (mg/m^3)	0.95		
B.	**Chemical properties**			
1.	pH	4.5	Acidic	Systronic glass electrode pH meter (Jackson,1973)
2.	Electric conductivity (ds/m)	0.24 dSm^{-1}		Conductivity bridge method (Jackson, 1973)
3.	Organic carbon	1.25	High	Walkley and Black,1934
4.	Available nitrogen (kg ha^{-1})	282.64	Medium	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available phosphorus (kg ha^{-1})	20.52	low	Bray’s No.1 method (Bray and Kurtz, 1945)
6.	Available potassium (kg ha^{-1})	150.47	Medium	Neutral normal ammonium method (Jackson, 1973)
7.	Available zinc (mg/kg)	0.45 mg/kg	Low	Atomic absorption spectrometer (Lindsay and Norvell, 1978)

Table 3.3: Chemical analysis of FYM, poultry manure and vermicompost.

Sl.No.	Particulars	Value	Methods adopted
B.	**FYM**		
1.	Available nitrogen (% kg^{-1})	0.52 %	Alkaline permanganate method (Subbiah and Asija, 1956)
2.	Available phosphorus (% kg^{-1})	0.3 %	Bray's No.1 method (Bray and Kurtz, 1945)
3.	Available potassium (% kg^{-1})	0.21 %	Neutral normal ammonium method (Jackson, 1973)
	Poultry manure		
4.	Available nitrogen (% kg^{-1})	7.42 %	Alkaline permanganate method (Subbiah and Asija, 1956)
5.	Available phosphorus (% kg^{-1})	6.3 %	Bray's No.1 method (Bray and Kurtz, 1945)
6.	Available potassium (% kg^{-1})	3.6 %	Neutral normal ammonium method (Jackson, 1973)
	Vermicompost		
7.	Available nitrogen (% kg^{-1})	1.9 %	Alkaline permanganate method (Subbiah and Asija, 1956)
8.	Available phosphorus (% kg^{-1})	1.32 %	Bray's No.1 method (Bray and Kurtz, 1945)
9.	Available potassium (% kg^{-1})	1.49 %	Neutral normal ammonium method (Jackson, 1973)

The findings of the table indicate that the soil of the experimental plot was sandy loam in texture and well drained. Organic carbon, nitrogen, phosphorus and potassium, and Zinc content were medium and it was also noted that the soil of the experimental site was acidic in reaction.

3.2. Details of the experiment

The experiment was carried out at the same site during two consecutive *kharif* season of 2016 and 2017. The experimental field was laid out in Split–Split plot design with three replications. Each replication is divided into three main plots for main plot factor (organic manure) further which is divided into three subplots for subplot factor (RDF) and the subplot into three sub-subplot for sub–subplot factor (Zinc).

3.2.1. Layout and design

The specification of the design, plot size and inter plot spacing of the experiments are indicated below (Fig. 3.2):

a)	Design	: Split – Split Plot
b)	Number of Replications	: 3
c)	Number of Experimental Units	: 81
d)	Spacing	: 60 cm x 30 cm
e)	Plot Size (each experimental unit)	: 5 m x 4 m
f)	Net plot size	: 3.8 m x 3.4 m
g)	Inter plot spacing	: 0.5 m
h)	Inter replication spacing	: 1 m
i)	Gross Experimental area	: 1620 m^2
j)	Net Experimental area	: 1318.52 m^2
k)	Variety	: HQPM-1

3.2.2 Treatments details

The treatment consists of three factors i.e., organic manure, level of fertilizer and level of Zinc. The main plot factors consist three level of organic manures *i.e*. M_1 (10 t ha^{-1} FYM), M_2 (4 t ha^{-1} PM) and M_3 (2 t ha^{-1} VC); subplot factor consists of three level of fertilizer *i.e*. F_1 (0% RDF), F_2 (50% RDF) and F_3 (100% RDF); lastly sub – subplot factors with three level of Zinc i.e. Z_1 (0 kg ha^{-1}), Z_2 (15 kg ha^{-1}) and Z_3 (30 kg ha^{-1}). The details of treatment combinations are mentioned below:

The treatment consists of three factors: -

1.	Organic manures	:	M_1= 10 t ha^{-1} FYM
			M_2= 4 t ha^{-1} PM
			M_3= 2 t ha^{-1} VC
2.	Fertilizer levels	:	F_1= 0% RDF
			F_2= 50% RDF
			F_3 = 100% RDF
3.	Zinc level	:	Z_1= 0 kg ha^{-1} Zn
			Z_2= 15 kg ha^{-1} Zn
			Z_3= 30 kg ha^{-1} Zn

***RDF = Recommended dose of fertilizer,**

3.2.3 Treatment combinations

The details of the treatment combinations are given below:

Treatment notations	Treatment combination
$T_1(M_1F_1Z_1)$	10 t ha^{-1} FYM +0% RDF + 0 kg ha^{-1} Zn
$T_2(M_1F_1Z_2)$	10 t ha^{-1} FYM + 0% RDF + 15 kg ha^{-1} Zn
$T_3(M_1F_1Z_3)$	10 t ha^{-1} FYM + 0% RDF + 30 kg ha^{-1} Zn
$T_4(M_1F_2Z_1)$	10 t ha^{-1} FYM + 0% RDF + 0 kg ha^{-1} Zn
$T_5(M_1F_2Z_2)$	10 t ha^{-1} FYM + 0% RDF + 15 kg ha^{-1} Zn
$T_6(M_1F_2Z_3)$	10 t ha^{-1} FYM + 0% RDF + 30 kg ha^{-1} Zn
$T_7(M_1F_3Z_1)$	10 t ha^{-1} FYM + 0% RDF + 0 kg ha^{-1} Zn
$T_8(M_1F_3Z_2)$	10 t ha^{-1} FYM + 0% RDF + 15 kg ha^{-1} Zn
$T_9(M_1F_3Z_3)$	10 t ha^{-1} FYM + 0% RDF + 30 kg ha^{-1} Zn

$T_{10}(M_2F_1Z_1)$	4 t ha^{-1} PM + 50% RDF + 0 kg ha^{-1} Zn
$T_{11}(M_2F_1Z_2)$	4 t ha^{-1} PM + 50% RDF + 15 kg ha^{-1} Zn
$T_{12}(M_2F_1Z_3)$	4 t ha^{-1} PM + 50% RDF + 30 kg ha^{-1} Zn
$T_{13}(M_2F_2Z_1)$	4 t ha^{-1} PM + 50% RDF + 0 kg ha^{-1} Zn
$T_{14}(M_2F_2Z_2)$	4 t ha^{-1} PM + 50% RDF + 15 kg ha^{-1} Zn
$T_{15}(M_2F_2Z_3)$	4 t ha^{-1} PM + 50% RDF + 30 kg ha^{-1} Zn
$T_{16}(M_2F_3Z_1)$	4 t ha^{-1} PM + 50% RDF + 0 kg ha^{-1} Zn
$T_{17}(M_2F_3Z_2)$	4 t ha^{-1} PM + 50% RDF + 15 kg ha^{-1} Zn
$T_{18}(M_2F_3Z_3)$	4 t ha^{-1} PM + 50% RDF + 30 kg ha^{-1} Zn
$T_{19}(M_3F_1Z_1)$	2 t ha^{-1} VC + 100% RDF + 0 kg ha^{-1} Zn
$T_{20}(M_3F_1Z_2)$	2 t ha^{-1} VC + 100% RDF + 15 kg ha^{-1} Zn
$T_{21}(M_3F_1Z_3)$	2 t ha^{-1} VC + 100% RDF + 30 kg ha^{-1} Zn
$T_{22}(M_3F_2Z_1)$	2 t ha^{-1} VC + 100% RDF + 0 kg ha^{-1} Zn
$T_{23}(M_3F_2Z_2)$	2 t ha^{-1} VC + 100% RDF + 15 kg ha^{-1} Zn
$T_{24}(M_3F_2Z_3)$	2 t ha^{-1} VC + 100% RDF + 30 kg ha^{-1} Zn
$T_{25}(M_3F_3Z_1)$	2 t ha^{-1} VC + 100% RDF + 0 kg ha^{-1} Zn
$T_{26}(M_3F_3Z_2)$	2 t ha^{-1} VC + 100% RDF + 15 kg ha^{-1} Zn
$T_{27}(M_3F_3Z_3)$	2 t ha^{-1} VC + 100% RDF + 30 kg ha^{-1} Zn

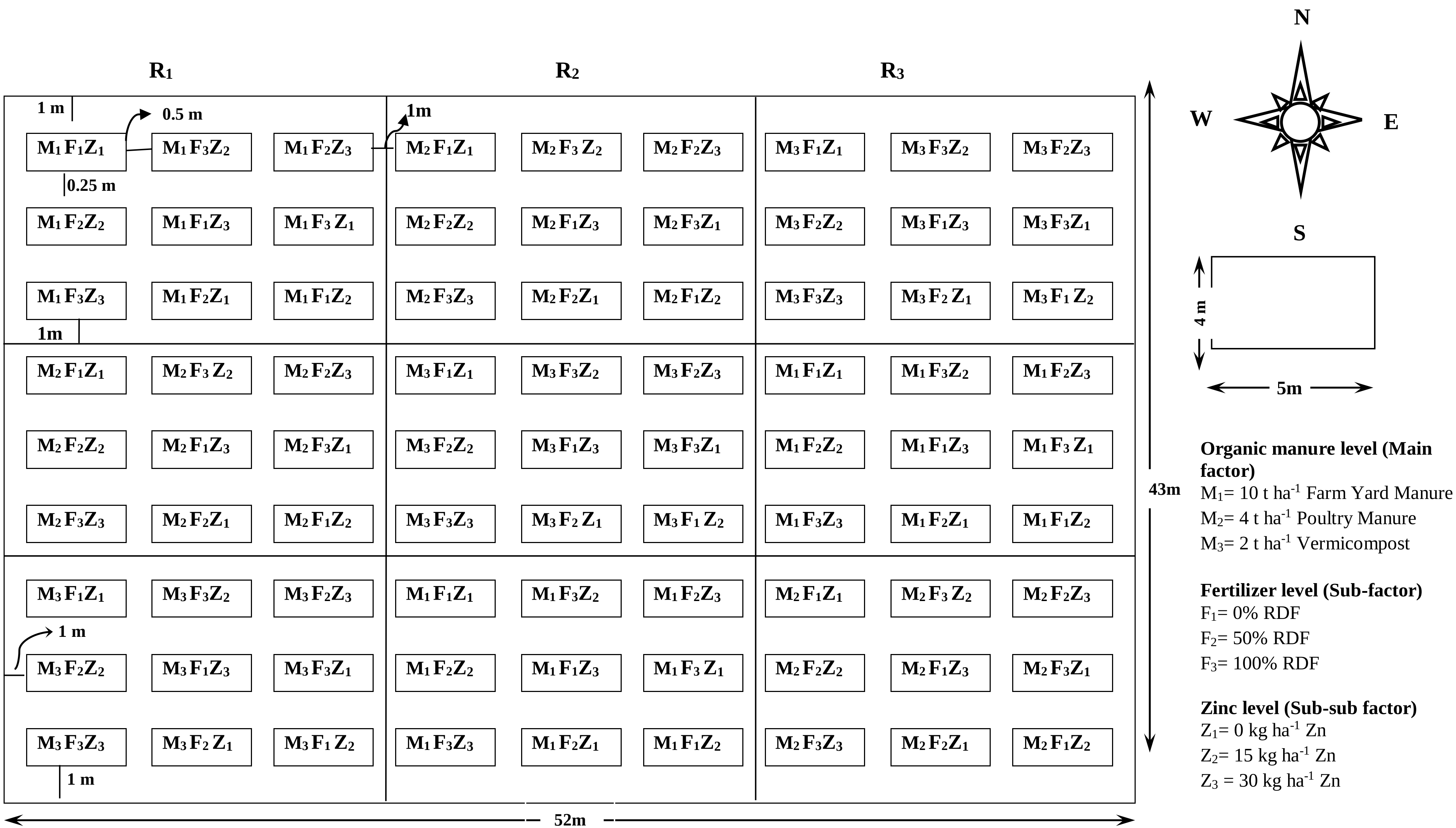


Fig. 3.2: Field layout of the experiment.

3.3. Cultivation details

3.3.1. Variety

Quality Protein Maize Hybrid "HQPM-1" is a single cross hybrid released from Haryana Agricultural University in the year 2006, was selected as a test variety for the experiment. It has a yellow flint grain with high lysine and tryptophan maturing in 100-105 days with an average yield potential of 57-62 q ha^{-1}.

3.3.2. Selection and preparation of the field

The field experiment was carried out in the experimental field of agronomy block at SASRD farm, Medziphema. The experimental field was ploughed with tractor drawn disc plough in the first week of May followed by harrowing in the second week of May and levelled properly. All the stubbles were removed and then the field was laid out to the plan and design of the experimental field.

3.3.3. Manures and fertilizers

Locally available well decomposed farm yard manure, vermicompost and poultry manure were analysed for their nutrient content and the results are presented in Table 3.3. Required quantities of different organic manures as per the treatments were broadcasted and mixed with the soil thoroughly 20 days before sowing.

Different level of fertilizer (0% RDF, 50% RDF and !00% RDF) and Zinc was applied on the day before sowing of the crop. Fifty percent of the different dose of Nitrogen as per the treatment in the form of Urea and the whole dose of P_2O_5 in the form of SSP and K_2O in the form of MOP were applied in the experimental plot as basal dose along the open furrows. Remaining 50% Nitrogen was applied in two splits at Knee height and silking stage of the crop, respectively.

3.3.4. Zinc biofortification

Biofortification is the process of increasing the micronutrient content of staple crops to improve the nutrition and hence health outcomes of populations. Which can be achieved through agronomic practices, conventional breeding or biotechnology-based approaches like genetic engineering and genome editing. Agronomic biofortification is the application of micronutrient-containing mineral fertilizer (blue circles) to the soil and/or plant leaves (foliar), to increase micronutrient contents of the edible part of food crops. In the present investigation agronomic biofortification of Zinc was carried out using $ZnSO_4$. Where three doses of $ZnSO_4$ *i.e.*, Z_1 ($ZnSO_4$ @ 0 kg ha^{-1}), Z_2 ($ZnSO_4$ @ 15 kg ha^{-1}) and Z_3 ($ZnSO_4$ @ 30 kg ha^{-1}) were tested. $ZnSO_4$ as per the treatment were applied in the experimental plot as basal dose along the open furrows on the day before sowing of the crop.

3.3.5. Seed and Sowing

Healthy and clean seeds were sown in the open furrows in lines by dibbling 2 seeds per hill with a spacing of 60 cm x 30 cm at the depth of 3-5 cm. The sowing was done on 1st June in the year 2016 and 2nd June in the year 2017.

Table 3.4 Calendar and mode of operation during experimentation.

Sl.no	Type of operation	Date and year		Mode of operation
		2016	2017	
1.	Collection of soil sample	1st May	3rd May	Manual
2.	Primary tillage	4th May	5th May	Tractor drawn disc plough
3.	Secondary tillage	7th May	8th May	Tractor drawn harrow
4.	Levelling and layout	10th May	12thMay	Manual
5.	Application of organic manure	11thMay	13th May	Manual
6.	Application of fertilizer	31st May	1st June	Manual
7.	Sowing	1st June	2nd June	Manual
8.	Irrigation	1st June	2nd June	Manual
9.	Gap filling and thinning	16th June	19thJune	Manual
10.	Weeding and earthing up			Manual
	First weeding	22nd June	29th June	
	Second weeding	18th July	26th July	
11.	Plant sampling			Manual
	First plant sampling	1st July	2nd July	

	Second plant sampling	31st July	1st August	
	Third plant sampling	30th August	1st September	
	Forth plant sampling	At Harvest	At harvest	Manual
12.	Top dressing and irrigation			Manual
	First top dressing	24th June	26th June	
	Second top dressing	20th July	24th July	
13.	Application of insecticide	21st July	15th July	Knapsack sprayer
14.	Harvesting	12th September	14th September	Manual
15.	Collection of post-harvest soil samples	14th September	15th September	Manual

3.3.6. Intercultural operations

Gap filling was done at 10 DAS to maintain the optimum plant population in the field. Similarly, thinning was carried out at 15 DAS keeping one plant with a view to obtain optimum plant population. Hand weeding was done with the help of Khurpi whenever required. Earthing up was done at 30 DAS.

3.3.7. Insect pest and disease management

'Malathion dust' was applied to protect the crop against termites and ants before sowing. "Furadan" @ 2-3 granules were applied on the top leaf whorl to control shoot borer at 20-30 DAS.

3.3.8. Harvesting

The cobs from each plant of every treatment were handpicked from the standing fully matured crop on 12/09/2016 and 14/09/2017 during first and second year of the experiment. Thereafter the plant (Stover) was harvested from all the plots separately. The harvested, tagged plants were kept separately for taking further observations. Dehusking was done and the cobs were further sun-dried. The seeds were shelled manually with the help of maize sheller, cleaned and sun-dried till a constant weight received and data were recorded for yield and yield attributes.

3.4. Biometrical observation

3.4.1. Growth attributes

For recording the growth attributes, five plants were selected randomly from each plot.

3.4.1.1. Plant height (cm)

Plant height from the five randomly selected plants from the middle rows was recorded at 30, 60 and 90 days after sowing (DAS). Plant height was measured by linear scale from the ground level to the terminal apex. The mean height from the selected plants was taken as the score for each plot.

3.4.1.2. Number of green leaves^{-1}

The number of leaves per plant was determined by counting the leaves of the five tagged plants from the middle row at 30, 60 and 90 DAS and average values were taken to compute the score.

3.4.1.3. Stem diameter (cm)

The stem diameter of the randomly selected five plant in the middle row was measured by using vernier calliper at the base of the maize plant at 30, 60 and 90 days after sowing (DAS), subsequently the average values were taken for computing the score.

3.4.1.4. Shoot dry weight (g plant^{-1})

Five plants were collected randomly from each plot and was sun dried for a week, then oven dried at 65ºC till constant weight was attained and their weight was taken using electronic balance. The average values were recorded as shoot dry weight (g plant^{-1}).

3.4.1.5. Days to 50 per cent tasselling

Number of days taken from the date of sowing to the stage when 50 per cent of the plants in the plot showed extrusion of tassels was recorded and expresses as number of days to 50 per cent tasselling.

3.4.1.6. Days to 50 per cent silking

Number of days taken from the date of sowing to the stage when 50 per cent of the plants in the plot showed extrusion of silk was recorded and expresses as number of days to 50 per cent silking.

3.4.1.7. Leaf Area Index (LAI)

Leaf area index (LAI) is defined as the ratio of leaf area to the area of ground cover. To calculate leaf area length and maximum width of leaves of five randomly tagged plants were measured using a meter scale during 30, 60 and 90 DAS. Then the leaf area was worked out as per the formula suggested by Montgomery (1911).

Leaf area per plant = Length x Maximum width x 0.75

The LAI was worked out using the formula (Watson, 1947). The LAI of the five tagged plants were taken at 30, 60 and 90 DAS.

$$\text{LAI} = \frac{Leaf\ area\ per\ plant}{Ground\ area}$$

3.4.1.8. Crop Growth rate (CGR) (gm m^{-2} day^{-1})

Crop Growth Rate (CGR) expresses the gain in dry matter production of the crop per unit land area per unit time and is expresses as gram per meter square per day (gm m^{-2} day^{-1}). Five plants were taken from each plot, oven dried and their dry weight was taken. It is calculated according to the formula given by Watson (1952).

$$\text{CGR} = \frac{W2-W1}{t2-t1}$$

Where, W_1 and W_2 was the dry weight of the aerial plants per unit area gained at time t_1 and t_2 respectively. CGR were calculated at 0-30 DAS, 30-60 DAS and 60-90 DAS days interval.

3.4.2. Yield attributes

3.4.2.1. Number of cobs plant^{-1}

The total number of cobs from 5 randomly tagged plants in each plot were counted and the average was worked out to obtain the number of cobs plant^{-1}.

3.4.2.2. Length of cob (cm)

After dehusking, the length of the five cobs was measured with the help of the linear scale from the bottom to the tip of cob. The average length of the tagged plants was worked out and recorded as length of cob (cm).

3.4.2.3. Weight of cob (g)

The cobs from the tagged plants from each plot were selected, dehusked and weight and the average value was recorded as cob weight.

3.4.2.4. Cob girth (cm)

Randomly selected five cobs from the tagged plants from each plot at the time of harvesting were obtained and diameters of each cob was measured separately using vernier calliper and the average value was worked out and recorded as cob diameter (cm).

3.4.2.5. Number of grain cob^{-1}

Randomly selected five cobs from the tagged plants from each plot were shelled individually and total grains were counted. The average was computed and expressed as number of grains cob^{-1}.

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

After counting of the number of grains plant$^{\mathbf{-1}}$ the weight of grain of the cobs was taken and their average weight had been expressed as grain weight cob^{-1} (g).

3.4.2.7. Test weight (g)

From the grain of individual plot, grain samples for test weight were taken randomly and 100 grain were counted and weighed separately to get the test weight (g) of grains.

3.4.2.8. Grain yield (kg ha^{-1})

After harvesting the crop from the demarcated area, the produce from each experimental plot was sundried, cleaned thoroughly and weighed (g). The grain yield per plot hence obtained was converted into kg ha^{-1}.

3.4.2.9. Stover yield (kg ha^{-1})

The plant (stover) harvested from each plot was sun-dried for a week and their weight was taken and recorded separately and thereafter stover yield was converted into kg ha^{-1}.

3.5 Soil analysis

Pre-sowing and post-harvest soil samples from each experimental plot were collected with the aid of auger from each block. The samples were bulked and air-dried at room temperature of between 25 and 27^0C. After grinding, the soil samples were allowed to pass through a 2.0 mm sieve and kept for chemical analysis.

3.5.1. Soil pH

The soil pH was determined in 1:2 soil-water suspensions at 25^oC and analysed using glass electrode pH meter (Richards, 1954).

3.5.2. Electrical conductivity (EC)

The electrical conductivity (EC) was determined using conductivity bridge (Richards, 1954) in 1:2 soil-water suspension at 25^oC.

3.5.3. Organic carbon

Organic carbon in soil was determined using alkaline potassium permanganate method outlined by Walkiey and Black (1934) and expressed in percentage as described by Jackson (1973).

3.5.4 Available Nitrogen

The available nitrogen in soil was determined using alkaline potassium permanganate method as described by Subbiah and Asija (1956).

3.5.5. Available Phosphorus

Available phosphorus was extracted with 0.03N NH_4F in 0.025N HCl Solution. The procedure is primarily mean for soils which are moderate to strongly acidic pH and determined by Brays and Kurtz method (1945).

3.5.6. Available potassium

The available potassium content in soil was extracted with neutral normal ammonium acetate (pH 7.0). The potassium content in the extract was determined by flame photometry (Jackson, 1973).

3.5.7. Available zinc

The available Zinc or the DTPA extractable Zinc was extracted with diethylene tri-amine penta acetic acid (DTPA) solution and subsequently analysed with the help of atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

3.6. Plant analysis

The grain and stover samples were dried in the hot air oven at a temperature of 60^0C to 70^0C to attain a constant weight then milled for analysis of nitrogen, phosphorus, potassium and Zinc content and quality parameters.

3.6.1. Nitrogen

Half a gram powdered sample was digested with concentrated H_2SO_4 in presence of digestion mixture ($CuSO_4$ +K_2SO_4) till the digest gave clear bluish green colour. The digested sample was further diluted carefully with distil water to know volume. Then a known volume of aliquot was transferred to distillation unit (Micro Kjeldahl – apparatus) and liberated ammonia was trapped in boric acid containing mixed indicator. Later it was titrated against Standard H_2SO_4 and the amount of ammonia liberated was estimated in the form of nitrogen as per the procedure given by Black (1965).

3.6.2. Digestion of plant samples for nutrients (Phosphorus, Potassium and Zinc estimation)

Half a gram powdered sample was pre-digested with concentrated HNO_3 overnight. Further pre-digested sample was treated with di-acid (HNO_3 : $HClO_4$ in the ratio 10:4) mixture and kept on hot plate for digestion till colourless thread like structures was obtained. After complete digestion precipitate was dissolved in 6N HCL and transferred to the100 mL volumetric flask through Whatman No. 42 filter paper and finally the volume of extract was made to 100ml with double distilled water and preserved for further analysis.

3.6.2.1. Phosphorus

Phosphorus in the digested sample was determined by vanado-molybdate yellow colour method (Jackson, 1967) and observations was recorded using spectrophotometer at 470 nm.

3.6.2.2. Potassium

The potassium content in the digestion sample was determined by flame photometer after making appropriate dilution as described by Chapman and Pratt (1961).

3.6.2.3. Zinc

Zinc in plant samples was estimated by using plant digest obtained by wet digestion of di acid (HNO_3 – $HClO_4$) with the help of AAS.

3.6.2.4. Carbohydrate

Carbohydrate was estimated by following the anthrone method and expressed in per cent (%) (Hedge and Hofreiter, 1962).

3.6.3. Nutrient uptake

The treatment wise uptake values for N, P, K and Zn in kilogram per hectare in grain and straw were calculated by multiplying grain or straw yield (kg ha^{-1}) with nutrient content in grain or straw (%).

3.7. Computation of economic indices

Economics of Maize cultivation were worked out from the cost of various inputs and income generated from the maize yield.

3.7.1. Cost of cultivation (₹ ha^{-1})

Cost of cultivation was calculated on per hectare basis for each treatment by taking into consideration the cost incurred in different steps separately for each treatment.

3.7.2. Gross return

Gross return was worked out by considering the monetary value of the economic produce of different treatments based on the prevailing market price of the product.

Gross return (₹ ha^{-1}) = Yield x selling price

3.7.3. Net return (₹ ha^{-1})

Net return of each treatment was estimated by subtracting the total cost of cultivation from the gross return.

Net return = Gross return – Cost of cultivation

3.7.4. Benefit cost ratio

Benefit cost ratio was calculated by the following formula:

$$\text{Benefit cost ratio} = \frac{Net\ return}{Cost\ of\ cultivation}$$

3.8. Statistical analysis:

The data recorded for various attributes were subjected to analysis of variance using OPSTATS software (http://14.139.232.166/opstat/). The homogeneity of variances was tested using the F-test as suggested by Gomez and Gomez (1984). Critical difference (CD) values are given in the table at 5 % level of significance, wherever the 'F' test was significant. The observation of both the seasons were also subjected to a pooled analysis of variance.

CHAPTER IV

RESULT AND DISCUSSION

RESULT AND DISCUSSION

The objective of the experiment entitled "Zinc Biofortification of Maize (*Zea mays* L.) and Integrated Nutrient Management in Foothill condition of Nagaland" was to evaluate the following:

1. To find out the effect of Zinc level on growth, yield and quality of maize.
2. To find out the suitable source of organic manure and level of fertilizer.
3. To find out the interaction effect and economics of the treatment combination.

The experimental data obtained periodically were subjected to statistical computation. This chapter attempt to apportioned the obtained results under various heads, sub-heads and furnished in the tables and illustrated wherever necessary. The results obtained through the experiment is also discussed critically in the light of principles and available evidence.

4.1 GROWTH PARAMETERS

4.1.1 Plant height (cm)

The data pertaining to the effect of manures, level of fertilizer and zinc application on the plant height of the maize is presented in Table 4.1.

4.1.1.1 Effect of manures

At initial growth stage *i.e*. 30 DAS there was no significant difference in the response of different types of manures on plant height.

In 2016, at 60 DAS there was no significant difference recorded in the response of plant height to different organic manure. However significant response was observed in year 2017 where application of poultry manure (M_2) exhibited a significant response and achieved highest plant height (174.97 cm) over that of vermicompost (M_3) (166.98 cm) and FYM (M_1) (166.24 cm). Pooled data also revealed that there is a significant effect on plant height due to different organic manures. The treatment where poultry manure (M_2) was administered maize plants recorded the highest plant height (170.29 cm) and the lowest plant height (161.72 cm) was observed in the plot were FYM (M_1) was applied.

At 90 DAS, there was significant difference in the response of the manures on plant height during the year 2016 and 2017 and similar trend was observed in case of pooled data. The result presented in the table revealed that application of Poultry manure results in significantly higher plant in both the year *i.e.* 2016 (174.52 cm) and 2017 (184.51 cm). Similarly, Poultry manure recorded significantly highest plant height in pooled data with the value of 179.52 cm in the same treatment and lowest plant height was observed where vermicompost was applied with the value of 168.23 cm.

It was known that of all the animal manure poultry manure has the highest amount of Nitrogen, Phosphorus and Potassium. The application of poultry manure resulted in noticeably higher plant height due to its ability to supply greater nutrients throughout the growing season (Farhad *et al.*, 2009). These findings are supported by these results of Chandrashekara *et al.* (2000) and Amakinde and Ayoola (2009).

4.1.1.2 Effect of Level of fertilizer

The results regarding the effect of level of fertilizer on plant height are presented in Table 4.1. It revealed that there was significant influence of fertilizer application on plant height of maize during 30 DAS. It was observed that application of fertilizer @ 100% RDF (F_3) recorded highest plant height in both the year with the value of 59.65 cm in the year 2016 and 61.02 cm in the year 2017. Similarly, in pooled data maximum plant height was observed in the treatment where 100% RDF was applied (60.33 cm) whereas lowest plant height was observed where 0% RDF was applied (51.25 cm).

Table 4.1: Effect of manure, fertilizer and zinc on mean plant height (cm) at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	53.34	55.63	54.48	157.20	166.24	161.72	163.74	176.34	170.04
M_2 - Poultry	56.24	57.39	56.82	165.61	174.97	170.29	174.52	184.51	179.52
M_3 - Vermicompost	55.55	56.20	55.88	158.40	166.98	162.69	162.54	173.91	168.23
Sem ±	1.19	0.89	1.05	2.46	2.59	2.53	3.49	2.94	3.23
CD (P=0.05)	NS	NS	NS	NS	7.18	5.82	9.69	8.16	7.44
Level of fertilizers									
F_1 - 0% RDF	50.44	52.07	51.25	145.42	156.03	150.73	147.29	157.66	152.47
F_2 - 50% RDF	55.05	56.14	55.59	162.95	170.33	166.64	165.00	177.74	171.37
F_3 - 100% RDF	59.65	61.02	60.33	172.84	181.83	177.33	188.51	199.37	193.94
Sem ±	0.87	0.70	0.79	2.31	2.43	2.37	3.38	2.71	3.06
CD (P=0.05)	1.90	1.52	1.63	5.04	5.29	4.90	7.36	5.90	6.32
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	54.07	55.36	54.72	156.16	166.10	161.13	160.76	172.81	166.79
Z_2- 15 kg ha^{-1} Zn	55.02	56.62	55.82	161.58	169.85	165.71	167.12	179.65	173.38
Z_3- 30 kg ha^{-1} Zn	56.04	57.25	56.64	163.47	172.24	167.85	172.92	182.30	177.61
Sem ±	0.86	1.60	1.28	2.06	2.30	2.18	3.01	2.49	2.76
CD (P=0.05)	NS	NS	NS	4.18	4.66	4.36	6.10	5.05	5.51

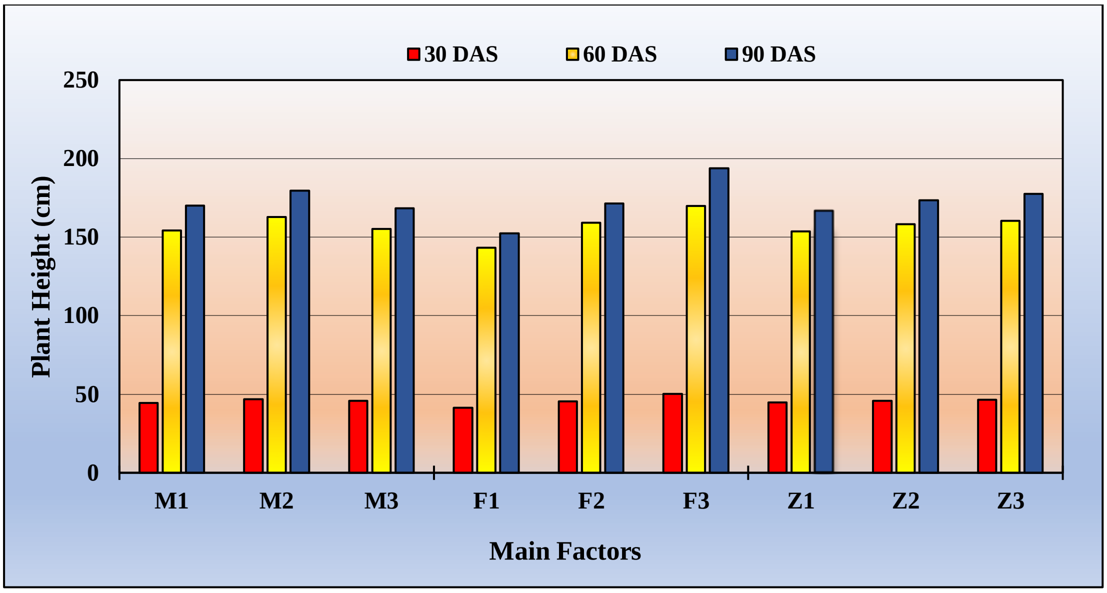


Fig 4.1: Effect of manure, fertilizer and zinc on mean plant height (cm) at different growth stages of maize.

At 60 DAS the same trend was observed where application of fertilizer @ 100% RDF showed significantly higher plant height in both the year 2016 (172.84 cm) and 2017 (181.83 cm). Similar effect was also reflected in pooled data where 100% RDF with the value of 177.33 cm achieved the highest plant height and lowest plant height (150.73 cm) was found where 0% RDF was applied.

Similar trend of the effect of different level of fertilizer application on plant height was observed during 90 DAS where fertilizer @ 100% RDF gave significantly highest plant height in both the year 2016 (188.51 cm) and 2017 (199.37 cm). Pooled data also showed significant increase in plant height where fertilizer @ 100% RDF was applied with the value of 193.94 cm followed by 50% RDF (171.37 cm) and plant height at its shortest was observed in 0% RDF treatment (152.47cm).

Boosted nutrient availability and better fertiliser usage by the plants may be the reason why fertiliser @100% RDF increased plant height to its maximum in all growth phases. The fact that nutrients (N, P, and K) aid in photosynthetic activity, cell and internodal elongation and maintenance of higher auxin levels, which ultimately results in obtaining taller plants than the other treatments, could be the cause of the increase in plant height with increasing level of fertiliser. These outcomes are consistent with those of Jeet *et al.* (2012) and Khan *et al.* (1999).

4.1.1.3 Effect of zinc on plant height

It is evident from the data presented in Table 4.1 that effect of zinc on plant height at 30 DAS did not differ significantly in both the year as well as in pooled data.

However, at 60 DAS, there was significant variation in plant height between treatments attributable to varying doses of zinc applied. Maximum plant height was obtained in the treatment where the crop received Zn @ 30 kg ha^{-1} in both the year. Pooled data also reflected significant effect on plant height where the highest plant height was recorded in treatment 30 kg ha^{-1} Zn (Z_3) with the plant height of 167.85 cm followed by 15 kg ha^{-1} Zn (Z_2= 165.71 cm) which is comparable to the Z_3 treatment. The lowest plant height of 161.13 cm was recorded in the treatment where no zinc was applied i.e., 0 kg ha^{-1} Zn (Z_1).

More or less similar trend was observed even at 90 DAS where plant height of both the year and the pooled data shows significantly higher plant height with the application of 30 kg ha^{-1} Zn. Application of Z_3 (30 kg ha^{-1} Zn) recorded maximum pooled plant height with 177.61 cm which was comparable to 15 kg ha^{-1} Zn (Z_2 = 173.38 cm). the lowest plant height (166.79 cm) was recorded in both the year and pooled data where no zinc (Z_1 = 0 kg ha^{-1} Zn) was applied.

Zinc may have a positive effect on plant height since it is essential for photosynthesis, nitrogen metabolism, and auxin concentration regulation in plants, all of which lead to greater plant height as compared to no zinc treatment. This outcome is found to be consistent with those of Khan *et al.* (2014), Mohsin *et al.* (2014) and Preetha and Stalin (2014).

Interactions effects of manure and fertilizer, manure and zinc, fertilizer and zinc and interaction effects of manure, fertilizer and Zinc on mean plant height (cm) at different growth stages of maize was found to be non-significant in all growth stages *i.e*., 30 DAS, 60 DAS and 90 DAS.

Table 4.2: Effect of manure, fertilizer and zinc on mean stem diameter (cm) at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
Manures									
M_1 - FYM	2.64	2.87	2.76	5.29	5.28	5.29	5.87	5.66	5.77
M_2 - Poultry	2.79	3.05	2.92	5.40	5.46	5.43	5.99	5.84	5.91
M_3 - Vermicompost	2.69	2.93	2.81	5.23	5.33	5.28	5.82	5.73	5.78
Sem ±	0.08	0.07	0.08	0.09	0.08	0.09	0.06	0.07	0.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Level of fertilizers									
F_1 - 0% RDF	2.56	2.83	2.70	5.14	5.23	5.19	5.78	5.57	5.68
F_2 - 50% RDF	2.85	2.95	2.90	5.34	5.35	5.34	5.93	5.72	5.83
F_3 - 100% RDF	2.71	3.08	2.90	5.44	5.49	5.46	5.97	5.95	5.96
Sem ±	0.10	0.09	0.10	0.11	0.09	0.10	0.08	0.14	0.11
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	2.64	2.89	2.77	5.26	5.30	5.28	5.82	5.68	5.75
Z_2- 15 kg ha^{-1} Zn	2.69	2.96	2.83	5.25	5.37	5.31	5.92	5.75	5.83
Z_3- 30 kg ha^{-1} Zn	2.79	3.01	2.90	5.41	5.40	5.41	5.94	5.81	5.88
Sem ±	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.10	0.08
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

4.1.2 Stem diameter (cm)

The data on the effect of various organic manure, fertilizer levels and Zinc levels on stem diameter at different growth stages is presented in Table 4.2.

4.1.2.1 Effect of manure

As per the data presented in the Table 4.2 indicated that the effect of different manure failed to evoke any significant differences in various stages of growth with respect to stem diameter.

4.1.2.2 Effect of Level of fertilizers

Results presented in the Table 4.2 did not show any significant effect on stem diameters of the maize plants due to the application of various levels of fertilizers.

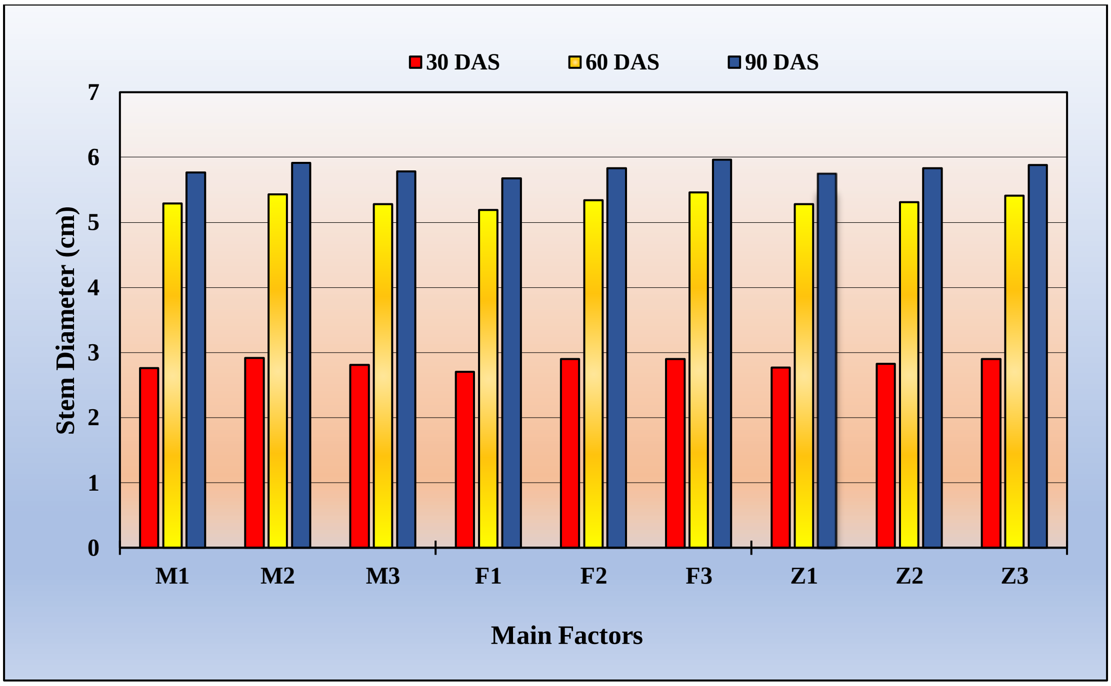


Fig 4.2: Effect of manure, fertilizer and zinc on mean stem diameter (cm) at different growth stages of maize.

4.1.2.3 Effect of Zinc

The effect of zinc on stem diameter was found to be non-significant in various stages of growth in both the year and in the pooled value.

Similarly, the interaction effect of the different manure, level of fertilizer and Zinc was found to be non-significant in all the stages of growth.

4.1.3 Leaf area Index

The effect of manure, fertilizer and Zinc on mean LAI at different growth stages of maize are presented in Table 4.3.

4.1.3.1 Effect of manure

As per the data recorded in the Table 4.3 the effect of manure on LAI does not show any significant effect during the early stages i.e., 30 DAS.

However, at 60 DAS effect of manure on LAI was found to be significant during the first year while it was found to be non-significant during the second year. Pooled data also reflected significant effect on LAI where maximum Value was recorded in Poultry manure (M_2) with a value of 2.17 and it appears comparable with treatment of FYM (M_1) with a value of 2.09. Lowest value of LAI was recorded where vermicompost was applied.

More or less same trend was observed at 90 DAS. Application of poultry manure increases the LAI significantly in both the year which appear comparable with treatment of FYM. The pooled data shows that poultry manure application gave significantly higher LAI (3.04) than FYM application (2.93) and vermicompost application (2.84).

Application of poultry manure shows better result with respect to leaf area index might be explained by the nutrients in poultry manure, which must have boosted photosynthetic efficiency and encouraged more vigorous development. The results resembles with the findings of Amakinde and Ayoola (2009), Okonmah (2012) and Ezeibekwe *et al.* (2009).

Table 4.3: Effect of manure, fertilizer and zinc on mean LAI at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	1.15	1.23	1.19	2.04	2.14	2.09	2.93	2.91	2.93
M_2 - Poultry	1.24	1.30	1.27	2.14	2.21	2.17	3.04	3.05	3.05
M_3 - Vermicompost	1.22	1.27	1.24	2.00	2.09	2.04	2.84	2.85	2.84
Sem ±	0.04	0.04	0.04	0.04	0.06	0.05	0.05	0.05	0.05
CD (P=0.05)	NS	NS	NS	0.10	NS	0.11	0.15	0.15	0.12
Level of fertilizers									
F_1 - 0% RDF	1.08	1.10	1.09	1.83	1.90	1.86	2.73	2.71	2.72
F_2 - 50% RDF	1.21	1.29	1.25	2.02	2.14	2.08	2.93	2.92	2.93
F_3 - 100% RDF	1.33	1.41	1.37	2.34	2.40	2.37	3.15	3.17	3.16
Sem ±	0.03	0.03	0.03	0.04	0.03	0.03	0.05	0.05	0.05
CD (P=0.05)	0.07	0.07	0.06	0.08	0.07	0.07	0.10	0.11	0.10
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	1.17	1.25	1.21	2.02	2.09	2.06	2.87	2.87	2.87
Z_2- 15 kg ha^{-1} Zn	1.21	1.27	1.24	2.08	2.15	2.12	2.97	2.94	2.95
Z_3- 30 kg ha^{-1} Zn	1.23	1.28	1.26	2.09	2.19	2.14	2.98	2.99	2.98
Sem ±	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.04	0.04
CD (P=0.05)	NS	NS	NS	0.06	0.07	0.06	0.09	0.09	0.09

4.1.3.2 Effect of Level of fertilizer

A reference to data presented in Table 4.3 revealed that a significant variation in LAI of maize was observed with the application of fertilizer @ 100% RDF throughout the growing stages of crop during both the year and even in pooled data. The maximum pooled value of LAI recorded at 30 DAS, 60 DAS and 90 DAS were 1.37, 2.37 and 3.16 respectively.

Second highest LAI value was observed at the treatments receiving fertilizer @ 50% RDF while LAI recorded lowest value from the treatments with no fertilizer (0% RDF) application.

Increased availability of nitrogen, phosphorus, and potassium, which contribute to balanced nutrition and play a key part in meristematic plant tissue's quick cell division and elongation, may be the cause of the greater LAI values brought on by higher fertiliser levels. These results seem comparable to the reports of Jeet *et al.* (2012) and Singh and Nepalia (2009).

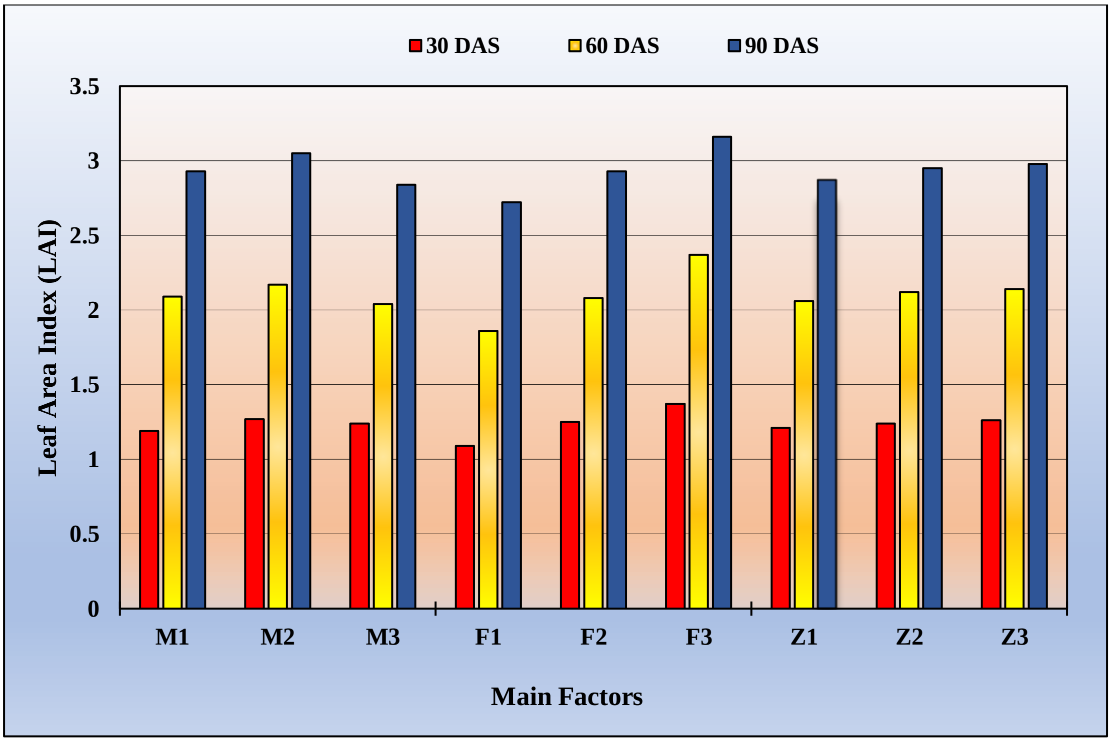


Fig 4.3: Effect of manure, fertilizer and zinc on mean LAI at different growth stages of maize.

4.1.3.3 Effect of Zinc

A critical examination of data presented in Table 4.3 showed that there is no significant variation of LAI during the early stages *i.e.* at 30 DAS. However, at 60 DAS and 90 DAS application of Z_3 = 30 kg ha^{-1} Zn significantly enhanced LAI in both the year as well as pooled data where the pooled value for 60 DAS was 2.14 and 2.98 for 90 DAS which was found comparable to Z_2 = 15 kg ha^{-1} Zn in both the year and the plots receiving no Zinc showed the lowest value.

The growth parameter LAI, must have increased as a result of the administration of zinc, which increases the plant or leaf's chlorophyll content, cell division, and photosynthesis. These reports are comparable with the findings of Sarwar *et al.* (2012), Arya and Singh (2000) and Amanullah *et al.* (2016).

The effect of interaction due to the treatment could not bring significant variation in LAI during all growth stages as well as in polled data.

4.1.4 Number of leaf

Close scrutiny of the data recorded on effect of manure, level of fertilizer and Zinc on the number of leaf in maize is presented in Table 4.4.

4.1.4.1 Effect of manure

A perusal data presented in Table 4.4 indicated that application of different types of manure could not result in significant differences in the numbers of leaf $plant^{-1}$ at 30 DAS.

Similarly, at 60 DAS and 90 DAS, the data of both the year failed to show significant difference in the number of leaf due to application of different types of manure. However, the pooled data of 60 DAS and 90 DAS reported a significantly higher number of leaves of maize plants in the plot where poultry manure was applied as organic manure with the value of 12.54 at 60 DAS and 13.24 at 90 DAS. It was also observed that application of FYM was equally effective or gave par effect as poultry manure. Whereas, vermicompost recorded the lowest number of leaves $plant^{-1}$ as per the pooled data at 60 DAS and 90 DAS.

Table 4.4: Effect of manure, fertilizer and zinc on mean number of leaf at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	6.95	6.33	6.64	12.38	11.86	12.12	12.77	12.78	12.77
M_2 - Poultry	7.22	5.91	6.57	12.74	12.34	12.54	13.19	13.28	13.24
M_3 - Vermicompost	7.06	5.81	6.44	12.28	11.74	12.01	12.64	12.62	12.63
Sem ±	0.12	0.15	0.14	0.22	0.19	0.20	0.17	0.20	0.19
CD (P=0.05)	NS	NS	NS	NS	NS	0.47	NS	NS	0.43
Level of fertilizers									
F_1 - 0% RDF	6.28	5.90	6.09	11.29	10.75	11.02	11.63	11.52	11.57
F_2 - 50% RDF	7.02	5.96	6.49	12.38	11.87	12.13	12.48	12.57	12.53
F_3 - 100% RDF	7.94	6.21	7.07	13.73	13.32	13.52	14.50	14.58	14.54
Sem ±	0.21	0.14	0.18	0.21	0.18	0.20	0.21	0.18	0.20
CD (P=0.05)	0.46	NS	0.37	0.45	0.40	0.40	0.47	0.40	0.41
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	7.02	5.99	6.50	12.28	11.77	12.03	12.69	12.71	12.70
Z_2- 15 kg ha^{-1} Zn	7.07	6.04	6.56	12.51	12.02	12.26	12.85	12.90	12.87
Z_3- 30 kg ha^{-1} Zn	7.14	6.04	6.59	12.61	12.15	12.38	13.07	13.06	13.06
Sem ±	0.13	0.15	0.14	0.15	0.15	0.15	0.14	0.14	0.14
CD (P=0.05)	NS	NS	NS	NS	NS	0.30	0.28	NS	0.27

In comparison to other organic manures, poultry manure has a greater and better nutrient content profile, both in terms of macronutrients and micronutrients, which may account for the increased number of leaves caused by its application. (Nahm, 2003). These micronutrients and macronutrients help plants grow and develop, which results in more leaves plant^{-1}. These reports are comparable with the findings of Akongwubel *et al.* (2012), Okonmah (2012) and Ezeibekwe *et al.* (2009).

4.1.4.2 Effect of level of fertilizer

The data presented in Table 4.4 indicated that increasing level of fertilizer upto 100% RDF significantly increased the numbers of leaf plant^{-1} in maize at all the stages except during second year particularly at 30 DAS. Fertilization of the crop with 100% RDF results in maximum number of leaf where the respective value of pooled data for 30 DAS is 7.07, 60 DAS is 13.52 and 90 DAS is 14.54. No application of fertilizer resulted in the maize plants with the lowest number of leaf compared to other treatments.

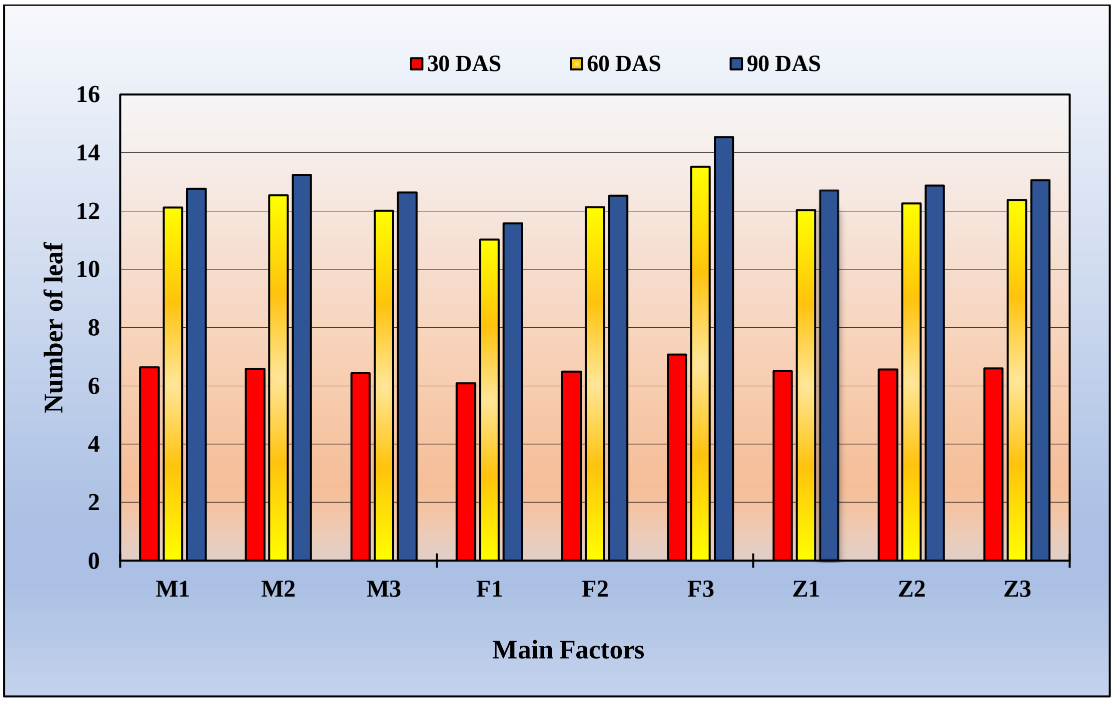


Fig 4.4: Effect of manure, fertilizer and zinc on mean number of leaf at different growth stages of maize.

Increased leaf number recorded with higher fertiliser levels may be caused by nitrogen application increasing plant height, which led to more nodes and internodes, which in turn increased the number of leaves plant^{-1} (Amin, 2011).

4.1.4.3 Effect of Zinc

A perusal of data presented in Table 4.4 revealed that increasing levels of zinc upto 30 kg ha^{-1} Zn significantly increases numbers of leaf plant^{-1} as observed in the pooled data of 60 DAS (12.38), first year of 90 DAS (13.07) and the pooled data of 90 DAS (13.06). In all the above cited stages application zinc @ 15 kg ha^{-1} was found to be at par. Lowest numbers of leaf was recorded where no zinc was given at all the stages of plant growth.

The significantly greater number of leaves in the zinc-treated plots may be attributable to zinc's beneficial stimulatory effects on the majority of the plant's physiological and metabolic processes These reports are comparable with the findings of Kumar *et al.* (2017) and Marngar and Dawson (2017).

4.1.5 Dry matter (g plant^{-1})

The experimental findings of the data on the effect of manure, fertilizer and Zinc on mean dry matter at different growth stages of maize are presented in Table 4.5 and 4.6.

4.1.5.1 Effect of manure

Analyzing the data in Table 4.5 critically showed that at 30 DAS, applying poultry manure caused the maximum accumulation of dry mater in second year (11.91 g plant^{-1}) and in pooled data (11.10 g plant^{-1}). Similar trend was observed at 60 DAS also where poultry manure gave the highest value of dry matter accumulation in both the years (82.75 g plant^{-1}) and pooled data with the pooled value of 81.77 g plant^{-1}. It was also observed that in the year 2017 application of FYM shows a value of 78.82 g plant^{-1} which was at par with that of poultry manure (82.75 g plant^{-1}).

At 90 DAS both poultry manure and FYM was showing quite positive responses where, during first year poultry manure recorded highest dry matter accumulation with the value of 198.03 g plant^{-1} which was at par with application of FYM (191.60 g plant^{-1}). In second year FYM recorded the highest dry matter accumulation of 195.14 g plant^{-1} which was comparable to application of poultry manure (190.68 g plant^{-1}). Coming to pooled data poultry manure accumulated highest dry matter (194.36 g plant^{-1}) which was comparable to FYM (193.37 g plant^{-1}). Lowest amount of dry matter accumulation was observed where vermicompost was applied at all the growth stages.

Due to its higher content of phosphorus and other beneficial micronutrients, which promote early root development necessary for better growth and ultimately lead to increased accumulation of dry matter in plants, poultry exhibits exceptional higher performance at all growth stages of crops in terms of dry matter accumulation. On the other hand, FYM could be good source of N and K but was inferior to poultry manure in term of phosphorus levels. These reports are comparable with the findings of Madhavi *et al.* (1995) and Ezeibekwe *et al.* (2009).

4.1.5.2 Effect of level of fertilizer

A reference to the data presented in the Table 4.5 indicated that Applying fertiliser up to 100% RDF greatly boosts the accumulation of dry matter at all growth stages during both the year. The pooled value was found to be 12.97 g plant^{-1} at 30 DAS, 93.98 g plant^{-1} at 60 DAS and 226.07 g plant^{-1} at 90 DAS. The lowest value of dry mater accumulation was recorded where 0% of RDF *i.e.* no fertilizer was applied.

Increased plant height, a larger photosynthetic system as seen by increased leaf area, and probably faster rates of photosynthesis due to balanced nutrition all contributed to a higher rate of growth and dry matter accumulation after fertiliser application. Present result of the experiments seems comparable with the reports of Madhavi *et al.* (1995) and Ezeibekwe *et al.* (2009).

Table 4.5: Effect of manure, fertilizer and zinc on mean dry matter (g $plant^{-1}$) at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	10.12	11.25	10.68	76.83	78.82	77.82	191.60	195.14	193.37
M_2 - Poultry	10.28	11.91	11.10	80.79	82.75	81.77	198.03	190.68	194.36
M_3 - Vermicompost	9.80	10.93	10.36	74.07	75.09	74.58	185.62	185.25	185.43
Sem ±	0.16	0.16	0.16	1.21	1.67	1.46	3.10	2.32	2.74
CD (P=0.05)	NS	0.43	0.36	3.36	4.63	3.36	8.62	6.46	6.32
Level of fertilizers									
F_1 - 0% RDF	7.68	8.61	8.14	62.96	61.01	61.99	162.28	162.60	162.44
F_2 - 50% RDF	10.29	11.77	11.03	76.40	80.01	78.20	183.80	185.50	184.65
F_3 - 100% RDF	12.24	13.71	12.97	92.34	95.63	93.98	229.16	222.97	226.07
Sem ±	0.15	0.15	0.15	1.08	1.30	1.20	2.99	3.20	3.09
CD (P=0.05)	0.33	0.33	0.31	2.35	2.84	2.47	6.51	6.97	6.39
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	9.69	10.99	10.34	75.36	75.81	75.58	183.23	179.75	181.49
Z_2- 15 kg ha^{-1} Zn	10.11	11.41	10.76	75.30	79.27	77.28	193.76	189.87	191.82
Z_3- 30 kg ha^{-1} Zn	10.39	11.69	11.04	81.03	81.58	81.31	198.26	201.45	199.85
Sem ±	0.10	0.10	0.10	1.25	1.50	1.38	3.00	3.07	3.04
CD (P=0.05)	0.21	0.21	0.21	2.53	3.04	2.75	6.09	6.22	6.05

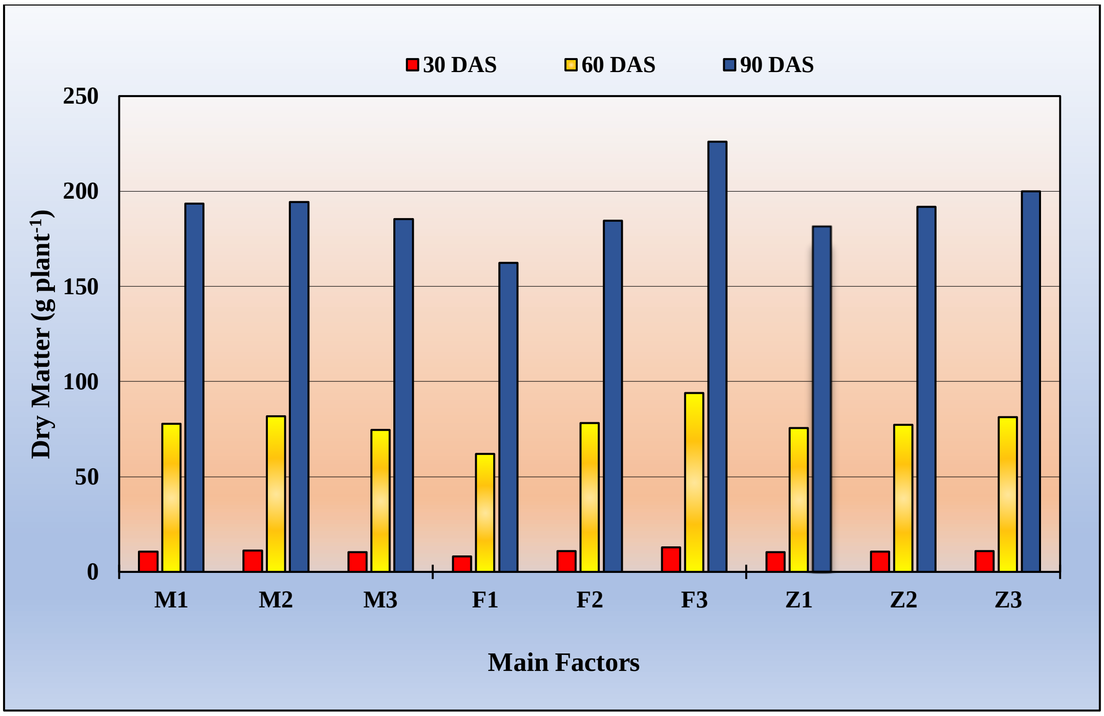


Fig 4.5: Effect of manure, fertilizer and zinc on mean dry matter (g plant^{-1}) at different growth stages of maize.

4.1.5.3 Effect of Zinc

The information in Table 4.5 clearly shows that the dry matter accumulation is greatly increased when zinc concentrations rise. At all growth phases, application of 30 kg per ha Zn resulted in the highest value of dry matter accumulation during both the year and in pooled data as well. The highest pooled value was recorded at 30 DAS was 11.04 g plant^{-1}, 81.31 g plant^{-1} at 60 DAS and 199.85 g plant^{-1} at 90 DAS respectively.

Zinc was found to stimulate the synthesis of tryptophan in plants, which is a precursor for the production of growth regulators like auxin, indole acetic acid, and cytokinin, which in turn increases cell division, cell elongation, and root growth, ultimately promoting the production of dry matter. This response can be attributed to the stimulatory effect of zinc on the synthesis of tryptophan in plants, which is a precursor for the production of these growth regulators. Present result of the experiments seems comparable with the reports of Reddy *et al.* (2019), Kumar *et al.* (2017), Meena *et al.* (2013) and Tariq *et al.* (2014).

4.1.5.4 Interaction effects of manure and fertilizer

A perusal of data pertaining to dry matter presented in Table 4.6 indicated that the pooled data analysis for the dry matter accumulation at 30 DAS indicated the presence of a significant interaction between different types of manures applied and various levels of fertilizer. The maximum amount of dry matter was reported in maize plants following the application of fertiliser @ 100% RDF and Poultry manure (M_2F_3) with the value of 13.48 g plant^{-1} which seem comparable to the M_2F_2 (11.55 g plant^{-1}).

Similarly, during 60 DAS of first year and the pooled data recorded significantly highest dry matter of 98.91 g plant^{-1} and 100.44 g plant^{-1} respectively in comparison with other treatment combination. However, 90 DAS of second year and pooled data did not show any significant differences on dry matter accumulation, the first year show significantly higher dry matter accumulation due to application of poultry manure in combination with fertilizer @ 100% RDF i.e., M_2F_3 with the value of 243.99 g plant^{-1} when compared with other treatment combinations.

The fact that the crop under this treatment has significantly more extractable and more nutrient available in the field in comparison to other treatment combinations allows us to realise the good influence of the combination of M2F3 (poultry manure and fertilizer @ 100% RDF) on dry matter at virtually all stages of growth gave higher dry matter accumulation. These results are comparable to the reports of Adeniyan and Ojeniyi (2005) and Unagwu *et al*. (2012).

4.1.5.5 Interaction effect of fertilizer and Zinc

The results presented in the Table 4.7 indicates the presence of significant interaction between fertilizer and Zinc application on dry matter of maize plants. Although crop in 30 DAS failed to show any significant interaction in both the year, but the pooled data showed significant interaction. Further analysis of pooled data showed that the highest dry matter of maize was achieved with F_3Z_3 (13.33 g plant^{-1}) which was comparable to F_3Z_2 (13.15 g plant^{-1}) and F_2Z_3 (11.49 g plant^{-1}).

Table 4.6: Interaction effects of manure and fertilizer on mean dry matter (g $plant^{-1}$) at different growth stages of maize.

Treatment		30 DAS			60 DAS			90 DAS		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
M_1F_1		7.82	8.59	8.21	63.34	61.82	62.58	161.94	166.52	164.23
M_1F_2		10.53	11.84	11.19	76.56	79.75	78.16	187.52	191.49	189.50
M_1F_3		12.00	13.31	12.66	90.60	94.88	92.74	225.33	227.41	226.37
M_2F_1		7.63	8.90	8.27	64.16	62.77	63.47	165.60	162.08	163.84
M_2F_2		10.65	12.46	11.55	79.30	83.50	81.40	184.51	184.56	184.53
M_2F_3		12.57	14.38	13.48	98.91	101.98	100.44	243.99	225.40	234.70
M_3F_1		7.57	8.34	7.96	61.38	58.45	59.91	159.30	159.18	159.24
M_3F_2		9.69	11.00	10.35	73.33	76.78	75.05	179.38	180.46	179.92
M_3F_3		12.13	13.44	12.79	87.50	90.04	88.77	218.17	216.11	217.14
Comparison:										
>A	**Sem ±**	0.26	0.26	0.26	1.87	2.26	2.07	5.17	5.54	5.36
	CD (P=0.05)	NS	NS	0.53	4.07	NS	4.28	11.28	NS	NS
>B	**Sem ±**	0.26	0.26	0.26	1.95	2.49	2.23	5.24	5.09	5.16
	CD (P=0.05)	NS	NS	2.15	2.41	NS	2.17	2.39	NS	NS

Table 4.7: Interaction effects of fertilizer and zinc on mean dry matter (g $plant^{-1}$) at different growth stages of maize.

Treatment		30 DAS			60 DAS			90 DAS		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
F_1Z_1		7.44	8.38	7.91	63.95	60.60	62.27	158.82	156.61	157.72
F_1Z_2		7.74	8.68	8.21	60.92	61.24	61.08	164.44	161.71	163.08
F_1Z_3		7.84	8.78	8.31	64.01	61.21	62.61	163.58	169.46	166.52
F_2Z_1		9.94	11.41	10.68	73.97	76.33	75.15	178.11	178.76	178.44
F_2Z_2		10.18	11.66	10.92	74.86	81.11	77.99	185.14	184.15	184.65
F_2Z_3		10.75	12.22	11.49	80.35	82.59	81.47	188.15	193.60	190.87
F_3Z_1		11.70	13.18	12.44	88.16	90.49	89.33	212.75	203.88	208.31
F_3Z_2		12.41	13.89	13.15	90.12	95.46	92.79	231.71	223.75	227.73
F_3Z_3		12.59	14.07	13.33	98.73	100.94	99.83	243.04	241.28	242.16
Comparison:										
>A	**Sem ±**	0.18	0.18	0.18	2.16	2.59	2.39	5.20	5.31	5.26
	CD (P=0.05)	NS	NS	0.36	4.38	NS	4.76	10.55	10.77	10.48
>B	**Sem ±**	0.21	0.21	0.26	2.07	2.49	2.23	5.19	5.39	5.16
	CD (P=0.05)	NS	NS	2.03	2.07	NS	2.01	2.08	2.08	2.02

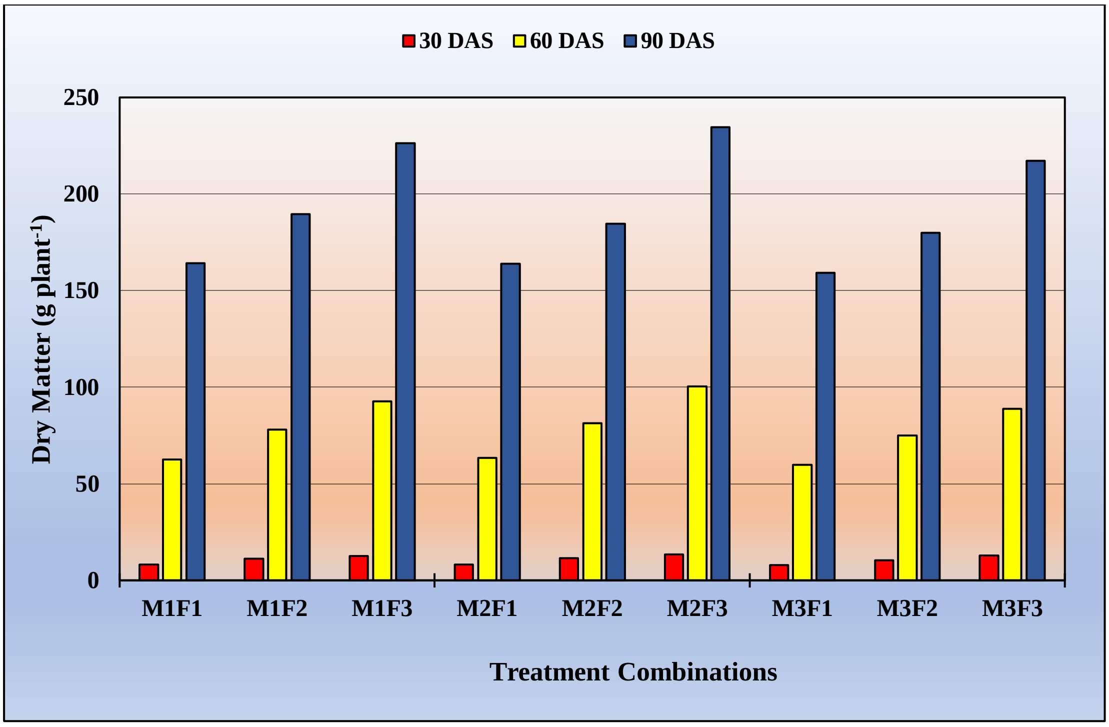


Fig 4.6: Interaction effects of manure and fertilizer on mean dry matter (g plant^{-1}) at different growth stages of maize.

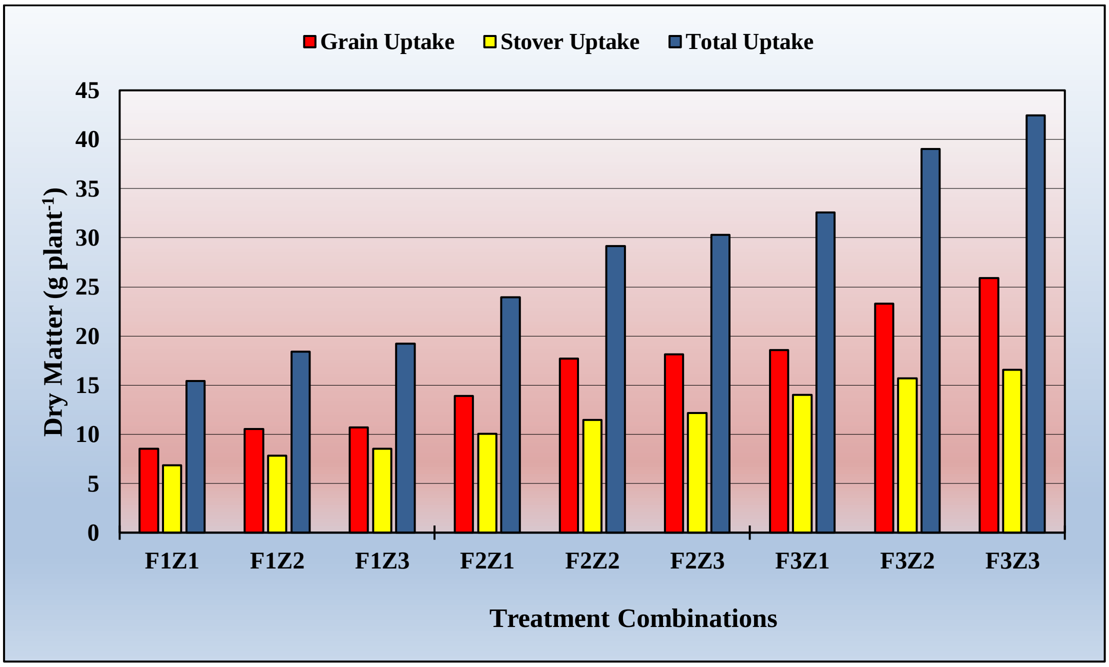


Fig 4.7: Interaction effects of fertilizer and zinc on mean dry matter (g plant^{-1}) at different growth stages of maize.

At 60 DAS the interaction was significant in year 2016 and pooled data. Careful examination of the response during 2016 suggested that the interactions between F_3Z_3 produced highest mean dry matter 98.73 (g $plant^{-1}$). The pooled data showed highest response on dry matter of maize plants with F_3Z_3 (99.83 g $plant^{-1}$).

The interaction response of fertilizer and Zinc level on dry matter of maize plants at 90 DAS was significant for both the years as well as in the pooled data. Interaction between fertilizer and Zinc level in the combination of F_3Z_3 produced the highest dry matter in maize plants during year 2016 (243.04 g $plant^{-1}$), year 2017 (241.28 g $plant^{-1}$) and as well as in pooled data (242.16 g $plant^{-1}$).

The fact that fertiliser and zinc together provide optimum nutrition with a combination of all the helpful minerals may be the cause of the combo's favourable effects. Increasing the degree of accessible fertility may involve supplying the ideal amount of nutrients during crucial growth phases. A higher level of fertiliser also enhanced protein synthesis, which in turn caused accelerated cell division and expansion and, eventually, robust plant growth. These results are comparable with the reports of Ashoka *et al.* (2009), Azab (2015) and Reddy *et al.* (2019).

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

The experimental finding of the data on effect of manure, fertilizer and Zinc on mean crop growth rate at different stages of maize are presented in Table 4.8.

4.1.6.1 Effect of manure

A reference to the data presented in Table 4.8 revealed that application of different types of manures did not differ significantly in terms of their effect when it comes to crop growth rate at all the growth stages during both the year and pooled value.

4.1.6.2 Effect of Level of fertilizer

It is apparent from the data presented in the Table 4.8 that increase in fertilizer level up to 100% RDF had significantly enhanced crop growth rate at all growth stages.

Table 4.8: Effect of manure, fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	2.50	2.55	2.52	3.11	3.14	3.13	3.41	3.47	3.44
M_2 - Poultry	2.47	2.53	2.50	3.09	3.13	3.11	3.32	3.42	3.37
M_3 - Vermicompost	2.34	2.44	2.39	2.95	3.09	3.02	3.31	3.35	3.33
Sem ±	0.11	0.08	0.10	0.11	0.11	0.11	0.12	0.05	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Level of fertilizers									
F_1 - 0% RDF	1.52	1.64	1.58	2.49	2.72	2.60	2.73	2.92	2.83
F_2 - 50% RDF	2.61	2.65	2.63	3.04	3.09	3.06	3.21	3.19	3.20
F_3 - 100% RDF	3.19	3.22	3.20	3.62	3.55	3.59	4.10	4.13	4.11
Sem ±	0.08	0.07	0.08	0.08	0.07	0.08	0.13	0.06	0.11
CD (P=0.05)	0.18	0.16	0.16	0.18	0.16	0.16	0.29	0.14	0.22
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	2.36	2.40	2.38	2.88	3.00	2.94	3.19	3.29	3.24
Z_2- 15 kg ha^{-1} Zn	2.50	2.53	2.52	3.08	3.10	3.09	3.36	3.40	3.38
Z_3- 30 kg ha^{-1} Zn	2.45	2.58	2.55	3.19	3.26	3.22	3.49	3.55	3.52
Sem ±	0.07	0.07	0.07	0.07	0.06	0.07	0.05	0.08	0.06
CD (P=0.05)	NS	0.13	0.13	0.14	0.13	0.13	0.09	0.15	0.13

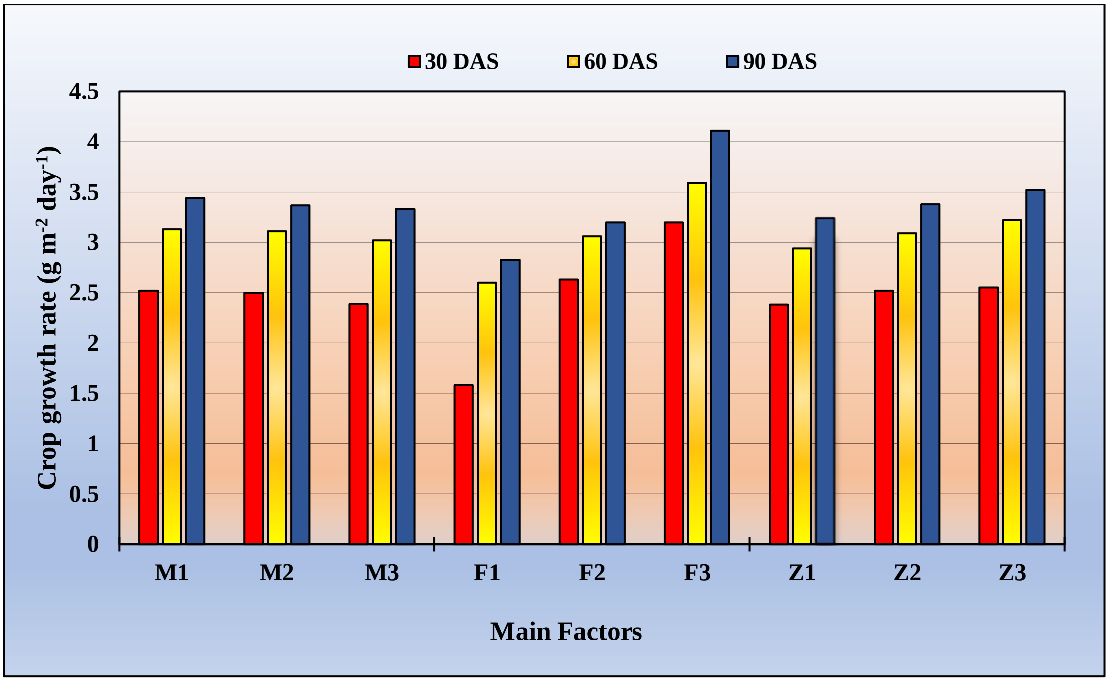


Fig 4.8: Effect of manure, fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at different growth stages of maize.

All the pooled data from 30 DAS, 60 DAS and 90 DAS growth stages shows that application of fertilizer @ 100% RDF recorded significantly highest value of crop growth rate of 3.20 g m^{-2} day^{-1}, 3.19 g m^{-2} day^{-1} and 4.11 g m^{-2} day^{-1} respectively, which was followed by application of fertilizer @ 50% RDF. While the lowest value of CGR at all growth stages was recorded where no fertilizer or 0% RDF was given.

As per the data observed crop growth rate increases with the increase in fertilizer level. Crop growth is the change in the rate of dry matter production per unit of land area with advancement of crop growth. It was observed that increase in fertilizer level (100 % RDF) increased the dry matter accumulation, this was the reason for such significantly higher CGR in this treatment. This may be attributable to improved nutrient availability and nitrogen usage efficiency, which may speed up cell division and lengthening and improve plant development overall, leading to an increase in CGR. This is comparable with the reports of Kumar and Bohra (2014) and Sobhana *et al.* (2012).

Table 4.9: Interaction effects of fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at different growth stages of maize.

Treatment		30 DAS			60 DAS			90 DAS		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
F_1Z_1		1.49	1.57	1.53	2.37	2.61	2.49	2.62	2.91	2.77
F_1Z_2		1.59	1.67	1.63	2.53	2.74	2.63	2.73	2.87	2.80
F_1Z_3		1.48	1.70	1.59	2.58	2.80	2.69	2.84	2.98	2.91
F_2Z_1		2.48	2.50	2.49	2.82	2.94	2.88	3.13	3.12	3.12
F_2Z_2		2.70	2.71	2.71	3.10	3.07	3.08	3.22	3.17	3.20
F_2Z_3		2.63	2.75	2.69	3.19	3.26	3.23	3.29	3.27	3.28
F_3Z_1		3.11	3.13	3.12	3.45	3.44	3.45	3.84	3.84	3.84
F_3Z_2		3.22	3.21	3.22	3.62	3.51	3.57	4.14	4.16	4.15
F_3Z_3		3.23	3.30	3.27	3.79	3.70	3.75	4.32	4.39	4.36
Comparison:										
>A	**Sem ±**	0.12	0.11	0.12	0.12	0.11	0.11	0.08	0.13	0.11
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.22
>B	**Sem ±**	0.13	0.12	0.15	0.13	0.11	0.15	0.15	0.13	0.17
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	2.03

4.1.6.3 Effect of Zinc

The experimental finding presented in the Table 4.8 revealed that application of Zinc increases CGR in all the growth stages except at 30 DAS during first year. It was also evident that maximum value of CGR was recorded in treatments with 30 kg ha^{-1} Zn i.e., Z_3 at all the stages during both the year and in the pooled data. The maximum values recorded in 30 DAS pooled, 60 DAS pooled and 90 DAS pooled are as follows 2.58 g m^{-2} day^{-1}, 3.22 g m^{-2} day^{-1} and 3.52 g m^{-2} day^{-1} respectively. Application of 15 kg ha^{-1} Zn seem comparable with 30kg ha^{-1} Zn at almost all the growth stages with the pooled value of 2.52 g m^{-2} day^{-1} at 30 DAS; 3.09 g m^{-2} day^{-1} at 60 DAS; and 3.38 g m^{-2} day^{-1} at 90 DAS. Significantly lowest value was recorded where no Zinc was applied. The above result may be attributable to zinc's role in auxin metabolism, which eventually increased hormonal activity and plant development. Kumar *et al.* (2017), Tariq *et al.* (2014) and Meena *et al.* (2013) also presented comparable results from their studies.

4.1.6.4 Interaction effect of Fertilizer and Zinc on mean CGR

Critical examination of data presented in Table 4.9 revealed that although at the early growth stages did not significantly affect the CGR of maize plants due to combined effect of Fertilizer and Zinc, however at the later stage say 90 DAS significant increase in CGR was observed in the plots where fertilizer and zinc were applied @ 100% RDF and @ 30 kg ha^{-1} Zn (F_3Z_3), respectively.

At 90 DAS the highest pooled value recorded was 4.36 g m^{-2} day^{-1} where fertilizer @ 100% RDF with Zinc @ 30 kg ha^{-1} was applied. It seems comparable to fertilizer @ 100% RDF and Zinc @ 15 kg ha^{-1} (F_3Z_2). CGR was recorded lowest in the plots where fertilizer @ 0% RDF and 0 kg ha^{-1} Zinc (F_1Z_1) was applied.

The reason for higher crop growth rate when combination of fertilizer @ 100% RDF and Zn @ 30 kg ha^{-1} (F_3Z_3) was given can be discussed in the light of the fact that combination of the nutrient components contributed to the soil's favourable nutritional status, making it easier to extract and increasing the amount of nutrients available to plants. Application of fertiliser must have had synergistic effects in addition to providing nutrients by improving micronutrient absorption and use, which improved crop growth rate. This is comparable to the reports of Kumar *et al.* (2017).

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

The experimental finding of the data on effect of manure, fertilizer and Zinc on mean relative growth rate at different stages of maize are presented in Table 4.10 and discussed here under.

4.1.7.1 Effect of manure

A reference to the data presented in Table 4.10 revealed that application of different types of manures exhibited significant differences in terms of relative growth rates of maize. As per the results its evident that at 30 DAS the differences in response of HQPM-1 maize in terms of relative growth rate due to application of various types of organic manures was only significant during year 2017 and Pooled data. Where poultry manure resulted in highest RGR during both year 2017 (0.082 g g^{-1} day^{-1}) and pooled data (0.079 g g^{-1} day^{-1}) which was followed by FYM and vermicompost. At 60 DAS stage although poultry manure recorded highest RGR but these differences among the various organic manures were not significant. Whereas during 90 DAS only pooled data showed significant differences in the effect on RGR of maize, where vermicompost (0.031 g g^{-1} day^{-1}) exhibited highest RGR followed by FYM (0.030 g g^{-1} day^{-1}) and poultry manure (0.029 g g^{-1} day^{-1}) this may be attributed to the prolonged days to flowering and maturity in maize plants receiving vermicompost.

4.1.7.2 Effect of Level of fertilizer

Close observation of the data presented in the Table 4.10 reveals that increase in fertilizer level up to 100% RDF had significantly enhanced relative growth rate at early stages while in the later generation the trend reversal was observed. The trend shows that highest RGR was observed at 30 DAS followed by 60 DAS and 90 DAS.

Table 4.10: Effect of manure, fertilizer and zinc on mean RGR (g g^{-1} day^{-1}) at different growth stages of maize.

Treatment	30 DAS			60 DAS			90 DAS		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M1 - FYM	0.077	0.080	0.078	0.068	0.065	0.066	0.031	0.030	0.030
M2 - Poultry	0.077	0.082	0.079	0.069	0.065	0.067	0.030	0.028	0.029
M3 - Vermicompost	0.075	0.079	0.077	0.068	0.064	0.066	0.031	0.030	0.031
Sed ±	0.0005	0.0005	0.0005	0.0004	0.0006	0.0005	0.0007	0.0007	0.0007
CD (P=0.05)	NS	0.0013	0.0011	NS	NS	NS	NS	NS	0.0016
Level of fertilizers									
F1 - 0% RDF	0.068	0.072	0.070	0.065	0.065	0.065	0.032	0.033	0.032
F2 - 50% RDF	0.078	0.082	0.080	0.067	0.066	0.067	0.029	0.028	0.029
F3 - 100% RDF	0.083	0.087	0.085	0.069	0.068	0.068	0.030	0.028	0.029
Sed ±	0.0005	0.0005	0.0005	0.0007	0.0006	0.0006	0.0008	0.0008	0.0008
CD (P=0.05)	0.0012	0.0010	0.0010	0.0014	NS	0.0013	0.0017	0.0016	0.0016
Zinc Level									
Z1- 0 kg ha^{-1} Zn	0.075	0.079	0.077	0.066	0.064	0.066	0.030	0.029	0.029
Z2- 15 kg ha^{-1} Zn	0.076	0.080	0.078	0.067	0.065	0.066	0.031	0.029	0.030
Z3- 30 kg ha^{-1} Zn	0.077	0.081	0.079	0.069	0.065	0.067	0.030	0.030	0.030
Sed ±	0.0004	0.0003	0.0004	0.0006	0.0007	0.0007	0.0006	0.0009	0.0008
CD (P=0.05)	0.0008	0.0007	0.0007	0.0013	NS	NS	NS	NS	NS

All the pooled data from 30 DAS and 60 DAS growth stages shows that application of fertilizer @ 100% RDF recorded significantly highest value of relative growth rate of 0.085 g g^{-1} day^{-1} and 0.068 g g^{-1} day^{-1} respectively, which was followed by application of fertilizer @ 50% RDF. While the lowest value of RGR at 30 DAS and 60 DAS was recorded where no fertilizer or 0% RDF was given. While at 90 DAS the pooled data showed that the lowest RGR was observed in treatments receiving fertilizer @ 100% RDF which was at par with that of the fertilizer @ 50% RDF, whereas the treatments which received fertilizer @ 0% RDF or no fertilizers, showed highest RGR (0.032 g g^{-1} day^{-1}).

As per the data observed crop growth rate increases with the increase in fertilizer level. It was observed that increase in fertilizer level (100 % RDF) increased the dry matter accumulation during early growth stages this was the reason for such significantly higher RGR in this treatment. This phenomenon could be explained by increased nutrient availability and nitrogen use efficiency, which might speed up cell division and elongation rates, resulting in greater plant development all around. As a result, plants were able to complete their vegetative phase faster and attain early tasselling and silking. This is the reason why we could see the lowest RGR at 90 DAS. Similar findings were also reported by Kumar and Bohra (2014) and Sobhana *et al.* (2012).

4.1.7.3 Effect of Zinc

The experimental finding presented in the Table 4.10 suggested that application of Zinc increases RGR at 30 DAS and 60 DAS growth stages while there were no significant differences during 90 DAS growth stage. It was also evident that maximum value of RGR of 0.077 g g^{-1} day^{-1}, 0.081 g g^{-1} day^{-1} and 0.079 g g^{-1} day^{-1} was recorded in treatments with 30 kg ha^{-1} Zn i.e., Z_3 at 30 DAS during both the year 2016 and 2017 and in the pooled data, respectively. Whereas at 60 DAS similar trend was evident but the differences were only significant during year 2016, where highest RGR was recorded from the treatments with 30 kg ha^{-1} Zn i.e., Z_3. Significantly lowest value was recorded where no Zinc was applied. The shown finding could be attributable to zinc's role in auxin metabolism, which eventually resulted in greater hormonal activity and early plant development. Kumar *et al.* (2017), Tariq *et al.* (2014) and Meena *et al.* (2013) reported comparable results to the above.

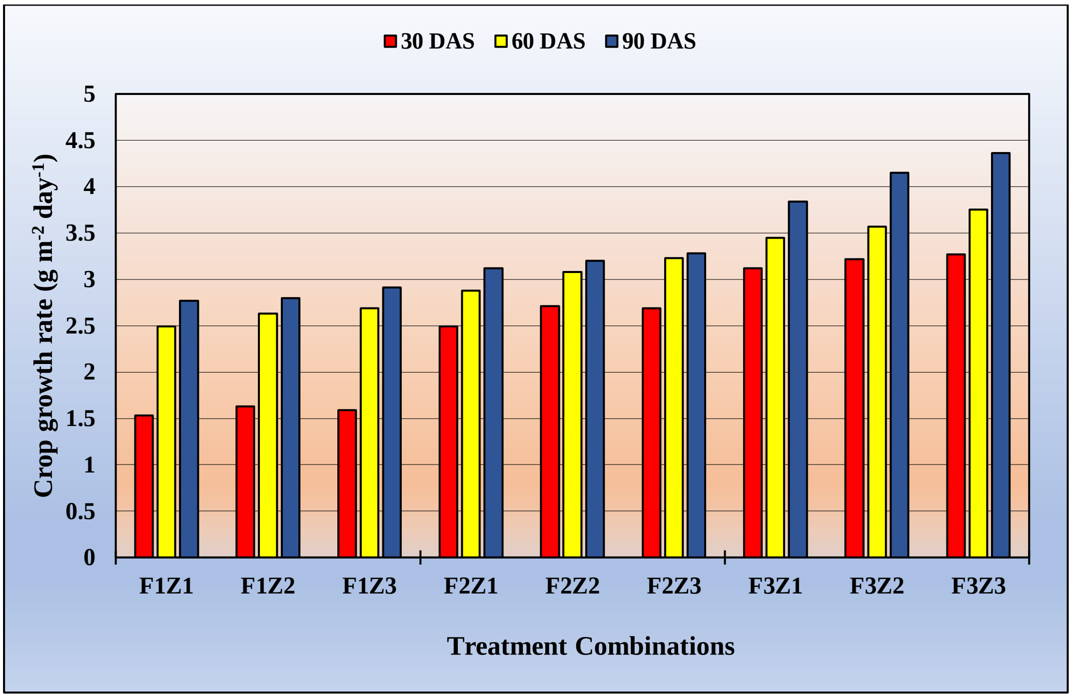


Fig 4.9: Interaction effects of fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at different growth stages of maize.

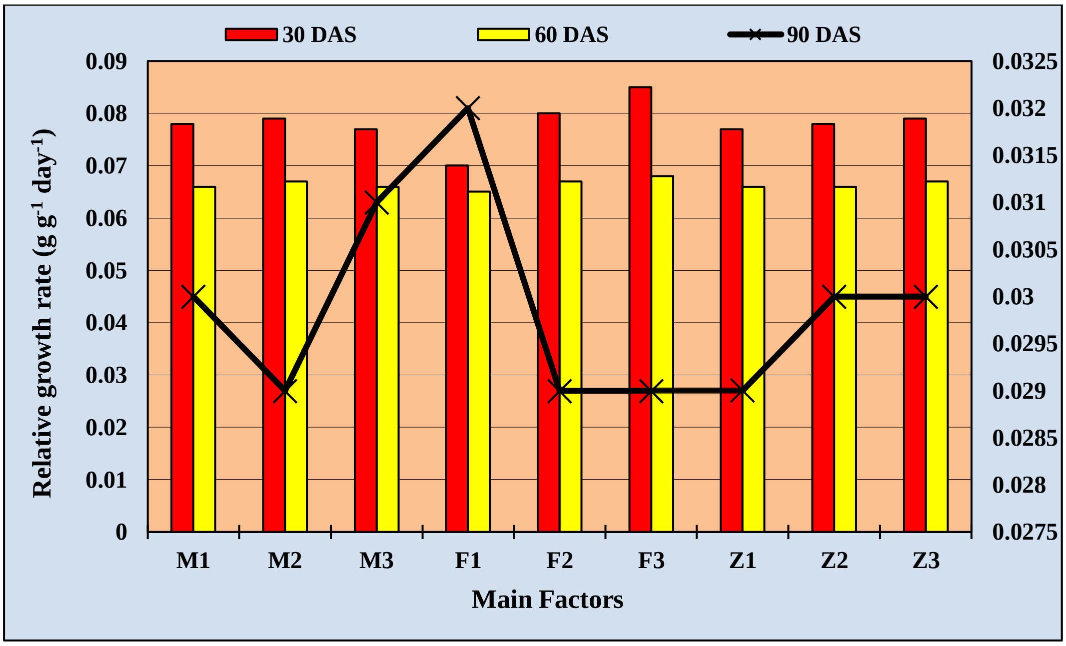


Fig 4.10: Effect of manure, fertilizer and zinc on mean RGR (g g^{-1} day^{-1}) at different growth stages of maize.

4.1.8 Days to 50% Tasselling

The experimental finding of the data on effect of manure, fertilizer and Zinc on mean days taken to attain 50% tasselling of maize are presented in Table 4.11.

4.1.8.1 Effect of manure

Experimental data pertaining to days to 50% tasselling of maize plant is presented in Table 4.11 critical examination of the data indicated that maize plants from the treatment involving application of poultry manure took minimum days to tasselling in both the years. Where during 2016 poultry manure recorded lowest day to tasselling with 70.15 days which was followed by FYM application with 71.41 days. Similarly, during 2017 recorded lowest number of days were required for tasselling (69.47 days) with poultry application which is at par with FYM application (71.11 days). Pooled data also followed the same trend where application of poultry manure significantly reduced the days to tasselling in maize plants with the value of 69.81 days.

Poultry manure is one of the rich sources of NPK in compared to other type of manure under comparison. High content of these nutrients particularly phosphorus, is responsible for early maturity and tasselling. Therefore, poultry manure rich in phosphorus are responsible for early tasselling when compared to other treatment. The result is in conformity with the findings of Ezeibekwe *et al.* (2009), Boochi and Tano (1994) and Amakinde and Ayoola (2009).

4.1.8.2 Effect of fertilizer

A reference to the data presented in Table 4.11 indicated that application of fertilizer up to 100% RDF reduces the days to tasselling significantly during both the year including pooled data. Application of fertilizer @ 100% RDF took 68.59 day for tasselling during the first year and 67.51 days during the second year and pooled data shows 68.05 days recording to be the lowest days to tasselling. Comparatively longest days to tasselling was recorded where fertilizer @ 0% RDF or no fertilizer was applied.

Table 4.11: Effect of manure, fertilizer and zinc on mean days to 50 % tasselling, days to 50 % silking and cob length (cm) at different growth stages of maize.

Treatment	Days to 50% Tasselling			Days to 50% Silking			Cob length (cm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	71.41	71.11	71.26	76.48	77.33	76.90	14.69	14.99	14.84
M_2 - Poultry	70.15	69.47	69.81	75.33	76.00	75.66	15.80	16.10	15.95
M_3 - Vermicompost	72.78	73.33	73.06	78.11	80.89	79.50	14.62	14.53	14.57
Sem ±	0.45	0.38	0.42	0.38	0.34	0.36	0.35	0.41	0.38
CD (P=0.05)	1.26	1.05	0.96	1.04	0.94	0.85	0.98	1.14	0.88
Level of fertilizers									
F_1 - 0% RDF	73.85	72.89	73.37	79.56	80.00	79.78	13.59	13.83	13.71
F_2 - 50% RDF	70.89	70.52	70.70	76.11	76.78	76.44	15.26	15.11	15.18
F_3 - 100% RDF	68.59	67.51	68.05	73.15	74.44	73.80	16.26	16.67	16.47
Sem ±	0.41	0.41	0.41	0.40	0.38	1.33	0.35	0.27	0.31
CD (P=0.05)	0.89	0.89	0.84	0.87	0.82	2.75	0.76	0.59	0.64
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	71.96	70.90	71.43	76.81	77.85	77.33	14.50	14.86	14.68
Z_2- 15 kg ha^{-1} Zn	70.96	70.45	70.71	76.37	76.93	76.65	15.21	15.29	15.25
Z_3- 30 kg ha^{-1} Zn	70.41	69.56	69.99	75.63	76.44	76.04	15.39	15.46	15.43
Sem ±	0.51	0.45	0.48	0.44	0.51	0.47	0.37	0.22	0.30
CD (P=0.05)	1.04	0.90	0.96	0.89	1.03	0.94	0.74	0.44	0.60

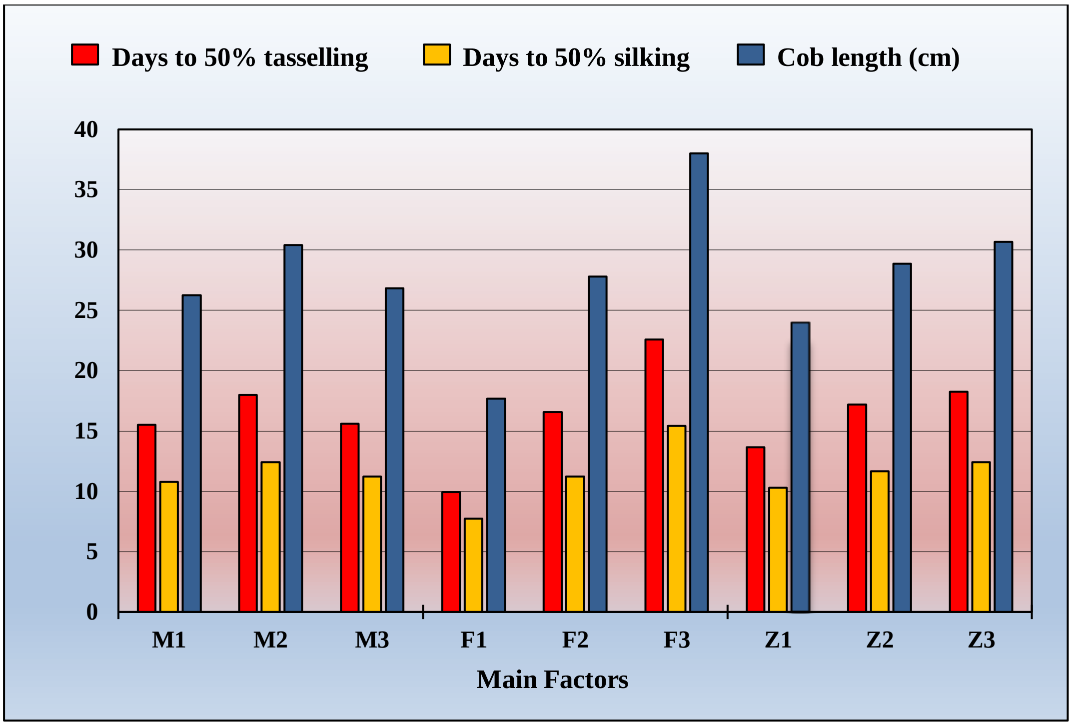


Fig 4.11: Effect of manure, fertilizer and zinc on mean days to 50 % tasselling, days to 50 % silking and cob length (cm) at different growth stages of maize.

Maximum days to 50% tasselling was observed in plot where no fertilizer were applied. The causes may be due to the lack of primary nutrients i.e., N, P and K in soil which subsequently lower the growth and result in attaining all the development stages very late. Hence application of fertilizer with right amount results in shorter day to tasselling. Similar observations were made by Kanton *et al*. (2016).

4.1.8.3 Effect of Zinc

A critical examination of the data presented on the Table 4.11 revealed that application of Zinc significantly reduces the days taken to tasselling as compared to no Zinc application. Significantly lowest number of days was recorded in both the year and as well as in pooled data where 30 kg ha^{-1} Zn was applied. During first year the number of days taken was 70.41 which was found to be par with application of 15 kg ha^{-1} Zn (70.96). Similarly, during second year and in pooled data same trend was followed. During year 2017 treatment Z_3 (30 kg ha^{-1} Zn) recorded the significantly lowest days to attain 50% tasselling i.e., 69.56 days, which was at par with the response of treatment Z_2 (15 kg ha^{-1} Zn).

The pooled data recorded for treatment Z_3 (30 kg ha^{-1} Zn) was 69.99 day which was found to be par with the treatment Z_2 (15 kg ha^{-1} Zn) with the value of 53.71 day. Highest days taken for tasselling was recorded during both the year as well as in pooled data were in the plot where no Zinc or 0 kg ha^{-1} Zn was given. The above finding is in consonance with the findings of Rashid (2004) where it was reported that high level of Zn application reduced number of days to tasselling and silking this might be due to the vigorous growth and development of the plant due to zinc helping it to attend maturity earlier that the treatment without zinc.

Though individual effect results in significant differences in days to 50% tasselling however the combine effect did not show any significant differences in days to 50% tasselling.

4.1.9 Days to 50% silking

4.1.9.1 Effect of manure

Experimental data on effect of manure on days to 50% Silking is presented in Table 4.11 and perusal of data revealed that application of different manures varied for their response on the number of days taken to attain 50% silking in maize plants. During first year application of poultry manure has resulted in significantly shortest days to 50% silking (75.33) while the maize plants receiving vermicompost as the source of manure took the longest time to produce silking. Similarly, during second year application of poultry manure gave lowest value for days to 50% silking with a value of 76.00 days. The value of pooled data showed a similar trend as was evident during both the years, where poultry manure was observed to have positive effect on the flowering of the maize plants due to which it enabled plants to attain 50 % silking on 75.66 days which was significantly earlier than the treatments of other manures.

The reason behind the obtained response can be because of the higher concentration of phosphorus and other micronutrients supplied by poultry manure which is responsible for early tasselling and silking. The result is in harmony with the findings of Ezeibekwe *et al*. (2009), Boochi and Tano (1994) and Amakinde and Ayoola (2009).

4.1.9.2 Effect of Fertilizers

Critical examination of Table 4.11 pertaining to effect of fertilizer on days to 50% silking revealed that with incorporation of fertilizer or increase level of fertilizer results in lesser days to 50% silking. Application of fertilizer @ 100 % RDF was found to result in significantly lesser days to silking in both the year and the pooled data too. Maize plants receiving fertilizer @ 100% RDF took days 73.15 days during 2016; 74.44 days during second year; and 73.80 days was recorded in pooled data.

Lowest number of days to 50% silking is observed in the plot where full dose of fertilizer was given and maximum number of days to 50% silking was recorded where fertilizer @ 0% RDF was given. This may be ascribed to the role of N, P and K which help in attaining faster growth and development stage than the plot where the nutrient is deprived for their growth and development. Similar observations were made by Kanton *et al*. (2016).

4.1.9.3. Effect of Zinc

Application of Zinc had a positive effect on the maize plants flowering where it significantly reduced days taken to obtain 50% silking as per the data presented in Table 4.11.

Analysis of the data obtained during 2016 experiment shows that lesser numbers of days to 50% silking was taken in the maize plots receiving Z_3 (30 kg ha^{-1} Zn) i.e., 75.63 days, while the treatment Z_2 (15 kg ha^{-1} Zn) with a value of 76.37 produced a statistically at par response. Similarly, during 2017 the treatment Z_3 (30 kg ha^{-1} Zn) resulted significantly lesser days to 50% silking (76.44 days) which was statistically at par with that of the treatment Z_2 (76.93 days). The combined pooled analysis of the data of days to 50% silking from both the year showed that Z_3 (30 kg ha^{-1} Zn) reduced days to 50 % silking significantly compared to Z_1 (0 kg ha^{-1} Zn) while the treatment Z_2 (15 kg ha^{-1} Zn) was at par with the Z_3.

The above finding is in consonance with the findings of Rashid (2004) where it was reported that high level of Zn application reduced number of days to tasselling and silking this might be due to the vigorous growth and development of the plant due to zinc helping it to attend maturity earlier that the treatment without zinc.

4.1.10. Cob length (cm)

The data pertaining to effect of manure, fertilizer and Zinc on cob length is presented in Table 4.11.

4.1.10.1. Effect of manure

The experimental finding of effect of manure on cob length shows that poultry manure recorded significantly longest cob length with the value of 15.80 cm during the year 2016. While during the year 2017 maize plants of the plots receiving poultry manure produced significantly longest cobs with 16.10 cm, which was at par with FYM (14.99 cm). Similarly, in pooled data application of poultry manure recorded longest cob length (15.95 cm).

Significantly longer cob length due to application of organic manure i.e., poultry manure and FYM can be associated with the release of macro and micronutrients during microbial decomposition attributing to the availability of sufficient amount of easily utilizable form of plant nutrient during the crop growth period which ultimately increase the growth and yield attributing character like cob length. This result, corroborates with the result of Chandrashekara *et al.* (2000).

4.1.10.2. Effect of fertilizer

A critical examination of data of cob length presented in Table 4.11 shows that application of fertilizer enhances the length of cob significantly. Generally, with the increasing level of fertilizer, the cob length increases. Application of fertilizer @ 100% RDF recorded longest cob during both the year and even in the pooled data. The first year second year and pooled data gave almost same cob length value of 16.26 cm, 16.67 cm and 16.47 cm respectively which is followed by fertilizer @ 50 % RDF treatment and the shortest cob is recorded where no fertilizer was given. Similar findings were earlier reported by Kanton *et al*. (2016).

4.1.10.3 Effect of Zinc

The data on the table revealed that cob length is influenced by Zn and different level of zinc application. The longest cob length was recorded with the application of 30 kg ha^{-1} Zn (Z_3) in both the year including pooled data with the value of 15.39 cm in the first year which is at par with Z_2 (15 kg ha^{-1} Zn), similar trend was followed in second year and the pooled data with the value of 15.46 cm for second year and 15.43 for pooled data.

The result indicated that application of Zn @ 30 kg ha^{-1} and 15 kg ha^{-1} Zn increases the cob length in compared to treatment without zinc or Zn @ 0 kg ha^{-1}. It is due to the role of zinc attributed to various physiological process and improvement in growth component specially LAI help in plant photosynthesis which ultimately improved yield attributing character like cob length etc. The above results are comparable to the reports of Mohsin *et al.* (2014), Raskar *et al.* (2012) and Azab (2015).

4.1.11 Cob girth (cm)

Application of manure, fertilizer and Zinc did not respond significantly when it comes to cob girth during both the year as well as in pooled value (Table 4.12).

4.1.12 Grain weight cob^{-1} (g)

4.1.12.1 Effect of manure

Data of the experimental finding of the effect of manure on grain weight cob^{-1} presented in the Table 4.12 revealed that during both the year and pooled data application of poultry manure significantly increase the grain weight cob^{-1}. The value was found to be 85.96 g cob^{-1} during 2016, 98.26 g cob^{-1} during 2017 and 92.11 g cob^{-1} for pooled data respectively.

Table 4.12: Effect of manure, fertilizer and zinc on mean cob girth (cm), grain weight cob^{-1} (g) and number of grain cob^{-1} at different growth stages of maize.

Treatment	Cob girth (cm)			Grain weight cob^{-1} (g)			No. of grain cob^{-1}		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	11.77	11.99	11.88	74.54	84.14	79.34	315.92	322.74	319.33
M_2 - Poultry	12.66	12.80	12.73	85.96	98.26	92.11	346.20	362.54	354.37
M_3 - Vermicompost	11.66	11.70	11.68	71.68	81.04	76.36	313.02	326.07	319.55
Sem ±	0.29	0.36	0.33	3.09	3.54	3.32	9.65	11.73	10.74
CD (P=0.05)	NS	NS	NS	8.57	9.82	7.66	26.79	32.56	24.76
Level of fertilizers									
F_1 - 0% RDF	11.35	11.24	11.29	60.39	67.24	63.82	283.13	289.18	286.16
F_2 - 50% RDF	12.09	12.14	12.11	77.15	89.50	83.33	326.96	340.50	333.73
F_3 - 100% RDF	12.64	13.12	12.88	94.64	106.71	100.67	365.05	381.67	373.36
Sem ±	0.23	0.34	0.29	2.68	3.44	3.08	10.01	10.57	10.29
CD (P=0.05)	NS	NS	NS	5.83	7.50	6.36	21.80	23.03	21.24
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	11.77	11.88	11.82	71.03	80.28	75.66	309.78	324.46	317.12
Z_2- 15 kg ha^{-1} Zn	12.02	12.18	12.10	79.06	89.17	84.12	326.59	337.95	332.27
Z_3- 30 kg ha^{-1} Zn	12.30	12.44	12.37	82.09	94.00	88.05	338.78	348.93	343.86
Sem ±	0.21	0.25	0.23	2.65	3.00	2.83	9.04	7.89	8.48
CD (P=0.05)	NS	NS	NS	5.38	6.08	5.64	18.34	15.99	16.91

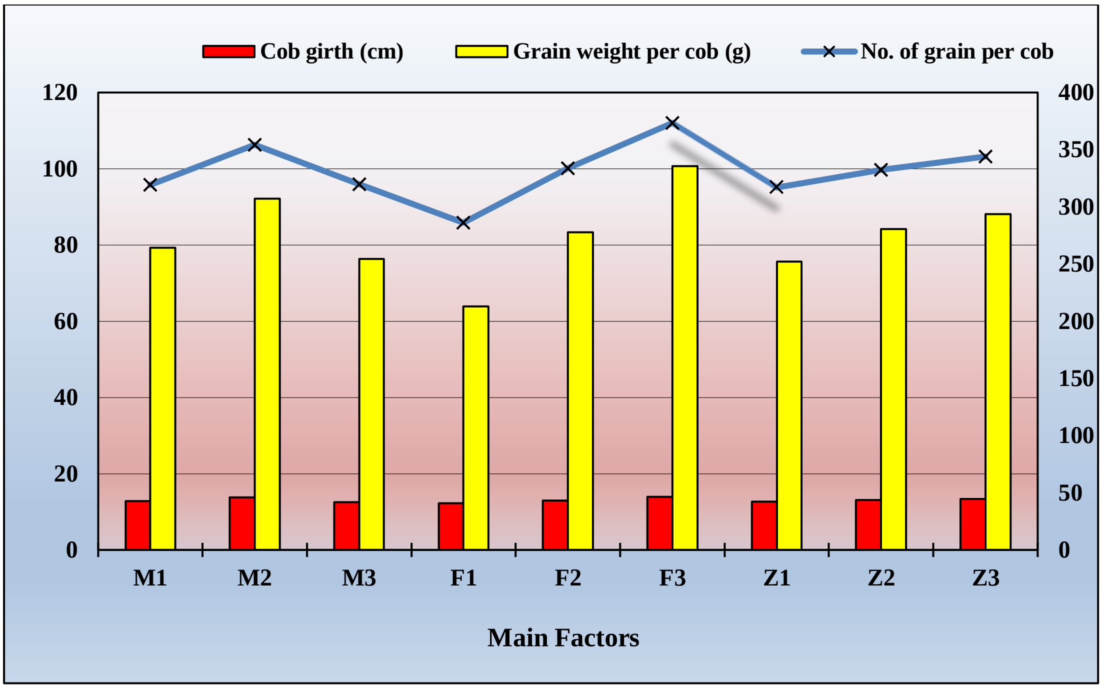


Fig 4.12: Effect of manure, fertilizer and zinc on mean cob girth (cm), grain weight cob^{-1} (g) and number of grains cob^{-1} at different growth stages of maize.

Significantly heavier weight of grain cob^{-1} with the application of poultry manure could be attributed to its higher nutritional status which are necessary to promote vigorous growth, meristematic and physiological activities in the plant there by increasing the synthesis of photo-assimilates that enhance the grain weight of the cob. The result was found to be in line with finding of Wailare and Kesarwani (2017).

4.1.12.2 Effect of doses of fertilizer

It is evident from the data presented in the Table 4.13 that application of fertilizer @ 100% RDF results in significantly heavier grain weight cob^{-1} during both the year which trend was similarly observed in pooled data. During 2016, F_3 (100% RDF) recorded highest value with 94.64 g cob^{-1}. Similarly, in 2017, F_3 (100% RDF) recorded highest value of 106.71 g cob^{-1}. The same effect was observed in pooled data where F_3 recorded highest value of 100.67 g cob^{-1} respectively. The lowest grain weight cob^{-1} was found where no fertilizer or 0% of RDF (F_1) was given.

Response of maize to application of higher level of fertilizer by producing well develop, bold grain and heavier grain in compare to lower or no fertilizer applied may be explained in term of lesser availability of nutrients. The adequate availability of NPK in treatments receiving F_2 and F_3 levels of fertilizer helped the maize plants in enhancing the overall growth of the maize plants there by creating larger source and also a larger sink.

The balanced and better partitioning between source and sink has resulted in producing higher grain weight cob^{-1}. The above findings are similar to earlier reports from Ali *et al*. (2011).

4.1.12.3 Effect of Zinc

It is explicit from the data presented in Table 4.12, that increasing levels of Zinc upto 30 kg ha^{-1} Zn significantly responded to grain weight cob^{-1} by recording the highest value of 82.09 g cob^{-1} in the year 2016, 94.00 g cob^{-1} in 2017 and 88.05 g cob^{-1} in pooled data. Lowest value of grain cob^{-1} was recorded where no Zn or 0 kg ha^{-1} Zn was given.

Higher grain weight cob^{-1} in the treatment can be attributed to marked improvement of plant height, leaf area index, dry matter accumulation and better nutrient utilization due to Zinc fertilization. Zinc plays a key role in increasing amount in protein synthesis during the grain filling. Above findings are comparable to the reports of Raskar *et al.* (2012) and Shivay and Prasad (2014).

4.1.13 Number of grains cob^{-1}

4.1.13.1 Effect of manure

A data presented in Table 4.12 showed that incorporation of poultry manure significantly increases the numbers of grain cob^{-1} during both the year and even in pooled data in comparison with other organic manure. The value recorded during 2016 was 346.20, in 2017 was 362.54 and pooled data recorded 354.37. Application of poultry manure in the present investigation recorded significantly higher yield attributing character like cob length, cob girth though not significant and maximum dry matter accumulation which ultimately leads to increase in numbers of grain cob^{-1}.

The result of the present investigation is in confirmation with the result of Farhad *et al.* (2009) and Wailare and Kesarwani (2017).

4.1.13.2 Effect of Level of fertilizer

The perusal of data pertaining to numbers of grain cob^{-1} in Table 4.12 indicated that increasing doses of fertilizer up to 100% RDF significantly increases the number of grains cob^{-1} in comparison to only 50% RDF and 0% RDF. The pooled value recorded maximum number where fertilizer @ 100% RDF was applied with the value of 373.36 followed by fertilizer @ 50% RDF with 333.73 and the lowest value was recorded where 0% RDF was applied.

From the above result we can conclude that most appropriate level of fertilizer to produce optimum number of grains cob^{-1} was found to be F_3 (100% RDF). This might be ascribed to adequate availability of nitrogen in Combination with P and K. Similar findings were reported earlier by Maqsood *et al*. (2001), Sharar *et al*. (2003), Rashid (2004) and Oktem (2005).

4.1.13.3 Effect of Zinc

A critical examination of the data presented in Table 4.12 on effect of Zinc on numbers of grain cob^{-1} indicated that application of Zinc on maize significantly increases the grain weight cob^{-1}. The highest number of grains cob^{-1} was recorded highest where Zn @ 30 kg ha^{-1} was given during both the year as well as pooled data with the value of 338.78 in the year 2016, 348.93 in 2017 and 343.86 in pooled data. the values were comparable to 15 kg ha^{-1} Zn in all the year including pooled data. But significantly lowest numbers of grain cob^{-1} was recorded in 0 kg ha^{-1} Zn.

Maximum number of grains cob^{-1} is a result of combine contribution of all the growth attributes out of which total dry matter production potential of crop is one of them. In the present investigation application of Zinc @ 30 kg ha^{-1} and 15 kg ha^{-1} recorded highest or higher total dry matter over 0 kg ha^{-1} Zn treatment. Increase dry matter accumulation further reflected in improvement in yield attributing character such as number of grains cobs^{-1}. The result cited above is in consistent with the findings of Khan *et al.* (2014b), Raskar (2012) Amanullah *et al.* (2016) and Shaaban (2001).

4.1.14 Test weight (g)

The data pertaining to effect of manure, fertilizer and Zinc on the test weight of maize are presented in Table 4.13. The results failed to show any significant differences among the various treatments in terms of the test weight of grains of the maize plants.

4.1.15 Shelling %

Experimental data pertaining to Effect of manure, fertilizer and Zinc on shelling % of maize are presented in the Table 4.13.

4.1.15.1 Effect of manure

The study of the experimental data in Table 4.13 indicated that application of poultry manure (M_2) gave significantly highest shelling % with the value of 78.97 g in 2016, 83.88g in 2017 and 81.42 in pooled data. The lowest value of shelling % was observed in M_3 (vermicompost).

Higher Shelling % of the maize may be due to increased growth parameters in these treatments, which attributed more photosynthates. Transportation from the vegetative parts (source) towards the reproductive organs (sink) and hence immense increase in yield parameter (Wailare and Kesarwani, 2017).

4.1.15.2 Effect of fertilizer

The data presented in Table 4.13 indicated that the higher dose of fertilizer or 100% RDF resulted in significantly highest shelling % in both the year as well as in pooled data as compared to 50% RDF and 0% RDF. Maximum value of pooled 82.53% was observed in F_3 (100% RDF) treatment.

Application of fertilizer @ 100% RDF promoted meristematic growth and physiological activities which promoted higher photosynthesis activity leading to the production of higher sink components like cob length, cob diameter, grain weight cob^{-1}, number of grains cob^{-1} and test weight of cob and hence improved the shelling % of the cob. Sharar *et al*. (2003), Rashid (2004).

Table 4.13: Effect of manure, fertilizer and zinc on mean test weight (g), shelling % and yield (kg ha^{-1}) at different growth stages of maize.

Treatment	Test weight (g)			Shelling %			Yield (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	23.13	24.22	23.68	74.01	78.09	76.05	3124.00	3106.26	3115.13
M_2 - Poultry	24.29	25.42	24.85	78.97	83.88	81.42	3258.59	3319.37	3288.98
M_3 - Vermicompost	22.36	24.00	23.18	73.25	77.08	75.17	3076.89	2976.56	3026.72
Sem ±	5.88	6.38	6.14	1.65	1.49	1.58	48.71	63.66	56.68
CD (P=0.05)	NS	NS	NS	4.59	4.14	3.63	135.24	176.74	130.70
Level of fertilizers									
F_1 - 0% RDF	22.95	22.01	22.48	70.02	73.83	71.92	2213.37	2140.81	2177.09
F_2 - 50% RDF	23.37	22.97	23.17	76.11	80.28	78.19	3270.44	3347.89	3309.17
F_3 - 100% RDF	24.46	23.66	24.06	80.11	84.95	82.53	3975.67	3913.48	3944.57
Sem ±	5.84	6.78	6.33	1.39	1.37	1.38	49.08	53.16	51.16
CD (P=0.05)	NS	NS	NS	3.03	2.99	2.85	106.93	115.84	105.59
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	22.62	23.89	23.26	73.97	77.97	75.97	3005.00	2968.00	2986.50
Z_2- 15 kg ha^{-1} Zn	23.49	24.55	24.02	74.89	79.63	77.26	3197.15	3202.00	3199.57
Z_3- 30 kg ha^{-1} Zn	23.68	25.20	24.44	77.37	81.45	79.41	3257.33	3232.19	3244.76
Sem ±	4.42	5.33	4.90	1.19	1.36	1.28	50.51	48.88	49.70
CD (P=0.05)	NS	NS	NS	2.41	2.76	2.55	102.436	99.136	99.08

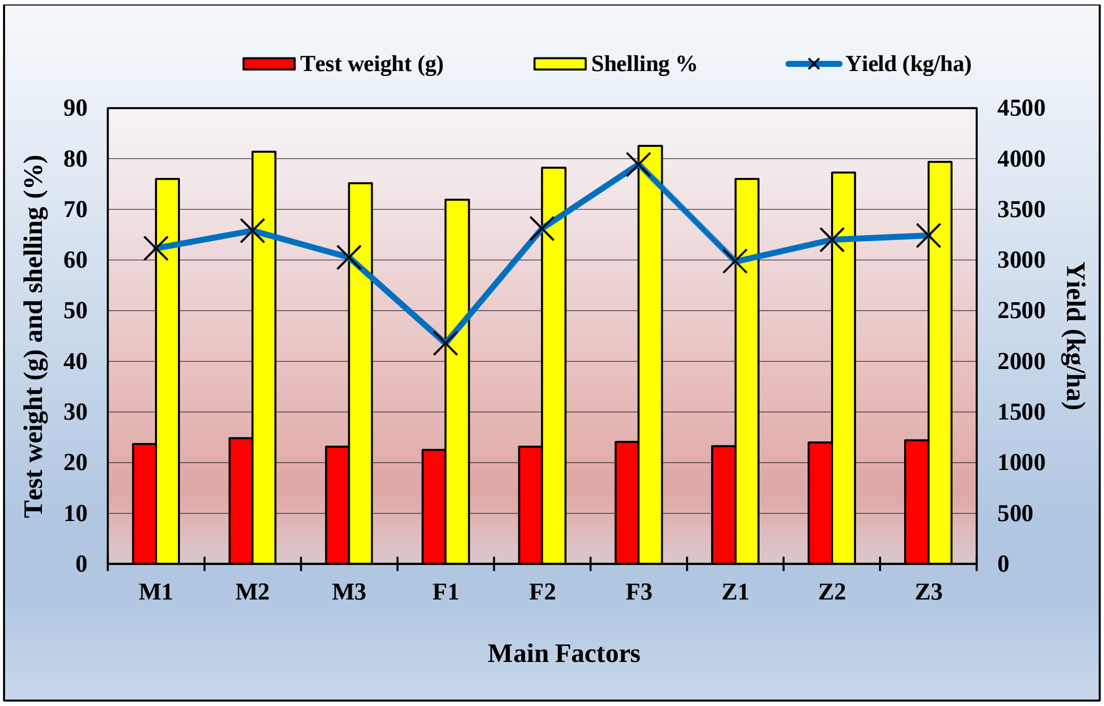


Fig 4.13: Effect of manure, fertilizer and zinc on mean test weight (g), shelling % and yield (kg ha^{-1}) at different growth stages of maize.

4.1.15.3 Effect of Zinc

It is evident from the data presented in the Table 4.13 that application of zinc result in higher shelling % of the maize cob. The data revealed that application of 30 kg ha^{-1} Zn gave significantly higher shelling % of the maize cob. The data revealed that application of 30 kg ha^{-1} Zn gave significantly higher shelling % in both the year as well as in pooled data with the value of 77.37 % in 2016, 81.45 % in 2017 and 79.41% in pooled data. However, the data during 2017 and pooled data was comparable to 15 kg ha^{-1} Zn. Lowest value was observed in 0 kg ha^{-1} Zn application.

Higher shelling % of crop with Zinc application may be due to the results of combination of growth attributing characters and yield attributing characters like number of grain cob^{-1}, cob length, cob girth etc. which was showing positive response to Zn application that increase the shelling % significantly. The result is in accordance with the finding of Raskar *et al.* (2012).

4.1.16 Yield (kg ha^{-1})

Experimental data on effect of manure, fertilizer and zinc on yield of maize are presented in Table 4.13.

4.1.16.1 Effect of manure

The data presented on Table 4.13 indicated that incorporation of poultry manure (M_2) results in significantly higher grain yield in both the year as well as in pooled data compared to vermicompost (M_3) application. It was also revealed that application of FYM (M_1) results to be at par with application of poultry manure (M_2) in both the year except in pooled data. The maximum yield recorded in pooled data due to application of poultry manure in pooled data was found to be 3288.98 kg ha^{-1} whereas the lowest yield was recorded where vermicompost was applied with the value of 3026.72 kg ha^{-1}.

The significant boost in yield that results from the application of poultry manure can be attributed to both the adequate supply of nutrients as well as their significant contribution to the soil's nutrient availability to plants. High yield brought on by FYM and poultry manure can also be ascribed to their positive effects in ensuring the harmony of the source-sink relationship. This seems comparable to the findings of Farhad *et al.* (2009), Okoroafor *et al.* (2013), and Obi and Ebo (1995).

4.1.16.2 Effect of Fertilizer

The perusal of data pertaining to yield presented in Table 4.13 revealed that response of yield to the level of fertilizer shows significant increase in yield when fertilizer @ 100% RDF (F3) was applied. Same trend was observed in both the year as well as pooled data. The maximum yield recorded in the year 2016 was 3975.67 kg ha^{-1}, in 2017 it was 3913.48 in 2017 and 3944.57 for pooled data.

From the above result we can draw that higher level of fertilizer will help increase grain yield on account of increased number of grains cob^{-1}, grain weight cob^{-1} and test weight. This could be result of the treatments receiving fertiliser @100% RDF (F_3) having improved nitrogen usage efficiency and macronutrient availability. And compared to previous treatments 50% or 0 % RDF, the current one offers the most favourable conditions. The current findings are in complete agreement with the findings of Sharma and Gupta (1998), Maqsood *et al*. (2001), Ali *et al*. (2011), Kogbe and Adediran (2003) and Sharar *et al*. (2003).

4.1.16.3 Effect of Zinc

The data presented in the Table 4.13 indicated that the effect of Zn on yield showed significant increase in yield. It is observed that application of zinc @ 30 kg ha^{-1} to maize significantly increased the yield when compared with no Zinc or 0 kg ha^{-1} application. Though application of Zinc @ 30 kg ha^{-1} gave highest yield in both the year as well as pooled data with the value of 3257.33 kg ha^{-1} during the first year, 3232.19 kg ha^{-1} during the second year and 3244.76 kg ha^{-1} respectively, it was comparable to the application of Zinc @15 kg ha^{-1} in both the year as well as pooled data.

Zinc availability could have increased meristematic cell activity and cell elongation, which in turn improved vegetative growth and eventually contributed to better dry matter production. This improved vegetative growth was further reflected in the yield-attributing character, and as a result, the yield of the crop under the current treatment was recorded to be significantly high. These results seem comparable to the reports of Khan *et al.* (2014a), Mohsin *et al.* (2014), Arya and Singh (2000), Kakar *et al.* (2006), Raskar *et al.* (2012) and Hossain *et al.* (2008).

4.1.16.4 Interaction effect of manure and zinc

The data pertaining to the interaction effect of manure and fertilizer on yield in Table 4.14 indicated that the yield was significantly affected by the combine application of manure and zinc during the year 2017 and in pooled data. The perusal of the data revealed that the yield was observed to increase with increase in zinc level when incorporated along with poultry manure. Though combination of zinc with other organic manure shows increase in yield it does not show significant increase in yield.

Maximum yield was recorded in M_2Z_3 (3537.89 kg ha^{-1}) during 2017 same trend was followed in pooled data where maximum yield was recorded in M_2Z_3 (3486.39 kg ha^{-1}) treatment combination. The result revealed that M_2Z_3 enhanced yield significantly compared to the other treatment combination.

The fact that only 2017 shows significant interaction effect might be due to the residual effect of the manure applied in the first year. Higher yield recorded by combine effect of poultry manure and Zn @ 30 kg ha^{-1} is attributed to the favourable nutritional states of the soil resulting in increased biomass production of the crop latter it increases the yield directly indirectly. The combination of zinc and poultry manure, which contains high concentrations of nitrogen, phosphorus, potassium, and other vital mineral nutrients, improved the growth and yield of the crop. The results are comparable to Sarwar *et al.* (2012), Saleem *et al.* (2017) and Abdel-Mawgoud *et al.* (2005).

4.1.16.5 Interaction effect of fertilizer and Zinc on yield

The data pertaining to the interaction effect of fertilizer and zinc are presented in Table 4.15 Critical study of the information demonstrated that fertilizers and zinc treatment together had a considerable impact on maize output during second year and pooled data.

It is observed that increase level of fertilizer and Zinc increased yield of maize at diminishing rate. Among the treatment combination maximum yield was recorded in F_3Z_3 (4090.22 kg ha^{-1}) in the year 2017 and even in pooled data maximum yield was observed in F_3Z_3 (4104.83 kg ha^{-1}) treatment combination. The result revealed that highest level of fertilizer *i.e.*, @ 100% RDF and Zinc @30 kg ha^{-1} $ZnSO_4$ enhanced yield significantly compared to other treatment.

The enhanced total dry matter production as a result of improved Zn and NPK intake and their translocation to reproductive regions is what causes fertiliser and zinc to interact favourably with maize yield. The key factor contributing to the increased maize yield in the combination application of Zn @ 30 Kg ha^{-1} Zn and fertilizer @ 100 % RDF was better or higher yield attributing feature. This seem comparable to the reports Abrol *et al.* (2007), Ashoka *et al.* (2009) and Ashoka and Sunitha (2011).

Table 4.14: Interaction effects of manure and zinc on mean test weight (g), shelling (%) and yield (kg ha^{-1}) at different growth stages of maize.

Treatment		**Test weight (g)**			**Shelling %**			**Yield (kg ha^{-1})**		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
M_1Z_1		22.57	23.57	23.07	72.39	76.07	74.23	2966.67	2949.67	2958.17
M_1Z_2		23.19	24.21	23.70	73.22	77.90	75.56	3201.22	3183.11	3192.17
M_1Z_3		23.63	24.89	24.26	76.40	80.30	78.35	3204.11	3186.00	3195.06
M_2Z_1		23.19	24.58	23.89	77.40	82.23	79.82	3066.67	3083.00	3074.83
M_2Z_2		24.89	25.49	25.19	78.86	84.25	81.56	3274.22	3337.22	3305.72
M_2Z_3		24.79	26.17	25.48	80.65	85.15	82.90	3434.89	3537.89	3486.39
M_3Z_1		22.10	23.52	22.81	72.11	75.61	73.86	2981.67	2871.33	2926.50
M_3Z_2		22.37	23.94	23.16	72.58	76.74	74.66	3116.00	3085.67	3100.83
M_3Z_3		22.60	24.55	23.58	75.07	78.91	76.99	3133.00	2972.67	3052.83
Comparison:										
>A	**Sem ±**	7.66	9.23	8.48	2.06	2.36	2.21	87.48	84.66	86.09
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	171.71	171.61
>B	**Sem ±**	8.58	9.88	9.25	2.36	2.44	2.40	86.46	93.97	90.29
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	2.37	2.12

Table 4.15: Interaction effects of fertilizer and zinc on mean test weight (g), shelling (%) and yield (kg ha^{-1}) at different growth stages of maize.

Treatment		**Test weight (g)**			**Shelling %**			**Yield (kg ha^{-1})**		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
F_1Z_1		21.00	21.49	21.25	69.20	72.57	70.88	2163.33	2099.67	2131.50
F_1Z_2		21.12	22.04	21.58	70.26	74.30	72.28	2221.89	2169.33	2195.61
F_1Z_3		20.74	22.49	21.62	70.59	74.62	72.60	2254.89	2153.44	2204.17
F_2Z_1		22.59	24.12	23.36	74.07	77.98	76.02	3111.67	3148.00	3129.83
F_2Z_2		23.49	24.88	24.19	75.48	79.95	77.71	3302.00	3442.78	3372.39
F_2Z_3		24.03	25.91	24.97	78.77	82.91	80.84	3397.67	3452.89	3425.28
F_3Z_1		24.28	26.05	25.16	78.64	83.37	81.00	3740.00	3656.33	3698.17
F_3Z_2		25.85	26.72	26.29	78.92	84.65	81.79	4067.56	3993.89	4030.72
F_3Z_3		26.26	27.21	26.73	82.76	86.83	84.80	4119.44	4090.22	4104.83
Comparison:										
>A	**Sem ±**	7.66	9.23	8.48	2.06	2.36	2.21	87.48	84.66	86.09
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	171.71	171.61
>B	**Sem ±**	8.56	10.14	10.86	2.18	2.36	2.51	86.66	87.21	91.91
	CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	2.08	2.02

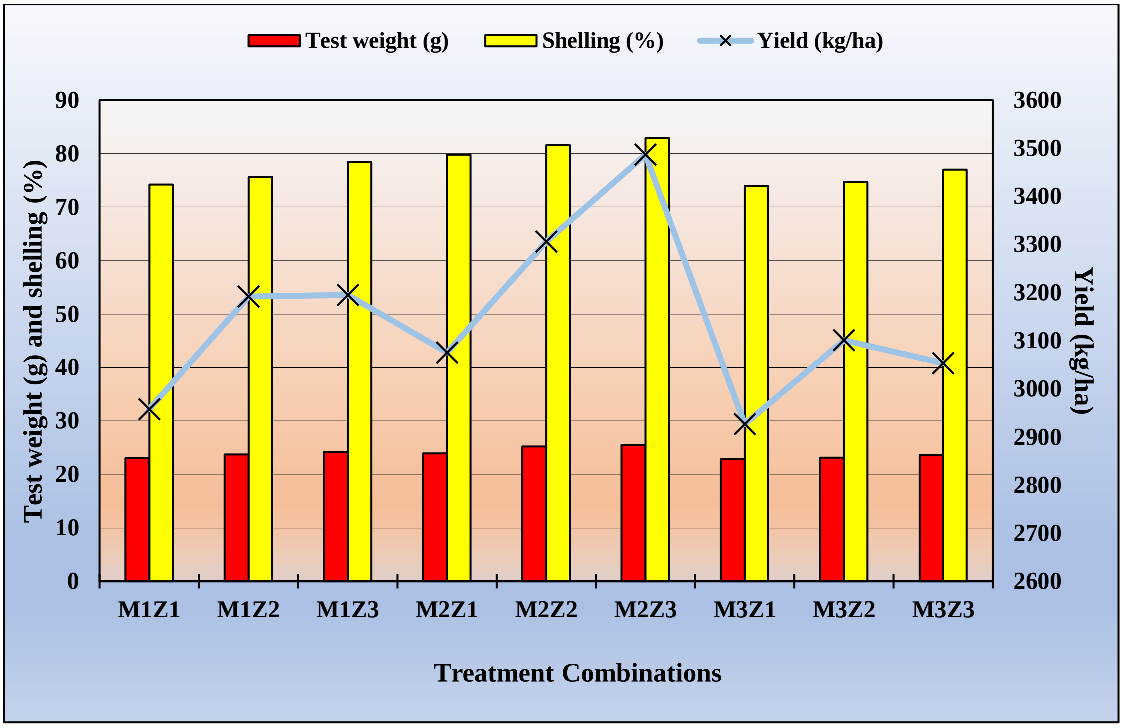


Fig 4.14: Interaction effects of manure and zinc on mean test weight (g), shelling (%) and yield (kg ha^{-1}) at different growth stages of maize.

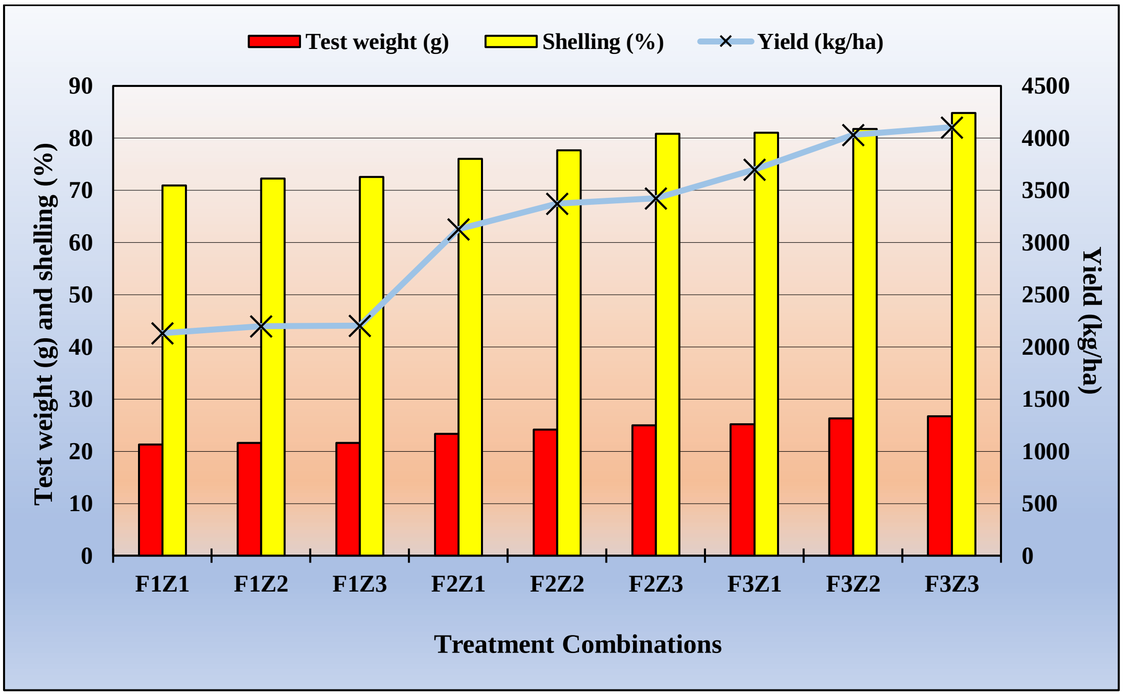


Fig 4.15: Interaction effects of fertilizer and zinc on mean test weight (g), shelling (%) and yield (kg ha^{-1}) at different growth stages of maize.

4.1.17 Stover yield (kg ha^{-1})

The results of the experiment regarding the effects of manure, level of fertilizers and zinc application in stover yield of maize plants are well presented in Table 4.16.

4.1.17.1 Effect of various sources of organic manures

The results indicated that there were no significant differences in the responses of three types of organic manure used in this study i.e., FYM, Poultry manure and Vermicompost. The performance of each of these organic manures were therefore statistically at par with each other in terms of stover yield of maize plants.

4.1.17.2 Effect of level of fertilizers

The data related to the effects of different treatments of fertilizers on stover yield of maize is presented in the Table 4.16. The analysis of variance study of the data indicated towards a significant difference among the responses of the various fertilizer treatments on stover yield of maize. The application of fertilizer @ 100% RDF (F_3) on an average was able to produce highest significant stover yield during 2016 (5733.96 kg ha^{-1}), 2017 (5788.30 kg ha^{-1}) and in pooled data (5761.13 kg ha^{-1}). It was followed by F_2 (50% RDF) which produced 5230.52 kg ha^{-1}, 5276.86 kg ha^{-1} and 5253.69 kg ha^{-1} stover yield during 2016, 2017 and in pooled data respectively.

Statistical analysis of the data revealed a significant change in stover yield of maize due to the application of different levels of fertilizers. Singh *et al.* (2000), Sanjeev *et al.* (1997) reported that as fertiliser application levels increased, stover yield increased. Krishnamurthy *et al.* (1974) saw a comparable gain in stover yield with higher fertilizer levels.

4.1.17.3 Effect of Zn application

The results indicated that there were no significant differences in the responses of three types of doses of Zn application during the study. The performance of each of these doses were therefore statistically at par with each other in terms of stover yield of maize plants.

Table 4.16: Effect of manure, fertilizer and zinc on mean stover yield (kg ha^{-1}) of maize.

Treatment	2016	2017	Pooled
Manures			
M_1 - FYM	4996.26	5040.09	5018.18
M_2 - Poultry	5136.26	5160.09	5148.18
M_3 - Vermicompost	4945.67	4989.51	4967.59
Sem ±	83.75	94.13	89.09
CD (P=0.05)	NS	NS	NS
Level of fertilizers			
F_1 - 0% RDF	4113.70	4124.54	4119.12
F_2 - 50% RDF	5230.52	5276.86	5253.69
F_3 - 100% RDF	5733.96	5788.30	5761.13
Sem ±	75.80	75.15	75.48
CD (P=0.05)	165.15	163.75	155.78
Zinc Level			
Z_1- 0 kg ha^{-1} Zn	4934.30	4980.47	4957.38
Z_2- 15 kg ha^{-1} Zn	5058.41	5094.58	5076.49
Z_3- 30 kg ha^{-1} Zn	5085.48	5114.65	5100.07
Sem ±	70.615	73.050	71.843
CD (P=0.05)	NS	NS	NS

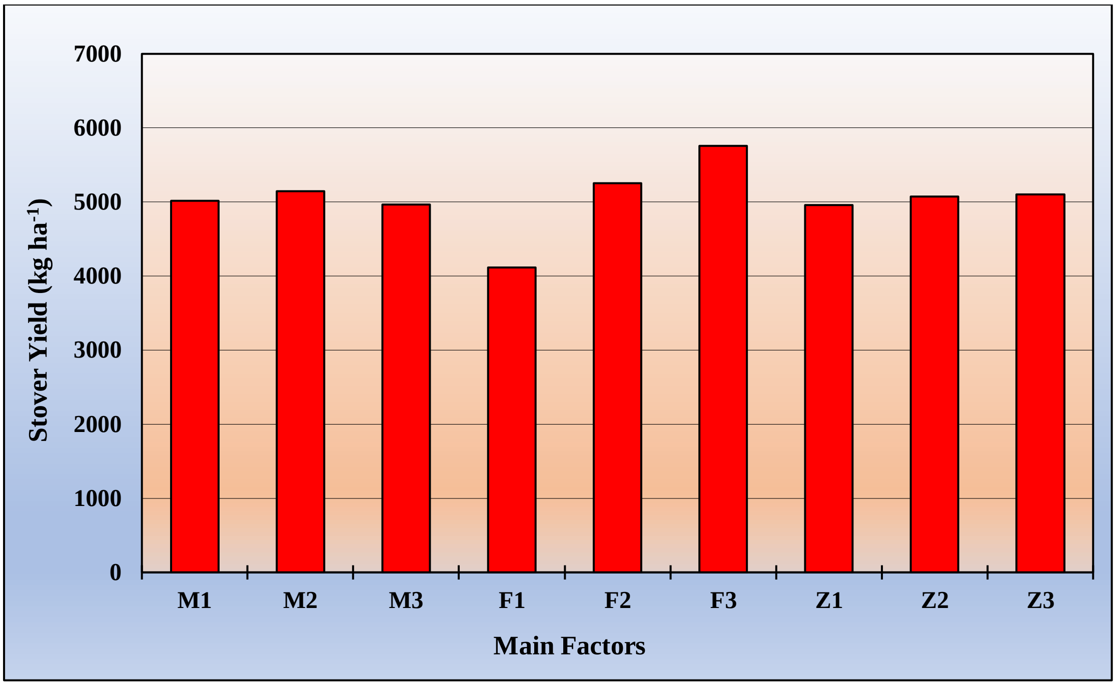


Fig 4.16: Effect of manure, fertilizer and zinc on mean stover yield (kg ha^{-1}) of maize.

4.2 QUALITY PARAMETERS

4.2.1 Available nitrogen in soil (kg ha^{-1})

4.2.1.1 Effect of sources of manure

Data pertaining to soil available nitrogen is presented in the Table 4.17. The critical examination of the data suggested that poultry manure @ 4 t ha^{-1} recorded higher available. Nitrogen (366.58 kg ha^{-1}) during 2016 which is comparable to application of vermicompost (357.77 kg ha^{-1}). However, in 2017 M_1 (FYM) recorded significantly highest available N (383.26 kg ha^{-1}). Similar trend was evident in pooled data too, but it failed to show any significant effect.

Increase in soil available nitrogen in poultry manure incorporated treatment may be attributed to the fact that organic materials supply nitrogen to the soil besides contributing many other beneficial effects to the soil. Bhandari *et al.* (2001) reported that organic manure released nitrogen which get incorporated in the soil humic material, thereby accounting for higher total nitrogen build-up.

Table 4.17: Effect of manure, fertilizer and zinc on mean nitrogen content of grain (%), stover (%) of maize and available soil nitrogen (kg ha^{-1}).

Treatment	Grain (%)			Soil (kg ha^{-1})			Stover (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	1.54	1.63	1.59	346.30	386.61	366.45	0.63	0.85	0.74
M_2 - Poultry	1.56	1.71	1.63	366.58	356.58	361.58	0.62	0.93	0.77
M_3 - Vermicompost	1.48	1.58	1.53	357.77	355.31	356.54	0.59	0.71	0.65
Sem ±	0.02	0.02	0.02	5.43	9.49	7.73	0.01	0.01	0.01
CD (P=0.05)	0.06	0.06	0.05	15.08	26.36	17.84	0.03	0.03	0.02
Level of fertilizers									
F_1 - 0% RDF	1.41	1.51	1.46	324.41	334.76	329.59	0.57	0.75	0.66
F_2 - 50% RDF	1.53	1.60	1.57	361.03	364.59	362.81	0.61	0.81	0.71
F_3 - 100% RDF	1.65	1.80	1.72	385.22	399.14	392.18	0.65	0.92	0.79
Sem ±	0.02	0.02	0.02	5.31	6.21	5.78	0.01	0.01	0.01
CD (P=0.05)	0.04	0.04	0.04	11.58	13.52	11.92	0.02	0.02	0.02
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	1.49	1.58	1.53	353.63	360.40	357.02	0.55	0.78	0.66
Z_2- 15 kg ha^{-1} Zn	1.51	1.63	1.57	355.51	363.63	359.32	0.61	0.83	0.72
Z_3- 30 kg ha^{-1} Zn	1.58	1.72	1.65	361.52	374.96	368.24	0.62	0.88	0.75
Sem ±	0.02	0.02	0.02	3.15	5.60	4.55	0.01	0.01	0.01
CD (P=0.05)	0.04	0.03	0.04	6.40	11.37	9.06	0.01	0.02	0.02

Poultry manure has inherent capacity to add good amount of organic carbon to the soil which ultimately hastens the process of mineralization of organically bound nitrogen present in native soil. The above findings are comparable with that of Toor and Bishnoi (1996) and Keelara (2001).

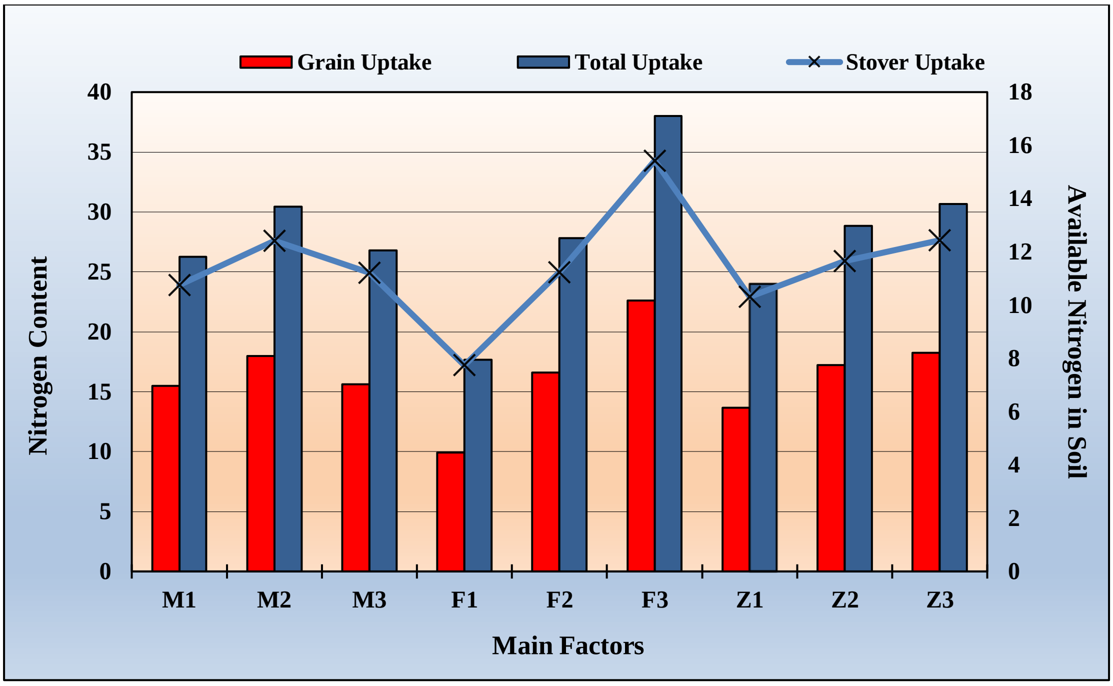


Fig 4.17: Effect of manure, fertilizer and zinc on mean nitrogen content of grain (%), stover (%) of maize and available soil nitrogen (kg ha^{-1}).

4.2.1.2 Effect of level of fertilizer

The data pertaining to the effect of fertilizer on available nitrogen is presented in Table 4.17. The perusal of the data revealed that application of fertilizer @ 100% RDF gave significantly high available Nitrogen with the value of 385.22 kg ha^{-1} during 2016, 399.19 kg ha^{-1} during 2017 and 392.18 kg ha^{-1} in pooled data. Further the data shows that available N increases with increase of fertilizer application.

The increase in the available nitrogen due to the incorporation of higher levels of fertilizer was evident from the results of current study. The increase in the availability of any nutrient in soil may be attributed to the direct addition of these nutrients in the experimental soil. Synergism between nitrogen, phosphorus and Zinc may also be responsible for the increase in available nitrogen. Similar result was also reported by Sharma and Jain (2012). Similarly, Kumar *et al.* (2005) noted that application of increasing level of fertilizers up to 100% RDF significantly increased available N, P and K status in soil.

4.2.1.3 Effect of Zinc level:

Critical examination of the data on effect of Zinc level in available nitrogen is presented in Table 4.17. The results indicated positive effect of Zinc application on the availability of nitrogen in the soil where with the increase in level of Zinc application the availability of nitrogen in soil increased. Further Zinc application at 30 kg ha^{-1} resulted in the significantly high available nitrogen in compared to control. Application of Zn @ 30 kg ha^{-1} recorded the highest nitrogen content in stover in all the year as well as pooled data. However, application of Zn @ 15 kg ha^{-1} was comparable during both the year as well as in pooled data.

The study gave clear indication of increased available nitrogen due to the incorporation of higher levels of $ZnSO_4$. This may be due to the synergism between nitrogen, phosphorus and Zinc may also be responsible for the increase in available nitrogen. Similar result was also reported by Sharma and Jain (2012). Paramasivan *et al.* (2011) noticed significantly higher available N in soil with application of 10 kg ha^{-1} Zn.

4.2.2 Nitrogen content in stover (%)

4.2.2.1 Effect of manure

Data pertaining to nitrogen content in stover is presented in Table 4.17. Critical examination of the data suggested that application of FYM results in significantly higher nitrogen content in stover with the value of 0.63 in 2016 which was at par with poultry manure. Whereas during 2017 and in pooled data poultry manure resulted in significantly higher nitrogen content in stover with the value of 0.93 and 0.77 respectively.

Uptake of any nutrient is subject to its relative availability in the soil solution. Application of poultry manure in soil increases the availability of nitrogen in soil by first slow release through degradation, mineralization of the fixed nitrogen and modification of the soil properties. All these factors make nitrogen available for absorption to the roots of plants for longer duration. Thereby increase the overall status of nitrogen in the maize plant stover. The above findings are comparable to Toor and Bishnoi (1996) and Keelara (2001).

4.2.2.2 Effect of level of fertilizer

An examination of data presented in Table 4.17 revealed that nitrogen content in stover was significantly increased due to application of fertilizer @ 100 % RDF during both the year (2016 and 2017) as well as pooled data with the value of 0.65, 0.92 and 0.79 respectively.

The results suggested towards the increase of nitrogen content in stover due to application of the increased levels of fertilizer. The direct application of nitrogen in combination with phosphorus increases the availability of nitrogen in soil. Therefore, higher absorption and accumulation of nitrogen to the maize plant stover. Karki *et al.* (2005); Zende *et al.* (2009) and Kumar and Dhar (2010) noted a similar increase in the nitrogen content in stover and grain of maize following application of 100% RDF.

4.2.2.3 Effect of Zinc

Effect of Zinc level in nitrogen content of stover is presented in Table 4.17. The data of revealed that application of Zn increased nitrogen content in stover significantly in compared to treatments with no Zn application. Application of Zn @ 30 kg ha^{-1} recorded the overall highest nitrogen content in stover in all the year as well as pooled data with the value of 0.62, 0.88 and 0.75 respectively. However, application of Zn @ 15 kg ha^{-1} (0.61) was comparableduring 2016. The above findings are comparable to that of Karki *et al.* (2005) and Abrol *et al.* (2007).

4.2.3 Available potassium in soil (kg ha^{-1})

4.2.3.1 Effect of manure

Data pertaining to effect of different sources of organic manure in soil available potassium is presented in Table 4.18.

Table 4.18: Effect of manure, fertilizer and zinc on mean potassium content (%) of grain, stover of maize and available soil potassium (kg ha^{-1}).

Treatment	Grain (%)			Soil (kg ha^{-1})			Stover (%)		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
Manures									
M_1 - FYM	0.47	0.61	0.53	160.73	164.75	162.74	1.15	1.71	1.43
M_2 - Poultry	0.52	0.64	0.58	175.34	182.49	178.91	1.24	2.31	1.77
M_3 - Vermicompost	0.49	0.63	0.56	172.69	178.23	175.46	1.17	1.84	1.50
Sem ±	0.01	0.01	0.01	2.65	2.96	2.81	0.02	0.02	0.02
CD (P=0.05)	0.02	0.02	0.02	7.35	8.21	6.47	0.06	0.06	0.05
Level of fertilizers									
F_1 - 0% RDF	0.46	0.57	0.51	147.99	154.42	151.20	1.11	1.76	1.43
F_2 - 50% RDF	0.50	0.62	0.56	174.28	175.00	174.64	1.19	1.85	1.52
F_3 - 100% RDF	0.54	0.69	0.61	186.48	196.05	191.26	1.25	2.25	1.75
Sem ±	0.01	0.01	0.01	2.10	2.56	2.34	0.02	0.02	0.02
CD (P=0.05)	0.02	0.02	0.02	4.57	5.58	4.83	0.04	0.04	0.03
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	0.45	0.60	0.52	166.57	171.08	168.82	1.14	1.73	1.45
Z_2- 15 kg ha^{-1} Zn	0.49	0.61	0.55	169.91	174.89	172.40	1.17	1.87	1.52
Z_3- 30 kg ha^{-1} Zn	0.52	0.67	0.59	172.28	179.50	175.89	1.22	2.25	1.73
Sem ±	0.01	0.01	0.01	1.63	2.16	1.91	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.02	3.30	4.37	3.81	0.03	0.02	0.03

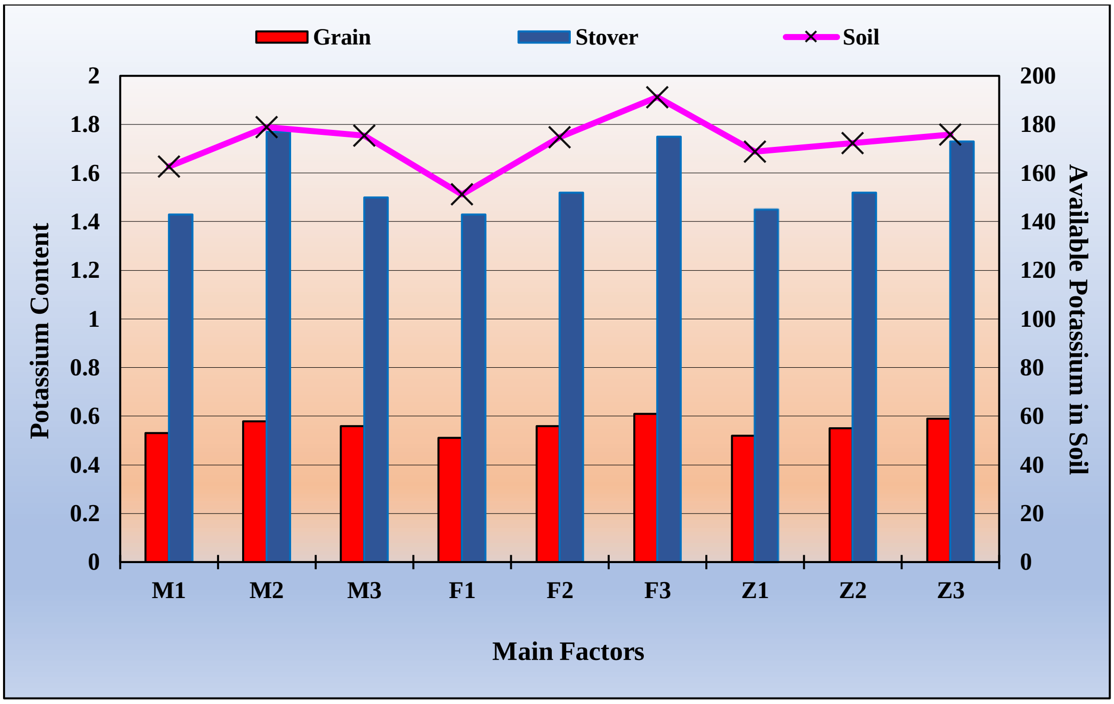


Fig 4.18: Effect of manure, fertilizer and zinc on mean potassium content (%) of grain, stover of maize and available soil potassium (kg ha^{-1}).

Close examination of the data revealed that in both the years as well as pooled data, application of poultry manure resulted in highest soil available potassium with the value of 175.34 kg ha^{-1} in 2016, 182.49 kg ha^{-1} in 2017 and 178.91 kg ha^{-1} in pooled data. However, application of vermicompost was comparable to poultry manure application in both years as well pooled data. The beneficial effect of poultry manure may be due to the slow release of the K throughout the growing period of the crop along with the reduction of K fixation and release of the fixed K due to the interaction of poultry manure with the clay minerals. Similar beneficial effects were also reported by Toor and Bishnoi (1996) and Keelara (2001).

4.2.3.2 Effect of level of fertilizer

An inference to data presented in Table 4.18 revealed that application of fertilizer up to 100 % RDF significantly increased the available potassium in soil. Similar trend of effect was observed in both the year as well as pooled data where the highest value was recorded in treatments with fertilizer @100 % RDF with the value of 186.48 kg ha^{-1} in 2016, 196.05 kg ha^{-1} in 2017 and 191.26 kg ha^{-1} in pooled data.

The evident increase in the available potassium with the incorporation of the higher levels of fertilizer may be attributed to the direct addition of the potassium along with the fertilizers. Similarly, Singh and Nepalia (2009) recorded the favourable effect of 125% RDF in increasing the available N and K status in the soil.

4.2.4 Potassium content in grain (%)

4.2.4.1 Effect of manure

The data of potassium content in grain due to the effect of different sources of manure is presented in Table 4.18. According to an analysis of the data, applying poultry manure caused considerably higher potassium content in grain both for the year and for the pooled data with the value of 0.58. However, application of vermicompost was at par with poultry manure except in 2016.

Application of poultry manure in the soil has improved the content of potassium in maize grain. It not only increased the availability of the potassium in soil solution for absorption by root, but the release of beneficial micronutrient by the decomposition of poultry manure enhances the mobilization of the potassium in the plant towards the grain, Similar beneficial effect on potassium content in grain by poultry manure were recorded by Toor and Bishnoi (1996) and Keelara (2001).

4.2.4.2 Effect of levels of fertilizer

It is apparent from the data presented in Table 4.18 that treatment with fertilizer @v100% RDF was found effective in increasing the potassium content in grain. In both the years as well as pooled data application of 100% RDF (F_3) recorded highest potassium concentration in grain with a pooled value of 0.61. while the treatments with 0% RDF recorded lowest average pooled value of 0.51.

Uptake of any nutrient is subject to its relative availability in the soil solution. The increase in the availability of any nutrient in soil may be attributed to the direct addition of these nutrients in the experimental soil. The increase in the availability of potassium in soil through the application of fertilizer increases the concentration of potassium around the roots of maize plant. Thereby increasing its absorption and accumulation in the grains during grain filling stage. Similar beneficial effect of fertilizer application was also noticed by Singh and Nepalia (2009); and Sobhana *et al.* (2012) and Singh *et al.* (2000).

4.2.4.3 Effect of Zinc

Critical examination of the data presented in Table 4.18 indicated that Zinc application @ 30 kg ha^{-1} recorded significantly high potassium content in grain during 2016 (0.52), 2017 (0.67) and even in pooled data with an average pooled value of 0.59.

Paramasivan *et al.* (2010) observed significant improved potassium content in grain upon application of Zinc @4.8 kg ha^{-1}. Similarly, Ashoka and Sunitha (2011) noticed that N, P, K and Zn content in baby corn significantly increased with application of 25 kg ha^{-1} $ZnSO_4$.

4.2.5 Stover potassium content (%)

4.2.5.1 Effect of manure

It is explicit from the data presented in Table 4.18 that application of poultry manure recorded significantly highest potassium content during both the cropping season i.e., 2016 (1.24), 2017 (2.31) as well as in pooled data with the value of 1.77.

Among the organic manures the superiority of poultry manures over vermicompost and FYM is well established in increasing nutrient content and uptake, may be due to its higher nutrient composition and easy mineralization with low C:N ratio. Similar finding was reported by Toor and Bishnoi (1996) and Keelara (2001).

4.2.5.2 Effect of level of fertilizer:

The experimental findings of potassium content in stover are presented in Table 4.18. It is evident from the data that application of fertiliser @ 100% RDF was found to be effective in increasing the potassium content significantly in stover. Significantly highest potassium content of stover was observed in F_3 (100 % RDF) treatment in both the years (1.25 in 2016, 2.25 in 2017) and pooled data (1.75).

Uptake of any nutrient is subject to its relative availability in the soil solution. The increase in the availability of any nutrient in soil may be attributed to the direct addition of these nutrients in the experimental soil. The increase in the availability of potassium in soil through the application of fertilizer increases the concentration of potassium around the roots of maize plant. Thereby increasing its absorption and accumulation in the stover. Similar beneficial effect of fertilizer application was also noticed by Singh and Nepalia (2009); and Sobhana *et al.* (2012) and Singh *et al.* (2000).

4.2.5.3 Effect of Zinc

Data pertaining to effect of Zinc in potassium content in stover is presented in Table 4.18. A critical examination revealed that application of Zn @ 30 kg ha^{-1} recorded significantly highest potassium content in stover in both the cropping season (1.22 in 2016 and 2.25 in 2017) as well as pooled data with the value 1.73.

Paramasivan *et al.* (2010) observed significant improved potassium content in stover upon application of Zinc @4.8 kg ha^{-1}. Similarly, Ashoka and Sunitha (2011) noticed that N, P, K and Zn content in baby corn stover significantly increased with application of 25 kg ha^{-1} $ZnSO_4$.

4.2.6 Available phosphorus in soil (kg ha^{-1})

4.2.6.1 Effect of manure

Data presented in Table 4.19 showed that incorporation of poultry manure @ 4t ha^{-1} increases the soil availability of phosphorus significantly in compared to other sources of organic manure. Same trend was evident in year 2016 and 2017 and even in the pooled data where application of poultry manure recorded highest available phosphorus with the value of 18.14 kg ha^{-1} in 2016, 18.05 kg ha^{-1} in 2017 which is at par with vermicompost (17.90 kg ha^{-1}) application and 18.10 kg ha^{-1} in pooled data.

Table 4.19: Effect of manure, fertilizer and zinc on mean phosphorus content (%) of grain, stover of Maize and available soil phosphorus (kg ha^{-1}).

Treatment	Grain (%)			Soil (kg ha^{-1})			Stover (%)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	0.39	0.58	0.49	15.99	16.89	16.44	0.17	0.25	0.21
M_2 - Poultry	0.43	0.65	0.54	18.14	18.05	18.10	0.20	0.28	0.24
M_3 - Vermicompost	0.40	0.60	0.51	16.92	17.90	17.49	0.19	0.26	0.22
Sem ±	0.01	0.01	0.01	0.37	0.39	0.38	0.01	0.01	0.01
CD (P=0.05)	0.02	0.02	0.01	1.04	1.07	0.88	0.02	0.01	0.01
Level of fertilizers									
F_1 - 0% RDF	0.36	0.55	0.46	14.76	15.06	14.91	0.16	0.22	0.19
F_2 - 50% RDF	0.40	0.59	0.50	16.96	17.51	17.24	0.18	0.25	0.21
F_3 - 100% RDF	0.45	0.69	0.57	19.32	20.48	19.90	0.22	0.32	0.27
Sem ±	0.01	0.01	0.01	0.31	0.25	0.28	0.01	0.01	0.01
CD (P=0.05)	0.02	0.01	0.02	0.68	0.54	0.58	0.01	0.01	0.01
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	0.37	0.50	0.43	16.70	17.35	17.02	0.18	0.23	0.20
Z_2- 15 kg ha^{-1} Zn	0.40	0.66	0.53	17.03	17.69	17.36	0.19	0.26	0.22
Z_3- 30 kg ha^{-1} Zn	0.42	0.67	0.55	17.32	18.01	17.66	0.21	0.29	0.24
Sem ±	0.01	0.01	0.01	0.24	0.25	0.24	0.01	0.01	0.01
CD (P=0.05)	0.02	0.01	0.02	0.49	0.50	0.49	0.01	0.01	0.01

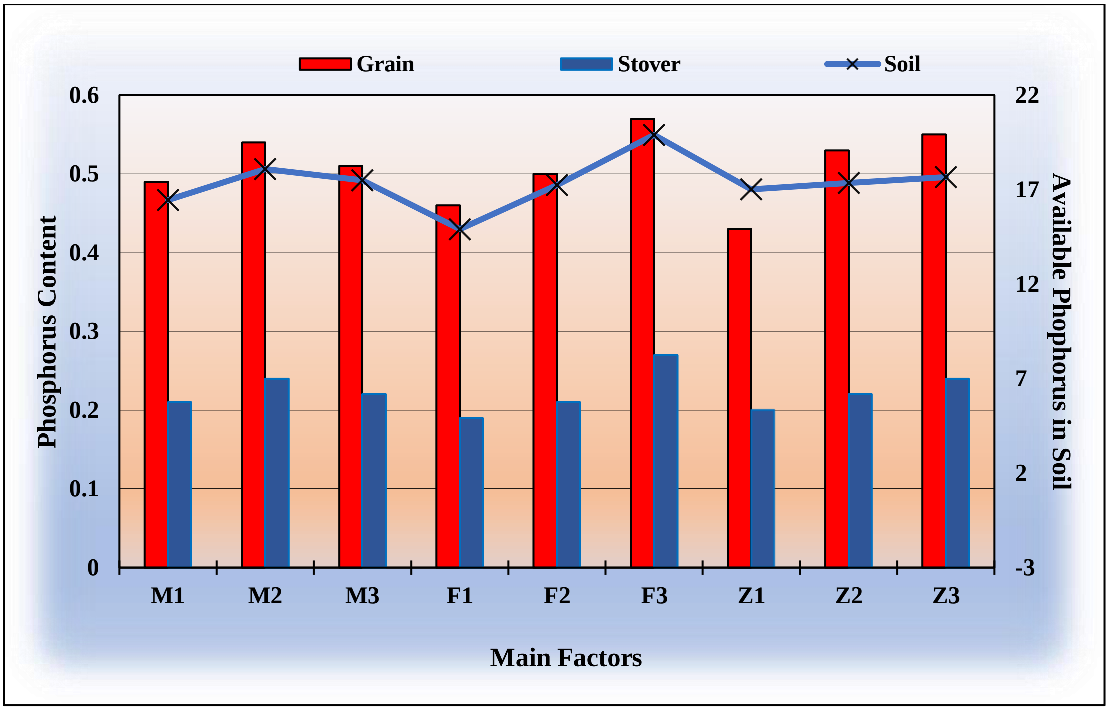


Fig 4.19: Effect of manure, fertilizer and zinc on mean phosphorus content (%) of grain, stover of Maize and available soil phosphorus (kg ha^{-1}).

Poultry manure is well known to have high nutrient status than the vermicompost and FYM. Increase in Soil available phosphorus in poultry manure incorporated treatment may be attributed to the fact that organic materials supply nitrogen to the soil besides contributing many other beneficial effects to the soil. Bhandari *et al.* (1992) reported that organic manure released nitrogen which get incorporated in the soil humic material, thereby accounting for higher total nitrogen build-up. Poultry manure has inherent capacity to add good amount of organic carbon to the soil which ultimately hastens the process of mineralization of organically bound nitrogen present in native soil. The above findings are comparable to Toor and Bishnoi (1996) and Keelara (2001).

4.2.6.2 Effect of levels of fertilizer

An inference drawn from the data presented in Table 4.19 showed that fertilizer application upto 100% RDF significantly increases the available phosphorus in soil during both the season and in pooled data. The value recorded are 19.32 in 2016 and 20.48 in 2017 and 19.90 in pooled data.

The increase in the available phosphorus is due to the incorporation of higher levels of fertilizers was evident from the results of current study. The increase in the availability of any nutrient in soil may be attributed to the direct addition of these nutrients in the experimental soil. Synergism between nitrogen, phosphorus and Zinc may also be responsible for the increase in available nitrogen. Similar results were also reported by Sharma and Jain (2012). Similarly, Kumar *et al.* (2005) noted that application of increasing level of fertilizers up to 100% RDF significantly increased available N, P and K status in soil.

4.2.6.3 Effect of Zinc

The data pertaining to effect of Zinc on mean available phosphorus in soil (Kg ha^{-1}) is presented in Table 4.19.

A critical examination of the data shows that available phosphorus in soil is positively affected by application of various level of Zinc. During 2016, highest available phosphorus in soil was recorded in treatments receiving Z_3 (30 kg ha^{-1} Zn) with the value of 17.32 kg ha^{-1} which is comparable to Z_2 (15 kg ha^{-1} Zn) with the value of 17.03 kg ha^{-1}. Similar trend was also observed during 2017 and in pooled data where Z_3 recorded the highest available of phosphorus in soil with 17.69 kg ha^{-1} and 17.36 kg ha^{-1} respectively.

Paramasivan *et al.* (2010) observed significant improved potassium content in grain upon application of Zinc @4.8 kg ha^{-1}. Similarly, Ashoka and Sunitha (2011) noticed that N, P, K and Zn content in baby corn significantly increased with application of 25 kg ha^{-1} $ZnSO_4$.

4.2.7 Phosphorus content in grain (%)

4.2.7.1 Effect of manure

The inference drawn from the data presented in Table 4.19 indicated that phosphorus content in grain was effectively influenced by the application of poultry manure. Highest phosphorus content in grain was recorded in treatment when poultry manure was applied. Similar trend was followed in both the year 2016 (0.43), 2017

(0.65) and pooled data (0.54). However, vermicompost was comparable to that to FYM.

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of potassium in soil compared to other form of organic manures. The positive effect on uptake of potassium by plants in PM treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.7.2 Effect of levels of fertilizer

The data presented in Table 4.19 revealed the effect of different level of fertilizer on phosphorus content in grain. From the data it was apparent that. Application of fertilizer @ 100% RDF recorded significantly highest phosphorus content in grain in both the cropping season (0.45 in 2016 and 0.69 in 2017) as well as in pooled data (0.57). while the lowest phosphorus content in grain were recorded from the maize plants receiving 0 % RDF *i.e.* F_1.

Application of fertilizer @ 100% RDF gave a substantial increase in the total uptake of potassium in the maize plants from the soil. Similar findings were also reporter earlier by Karki *et al.* (2005) and Fageria (2001).

4.2.7.3 Effect of Zinc

The data pertaining to effect of Zinc on mean phosphorus content of grain is presented in Table 4.19 critical examination of the data revealed that phosphorus content of the grain is influenced by level of Zinc. It was clear from data that application of different level of Zinc application has resulted in significantly increased phosphorus content of grain in the 2016, where highest phosphorus content in grain

(0.42) were recorded from maize plant receiving Z_3 (30 kg ha^{-1} Zn). Similarly, in 2017 highest phosphorus content of grain was recorded in treatment with Zinc application @ 30kg ha^{-1} Zn with the value of 0.67. Similar trend was observed in pooled data with highest value of 0.55.

The result indicated towards a positive association with the grain total Zinc and the potassium uptake. Similar result was also reported by Karki *et al.* (2005) and Paramasivan (2010).

4.2.7.4 Interaction of dose of fertilizer and Zinc

The interaction effect between Zinc application and fertilizer application on content for phosphorus in maize was found significant during both the years as well as on pooled data (Table 4.20). The finding reveals that the interaction between F_3 (@ 100% RDF) and Z_3 (Zinc @ 30 kg ha^{-1}) registered the significantly higher phosphorus content in maize grains during 2016 (0.49), 2017 (0.77) and in pooled data (0.63).

Orabi *et al.* (1981) postulated that the application of phosphorus through inorganic fertilizers and Zinc through $ZnSO_4$ results in increased phosphorus content due to the result of positive interaction between Zn and phosphorus.

4.2.8 Phosphorus content in stover (%)

4.2.8.1 Effect of manure

The data pertaining to the phosphorus content in stover during 2016, 2017 and pooled analysis is presented in the Table 4.19. Close examination of the data reveals that their significant differences among the response of various sources of organic manure in the accumulation of phosphorus in stover. However, the application of poultry manure has resulted in the highest phosphorus content in the stover during 2016, 2017 and pooled data as 0.20, 0.28 and 0.24 respectively. This was at par with vermicompost only in the year 2016.

Table 4.20: Interaction effects of fertilizer and zinc on mean phosphorus content (%) of grain, stover of Maize and available soil (kg ha^{-1}) phosphorus.

Treatment		Grain (%)			Soil (kg ha^{-1})			Stover (%)		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
F_1Z_1		0.36	0.45	0.40	14.40	14.90	14.65	0.15	0.18	0.17
F_1Z_2		0.36	0.60	0.48	14.86	15.00	14.93	0.16	0.22	0.19
F_1Z_3		0.37	0.61	0.49	15.01	15.28	15.15	0.16	0.25	0.20
F_2Z_1		0.40	0.49	0.44	16.76	17.24	17.00	0.17	0.21	0.19
F_2Z_2		0.40	0.65	0.52	16.95	17.50	17.22	0.18	0.25	0.22
F_2Z_3		0.41	0.65	0.53	17.18	17.78	17.48	0.19	0.27	0.23
F_3Z_1		0.43	0.57	0.50	18.95	19.90	19.42	0.21	0.29	0.25
F_3Z_2		0.44	0.72	0.58	19.27	20.58	19.92	0.22	0.32	0.27
F_3Z_3		0.49	0.77	0.63	19.75	20.96	20.35	0.22	0.35	0.28
Comparison:										
>A	**Sem ±**	0.01	0.01	0.01	0.42	0.43	0.42	0.01	0.01	0.01
	CD (P=0.05)	0.03	0.02	0.02	NS	NS	NS	NS	NS	NS
>B	**Sem ±**	0.01	0.01	0.01	0.46	0.43	0.55	0.01	0.01	0.01
	CD (P=0.05)	2.08	2.11	2.02	NS	NS	NS	NS	NS	NS

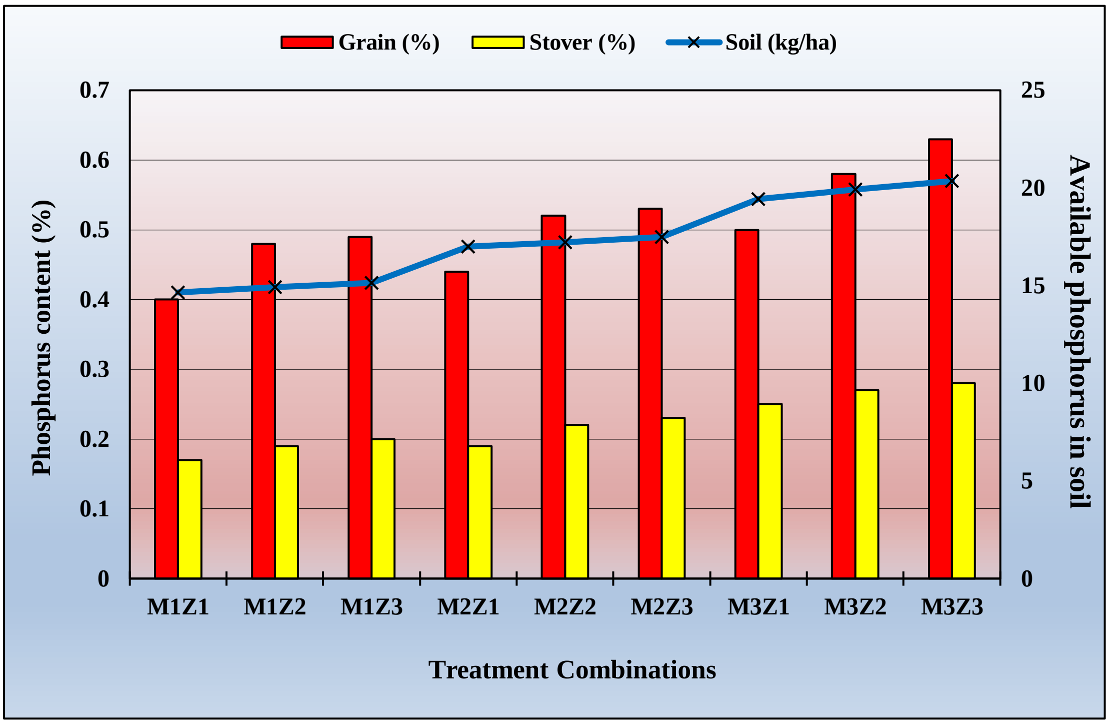


Fig 4.20: Interaction effects of fertilizer and zinc on mean phosphorus content (%) of grain, stover of Maize and available soil (kg ha^{-1}) phosphorus.

Several studies have revealed that poultry manure is more effective in increasing the availability of potassium in soil compared to other form of organic manures. The positive effect on uptake of potassium by plants in poultry manure treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.8.2 Effect of level of fertilizer

The data presented in the Table 4.19 regarding the effect of fertilizer application in phosphorus content in stover of maize plants showed a positive significant effect. With the increase in the level of fertilizer the overall phosphorus level in the stover increased significantly. This trend was consistent for both the years as well as the pooled data. The highest significant level of phosphorus on average were recorded from the treatments with the 100% RDF (F_3) *i.e*., 0.22 in 2016, 0.32 in 2017 and 0.27 in pooled data.

Application of highest level of fertilizer gave a substantial increase in the total uptake of potassium in the maize plants from the soil. Similar findings were also reporter earlier by Karki *et al.* (2005) and Fageria (2001).

4.2.8.3 Effect of Zinc application

The results associated to the effect of Zinc application in the total phosphorus content of maize stover presented in Table 4.19 reveals no significant differences for the response to various levels of Zinc application. The stover of maize plants with treatments involving application of Zinc @ 30kg ha^{-1} on an average accumulated highest significant phosphorus level during year 2016 (0.21), 2017 (0.29) and pooled data (0.24). The trends showed an increase in phosphorus levels with the increase in the application of Zinc.

The result indicated towards a positive association with the grain total Zinc and the potassium uptake. Similar result was also reported by Karki *et al.* (2005) and Paramasivan (2010).

4.2.9 Zinc content in Grain (ppm)

4.2.9.1 Effect of sources of manure

The data pertaining to the effect of manure in the mean zinc content in grain indicates towards a significant difference in response among the sources of manures (Table 4.21). Poultry manure showed the highest significant positive effect on Zinc level of grain where maize plants applied with it were able to accumulate highest Zinc in their grains as compared to the grains of plants applied with other manures. The trend was followed in both the year (0.46 in 2016 and 0.49 in 2017) and pooled data (0.47). However, the response of FYM was statistically at par with the response of poultry manure during 2016 (0.45), 2017 (0.47) and in pooled data (0.46).

The uptake of nutrient is a function of yield and its concentration in crop. Poultry manure is one of the potential organic sources of major, secondary and micro nutrients. The application of poultry manures therefore increases the availability of these micro nutrients which in turn increases the absorption of available Zinc by the roots. Similar findings were also reported by Karki *et al*. (2005).

4.2.9.2 Effect of level of fertilizer

The results presented in the Table 4.21 suggests the presence of the positive association between the fertilizer level applied and the Zinc content in the grain.

The significantly highest average grain zinc content was recorded with application of fertilizer @100% RDF during the year 2016 (0.55), 2017 (0.59) and pooled data (0.57). The overall trend suggests that with the increase in the levels of fertilizer resulted in higher accumulation of zinc in the grain of maize.

This effect is attributed to the synergistic effect of nitrogen and phosphorus on the absorption of available Zinc from the soil solution. Furthermore, high concentration of N and P also enhances the translocation of the absorbed Zinc in shoot to the grains during grain filling stage. Like that of our finding, Karki *et al*. (2005) reported an increase in Zn content as well as uptake in grains and stover of maize with fertilizer application of 100% RDF over 50% RDF and control.

4.2.9.3 Effect of Zinc application:

The results regarding the effect of Zinc application on the accumulation of Zinc in maize grain is presented in the Table 4.21. Highest significant accumulation of Zinc in maize grain were recorded from the application of Zinc @ 30 kg ha^{-1} during 2016 (0.47), 2017 (0.51) and pooled data (0.49). Close examination of the results indicated towards a positive trend in the Zinc accumulation with increasing level of Zinc application.

Table 4.21: Effect of manure, fertilizer and zinc on mean zinc content (ppm) of grain, stover of Maize and available soil zinc (kg ha^{-1}).

Treatment	Grain (ppm)			Soil (kg ha^{-1})			Stover (ppm)		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	0.45	0.47	0.46	23.64	23.82	23.73	1.49	1.76	1.63
M_2 - Poultry	0.46	0.49	0.47	24.22	24.74	24.48	1.51	1.79	1.64
M_3 - Vermicompost	0.43	0.46	0.44	24.06	24.40	24.23	1.44	1.71	1.57
Sem ±	0.01	0.01	0.01	0.61	0.62	0.62	0.01	0.02	0.02
CD (P=0.05)	0.01	0.02	0.01	NS	NS	NS	0.04	0.05	0.04
Level of fertilizers									
F_1 - 0% RDF	0.34	0.36	0.35	20.35	19.95	20.15	1.17	1.28	1.22
F_2 - 50% RDF	0.43	0.46	0.45	24.02	24.79	24.41	1.45	1.70	1.58
F_3 - 100% RDF	0.55	0.59	0.57	27.54	28.22	27.88	1.80	2.28	2.04
Sem ±	0.01	0.01	0.01	0.41	0.39	0.40	0.02	0.02	0.02
CD (P=0.05)	0.01	0.01	0.01	0.89	0.86	0.83	0.04	0.04	0.04
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	0.40	0.42	0.41	23.10	23.42	23.26	1.35	1.59	1.47
Z_2- 15 kg ha^{-1} Zn	0.45	0.49	0.47	24.15	24.43	24.29	1.51	1.79	1.65
Z_3- 30 kg ha^{-1} Zn	0.47	0.51	0.49	24.66	25.11	24.88	1.56	1.88	1.72
Sem ±	0.01	0.01	0.01	0.40	0.38	0.39	0.01	0.01	0.01
CD (P=0.05)	0.01	0.01	0.01	0.81	0.77	0.78	0.03	0.03	0.03

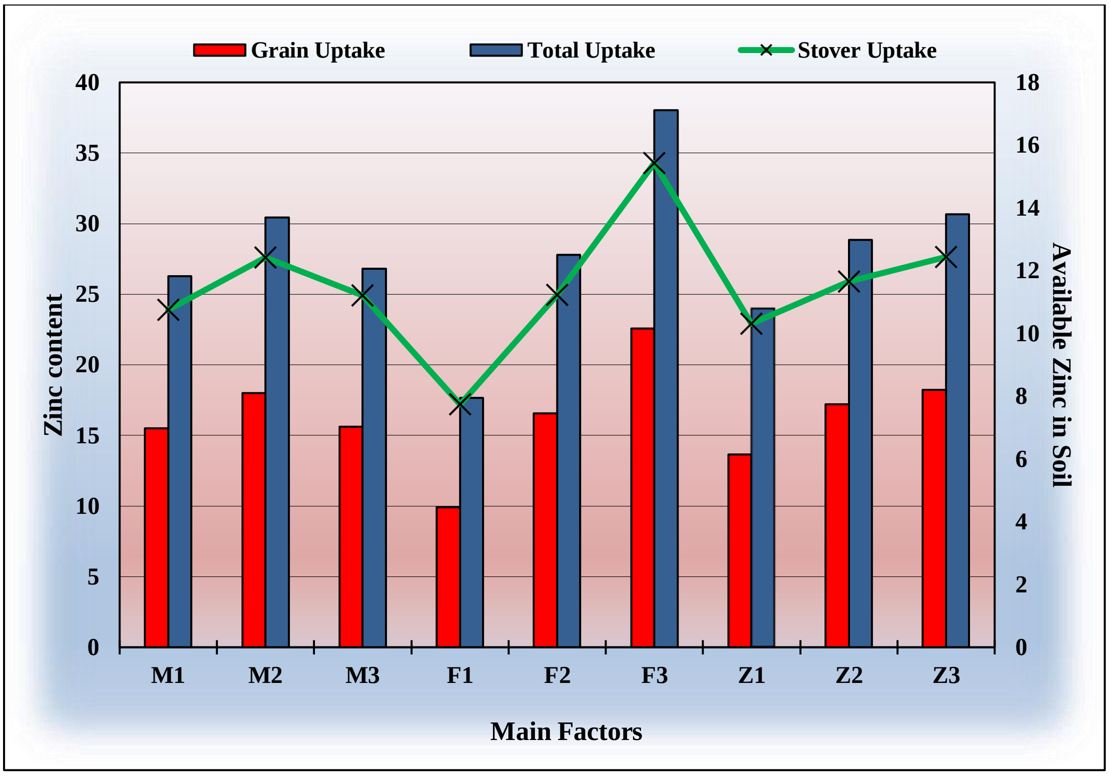


Fig 4.21: Effect of manure, fertilizer and zinc on mean zinc content (ppm) of grain, stover of Maize and available soil zinc (kg ha^{-1}).

Applying zinc by ZnSO4 may increase its availability in the soil close to roots; as a result, roots may take up more zinc, which would then increase its accumulation in maize shoots and grains. These results are entirely consistent with those of Zhang et al (2013). Similar to this, studies by Harris et al. (2007) and Hossain et al. (2008) demonstrated that applying zinc through ZnSO4 to plants can boost their uptake of zinc relative to the control..

4.2.10 Zinc content in soil (kg ha^{-1})

4.2.10.1 Effect of sources of manure

The data pertaining to the effect of various sources of organic manure in the mean available zinc in soil indicates towards no significant difference in the response of the three types of organic manure. However, application of poultry manure @ 4t ha^{-1} resulted in highest level of available Zinc in soil during 2016 (24.22), 2017 (24.74) and pooled data (24.48).

4.2.10.2 Effect of level of fertilizer

The data regarding the response of fertilizer in terms of available Zinc level in soil is presented in the Table 4.21. The highest available Zinc in soil after harvest was recorded from treatments involving application of fertilizer @ 100% RDF during both the years 2016 (27.54) and 2017 (28.22) and pooled data (27.88) as well. The overall trend indicated that with the increase in the levels of the fertilizer application resulted in the subsequent increase in the available Zinc content in soil after harvest. This trend was followed in both the year as well as pooled data.

Synergism between nitrogen, phosphorus and Zinc may also be responsible for the increase in available nitrogen. Increase available nitrogen and phosphorus in soil following the application of fertilizer is reported to increase availability of Zinc in soil. Similar results have been reported by Sankar *et al.* (2020) and Sharma and Jain (2012)

4.2.10.3 Effect of application of Zinc

Results pertaining to the effects of application of Zinc on the status of available zinc in soil is presented in the Table 4.21. The close examination of the result indicates that highest available Zinc in the soil resulted due to the application of Zinc @ 30 kg ha^{-1} during 2016 (24.66), 2017 (25.11) and pooled data (24.88). However, the response of Zinc application @ 15 kg ha^{-1} was at par with that of the Z_3. The trend shows that with increasing the levels of zinc application resulted in the subsequent increase in the levels of available Zinc in soil.

According to research study by Puga *et al*. (2013), the application of zinc greatly enhanced the soil's zinc concentration. The increase in the availability of any nutrient in soil may be attributed to the direct addition of these nutrients in the experimental soil. Similar results were also reported by Sankar *et al.* (2020) and Sharma and Jain (2012). Similarly, Kumar *et al.* (2002) noted that application of increasing level of fertilizers up to 100% RDF significantly increased available N, P and K status in soil.

4.2.11 Zinc content in stover (ppm)

4.2.11.1 Effect of types of organic manure

The data pertaining to the Zinc content in the stover is presented in the Table 4.21. The results suggest that during 2016 poultry manure (1.51) resulted in statistically highest Zinc content in maize stover. However, during year 2017 and pooled data application of poultry manure resulted in highest significant Zinc content in stover i.e., 1.79 and 1.64 respectively. This was closely followed by and statistically at par with FYM during 2016 (1.49), 2017 (1.76) and pooled data (1.63).

The uptake of nutrient is a function of yield and its concentration in crop. Poultry manure is one of the potential organic sources of major, secondary and micro nutrients. The application of poultry manures therefore, increase the availability of these micro nutrients which in turn increases the absorption of available Zinc by the roots.

4.2.11.2 Effect of level of fertilizer

The data presented in Table 4.21 describes the effect of the various fertilizer dose on the Zinc content in the maize stover. The results show that the highest Zinc content was recorded upon the application of the fertilizer @ 100% RDF during year 2016 (1.80), 2017 (2.28) and in pooled data (2.04). The overall trend shows a positive association between fertilizer level and the Zinc content in stover where, increasing the fertilizer levels also increases the zinc content.

This effect is attributed to the synergistic effect of nitrogen and phosphorus on the absorption of available Zinc from the soil solution. Furthermore, high concentration of N and P also enhances the translocation of the absorbed Zinc in shoot to the grains during grain filling stage. Like that of our finding, Karki *et al*. (2005) reported an increase in Zn content as well as uptake in stover of maize with application of 100% RDF over 50% RDF and control.

4.2.11.3 Effect of application of Zinc

The data on response of the Zinc application on the Zinc content of the maize stover has been presented in the Table 4.21. The significant highest Zinc content in the maize stover during 2016 was with Z_3 (1.56), during 2017 was again with Z_3 (1.88) and in pooled data as well with Z_3 (1.72). The trend suggests that with increase in the level of Zinc application the Zinc content in the stover will also increase.

Applying zinc by $ZnSO_4$ may increase its availability in the soil close to roots; as a result, roots may take up more zinc, which would then increase its accumulation in maize shoots and grains. These results are entirely consistent with those of Zhang *et al.* (2013). Similar to this, studies by Harris *et al.* (2007) and Hossain *et al.* (2008) demonstrated that applying zinc through $ZnSO_4$ to plants can boost their uptake of zinc relative to the control.

4.2.12 Nitrogen uptake in grain (kg ha^{-1})

4.2.12.1 Effect of source of organic manure

The data pertaining to the effect of various types of organic manure on the nitrogen uptake in the grain is presented in the Table 4.22. The result indicated towards the presence of the significant difference in the responses of the various organic manure. The highest mean nitrogen uptake in grain was recorded from the application of poultry manure @ 4 t ha^{-1} during year 2016 (51.81), 2017 (57.56) and pooled data (54.69). This response was similar in both the year as well as the pooled data.

Poultry manure is an excellent soil amendment that provides nutrients for growing crops and improves soil quality when applied wisely, because it has high organic matter content combined with available nutrients for plant growth.

Sugihara *et al.* (2010) observed that microbial biomass nitrogen clearly increases with the application of poultry manure during the early crop growth period, and that potentially leachable nitrogen is also immobilized. They also reported that the crop nitrogen uptake is improved by applying the poultry manure with the conclusion that the re-mineralization of immobilized nitrogen stimulates crop growth during the later period.

4.2.12.2 Effect of level of fertilizer

The data pertaining to the effect of various levels of fertilizer application on the mean nitrogen uptake in the grain is presented in the Table 4.22. The highest mean nitrogen uptake was recorded from the application of fertilizer @ 100 % RDF during 2016 (65.57), 2017 (70.76) and Pooled data (68.17). The overall trend observed shows a positive association between the fertilizer application and the mean nitrogen uptake of the grain where, increase in the levels of fertilizer application resulted in subsequent increase in the mean nitrogen uptake in the grain. Kar *et al.* (2006) noted that increase in the level of nitrogen from 0 to 80 kg N ha^{-1} increased the nitrogen uptake and protein yield in grain and stover significantly. Mishra *et al.* (1994) reported that increase in level of nitrogen from 100 to 200 kg ha^{-1} N significantly increased the nitrogen uptake and protein content of grain. Similarly, Killer and Zourarakis (1992) reported increase in nitrogen uptake and leaf and grain nitrogen concentration with increase in levels of nitrogen application.

4.2.12.3 Effect of the application of Zinc

The results of the effect of the application of the Zinc on the nitrogen uptake I grain is presented in the Table 4.23.

The highest nitrogen uptake in grain was recorded with the application of Zinc @ 30 kg ha^{-1} during 2016 (52.40), 2017 (56.80) and pooled data (54.60). The overall trend evident from the result was same in all the year and the pooled data as well, where with the increasing levels of Zinc application the uptake of nitrogen in maize grain also increased.

Table 4.22: Effect of manure, fertilizer and zinc on mean nitrogen uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

Treatment	Grain Uptake (kg ha^{-1})			Stover Uptake (kg ha^{-1})			Total Uptake (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	48.73	51.43	50.08	31.79	43.28	37.53	80.51	94.71	87.61
M_2 - Poultry	51.81	57.56	54.69	31.87	48.67	40.27	83.68	106.23	94.96
M_3 - Vermicompost	46.34	48.01	47.18	29.59	35.71	32.65	75.94	83.73	79.83
Sem ±	0.29	1.20	0.87	0.74	0.81	0.78	0.97	1.72	1.40
CD (P=0.05)	0.79	3.34	2.02	2.05	2.25	1.79	2.69	4.79	3.22
Level of fertilizers									
F_1 - 0% RDF	31.20	32.47	31.83	23.57	31.18	27.37	54.77	63.64	59.21
F_2 - 50% RDF	50.12	53.77	51.94	32.15	43.00	37.58	82.27	96.78	89.52
F_3 - 100% RDF	65.57	70.76	68.17	37.52	53.48	45.50	103.09	124.25	113.67
Sem ±	1.01	0.94	0.98	0.59	0.70	0.65	1.26	1.28	1.27
CD (P=0.05)	2.20	2.05	2.01	1.29	1.52	1.34	2.74	2.79	2.62
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	45.41	47.34	46.38	30.13	39.20	34.67	75.55	86.54	81.04
Z_2- 15 kg ha^{-1} Zn	49.07	52.86	50.97	31.15	42.73	36.94	80.22	95.60	87.91
Z_3- 30 kg ha^{-1} Zn	52.40	56.80	54.60	31.97	45.73	38.85	84.37	102.53	93.45
Sem ±	1.10	0.92	1.02	0.56	0.91	0.75	1.11	1.41	1.27
CD (P=0.05)	2.23	1.88	2.03	1.13	1.84	1.50	2.26	2.87	2.54

Table 4.23: Interaction effects of fertilizer and zinc on mean nitrogen uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

Treatment		Grain Uptake (kg ha^{-1})			Stover Uptake (kg ha^{-1})			Total Uptake (kg ha^{-1})		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
F_1Z_1		30.16	31.14	30.65	22.75	28.77	25.76	52.90	59.91	56.41
F_1Z_2		31.40	32.80	32.10	23.73	31.51	27.62	55.13	64.31	59.72
F_1Z_3		32.03	33.46	32.74	24.24	33.25	28.75	56.27	66.72	61.49
F_2Z_1		47.13	48.92	48.03	31.24	39.66	35.45	78.37	88.58	83.48
F_2Z_2		50.26	55.19	52.73	32.19	43.74	37.97	82.45	98.93	90.69
F_2Z_3		52.96	57.21	55.08	33.03	45.61	39.32	85.99	102.81	94.40
F_3Z_1		58.95	61.95	60.45	36.41	49.17	42.79	95.36	111.13	103.24
F_3Z_2		65.55	70.60	68.08	37.52	52.95	45.24	103.07	123.56	113.31
F_3Z_3		72.21	79.73	75.97	38.63	58.32	48.48	110.85	138.06	124.45
Comparison:										
>A	**Sem ±**	1.91	1.60	1.76	0.97	1.57	1.31	1.93	2.45	2.20
	CD (P=0.05)	3.87	3.25	3.51	NS	NS	NS	3.91	4.96	4.39
>B	**Sem ±**	1.85	1.61	1.63	0.99	1.46	1.20	2.02	2.37	2.27
	CD (P=0.05)	2.07	2.08	2.02	NS	NS	NS	2.09	2.07	2.02

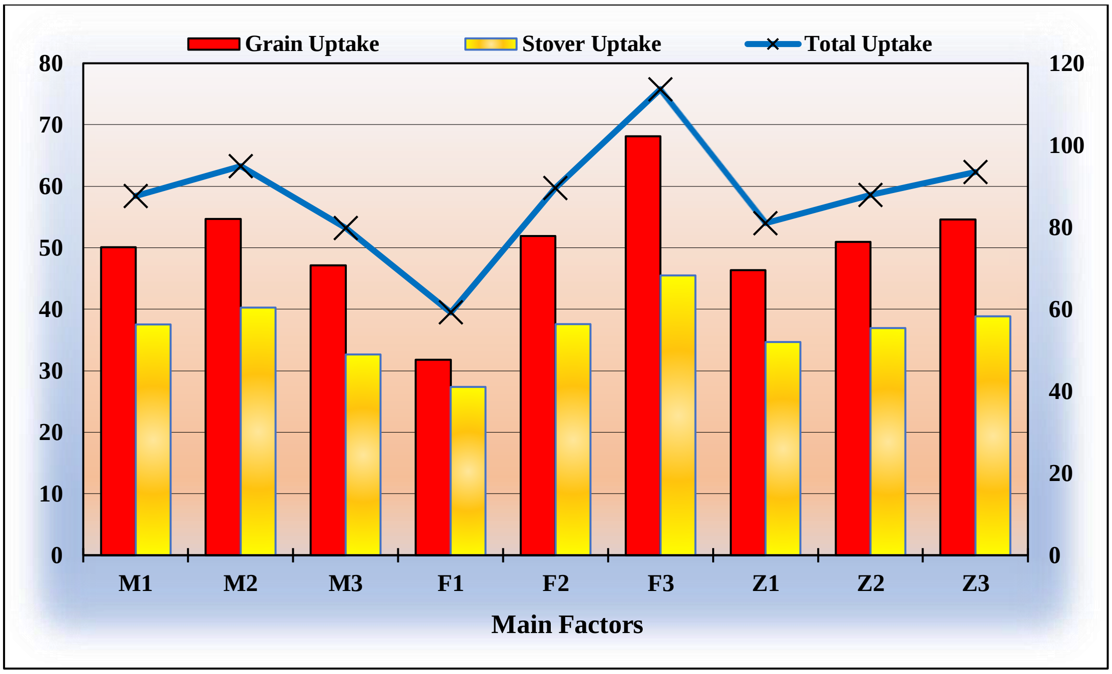


Fig 4.22: Effect of manure, fertilizer and zinc on mean nitrogen uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

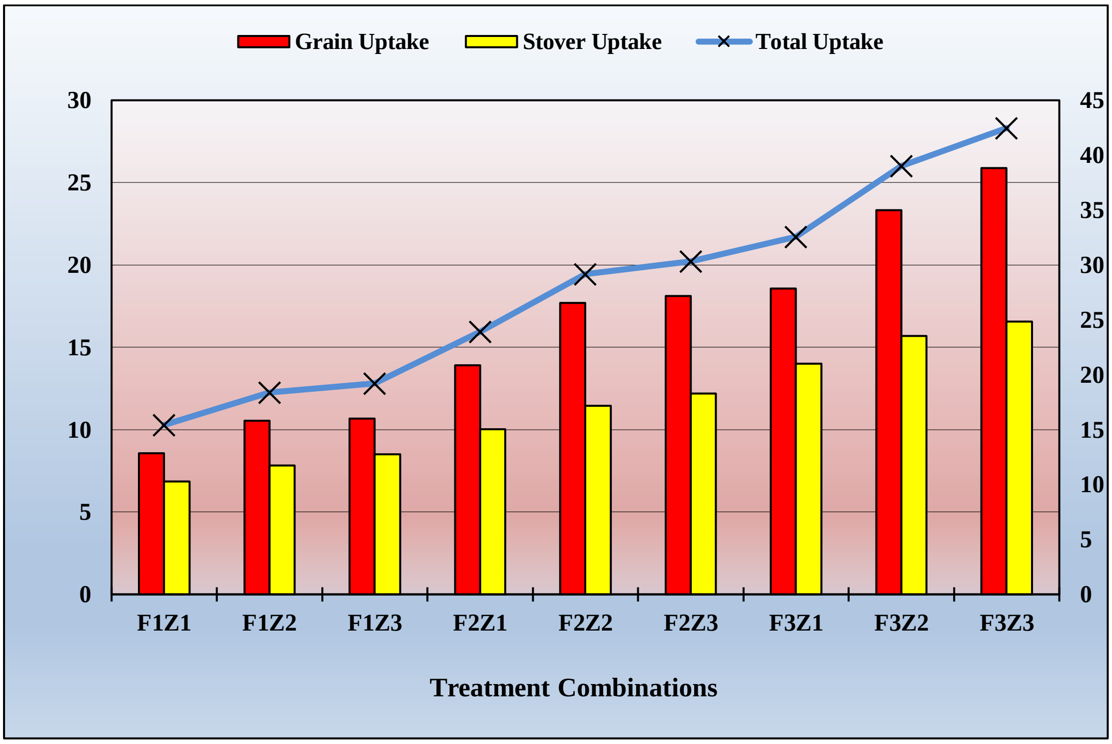


Fig 4.23: Interaction effects of fertilizer and zinc on mean nitrogen uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

The results of effect of Zn application on the grain nitrogen uptake shows that the increase in Zn fertilizer could significantly increase the N content and accumulation in individual plant organs at harvest. Zn significantly affected the biosynthesis and structural and functional integrity of proteins. It has been reported that proteins in grain are considered to be a pool for Zn, and, under Zn-sufficient conditions, there was a strong positive correlation between grain Zn content and grain N content (Cakmak *et al.*, 2010; Kutman *et al.*, 2010).

4.2.12.4 Interaction of Zinc and fertilizer level

The interaction effect between Zinc application and fertilizer application on nitrogen uptake in maize grains was found significant during both the years as well as on pooled data (Table 4.23). The finding reveals that the interaction between fertilizer @ 100% RDF (F_3) and Zinc @ 30 kg ha^{-1} (Z_3) registered the significantly higher uptake of nitrogen in maize grains during 2016 (72.21), 2017 (79.73) and in pooled data (75.97). This might be due to better absorption, translocation and assimilation of nitrogen in grains. Similar results were also reported by Kumar and Bohra (2014).

4.2.13 Nitrogen uptake in stover (kg ha^{-1})

4.2.13.1 Effect of various organic manure

The data pertaining to the effect of various types of organic manure on the nitrogen uptake in the stover is presented in the Table 4.22.

The result indicated towards the presence of the significant difference in the responses of the various organic manure. The response varied in each year. Where during 2016, the highest nitrogen uptake was recorded from the application of the poultry manure (31.87) but, this was statistically at par with the effects of FYM. During 2017, the highest nitrogen uptake in the maize stover was recorded from the application of the FYM (48.67). The pooled data shows that the highest mean nitrogen uptake in the maize stover was recorded by the application of FYM (40.27). During both the year and the pooled data, vermicompost resulted in the lesser mean nitrogen uptake in the maize stover.

Poultry manure is an excellent soil amendment that provides nutrients for growing crops and improves soil quality when applied wisely, because it has high organic matter content combined with available nutrients for plant growth. Sugihara *et al.* (2010) observed that microbial biomass nitrogen clearly increases with the application of poultry manure during the early crop growth period, and that potentially leachable nitrogen is also immobilized. They also reported that the crop nitrogen uptake is improved by applying the poultry manure with the conclusion that the re-mineralization of immobilized nitrogen stimulates crop growth during the later period.

4.2.13.2 Effect of the level of fertilizer

The results of the present experiment regarding the effects of the application of fertilizer in the uptake of nitrogen in the maize stover is presented in the Table 15. The significantly highest nitrogen uptake in maize stover was recorded from the application of fertilizer @ 100 % RDF during 2016 (37.52), 2017 (53.48) and pooled data (45.50). The overall trend showed an increasing response of the fertilizer application where, increase in the levels of fertilizer the average nitrogen uptake in stover also increased.

Kar *et al.* (2006) noted that increase in the level of nitrogen from 0 to 80 kg N ha^{-1} increased the nitrogen uptake and protein yield in grain and stover significantly. Mishra *et al.* (1994) reported that increase in level of nitrogen from 100 to 200 kg ha^{-1} N significantly increased the nitrogen uptake and protein content of grain. Similarly, Killer and Zourarakis (1992) reported increase in nitrogen uptake and leaf and grain nitrogen concentration with increase in levels of nitrogen application.

4.2.13.3 Effect of the application of Zinc

The results presented in the Table 4.22 shows that the highest value of mean nitrogen uptake in the maize stover were recorded from the application of Zinc @ 30 kg ha^{-1} during 2016 (31.97), 2017 (45.73) and pooled data (38.85). This was followed by the application of the zinc application @ 15 kg ha^{-1}. There was the increase response of the zinc application evident from the results. Where with increase in each level of the applied Zinc the uptake of nitrogen in the maize stover also increased subsequently.

The results of effect of Zn application on the grain nitrogen uptake shows that the increase in Zn fertilizer could significantly increase the N content and accumulation in individual plant organs at harvest. Zn significantly affected the biosynthesis and structural and functional integrity of proteins. It has been reported that proteins in grain are considered to be a pool for Zn, and, under Zn-sufficient conditions, there was a strong positive correlation between grain Zn content and grain N content (Cakmak *et al.*, 2010; Kutman *et al.*, 2010).

4.2.14 Total nitrogen uptake (kg ha^{-1})

4.2.14.1 Effect of organic manure

The data pertaining to the total uptake of the nitrogen in maize plant is presented in the Table 4.22. The data from 2016 shows that the significantly highest total nitrogen uptake was recorded from application of poultry manure (83.68). During 2017, the highest significant total nitrogen uptake in maize plants was recorded from the application of poultry manure (106.23). The data of pooled analysis also shows that the highest total nitrogen uptake was recorded from the maize plants subjected to the poultry manure (94.96) application as the source of the organic manure. While in both the year and in pooled data treatments receiving vermicompost consistently showed lowest total nitrogen uptake in the maize plants.

Poultry manure is an excellent soil amendment that provides nutrients for growing crops and improves soil quality when applied wisely, because it has high organic matter content combined with available nutrients for plant growth. Sugihara *et al.* (2010) observed that microbial biomass nitrogen clearly increases with the application of poultry manure during the early crop growth period, and that potentially leachable nitrogen is also immobilized. They also reported that the crop nitrogen uptake is improved by applying the poultry manure with the conclusion that the re-mineralization of immobilized nitrogen stimulates crop growth during the later period.

4.2.14.2 Effect of level of fertilizer

The result shows presence of the positive association between fertilizer level with the total nitrogen uptake in the maize plants. Where, with the increasing levels of fertilizer the subsequent increase in the total nitrogen uptake was evident. The highest total nitrogen uptake was recorded form the application of fertilizer @ 100% RDF during 2016 (103.09), 2017 (124.25) and pooled data (113.67). This trend was followed throughout the period of the experiment.

Kar *et al.* (2006) noted that increase in the level of nitrogen from 0 to 80 kg N ha^{-1} increased the nitrogen uptake and protein yield in grain and stover significantly. Mishra *et al.* (1994) reported that increase in level of nitrogen from 100 to 200 kg ha^{-1} N significantly increased the nitrogen uptake and protein content of grain. Similarly, Killer and Zourarakis (1992) reported increase in nitrogen uptake and leaf and grain nitrogen concentration with increase in levels of nitrogen application.

4.2.14.3 Effect of the application of Zinc

The data presented in the Table 4.22 regarding the total nitrogen uptake suggest that the increase in the levels of the Zinc applied resulted in the subsequent increase in total uptake of nitrogen in the maize. The highest significant uptake was recorded with the application of Zinc @ 30 kg ha^{-1} during 2016 (84.37), 2017 (102.53) and pooled data (93.45). This was followed by the application of Zinc @ 15 kg ha^{-1} (Z_2).

The results of effect of Zn application on the grain nitrogen uptake shows that the increase in Zn fertilizer could significantly increase the N content and accumulation in individual plant organs at harvest. Zn significantly affected the biosynthesis and structural and functional integrity of proteins. It has been reported that proteins in grain are considered to be a pool for Zn, and, under Zn-sufficient conditions, there was a strong positive correlation between grain Zn content and grain N content (Cakmak *et al.*, 2010; Kutman *et al.*, 2010).

4.2.14.4 Interaction of Zinc and fertilizer level

The interaction effect between Zinc application and fertilizer application on total nitrogen uptake in maize plants was found significant during both the years as well as on pooled data (Table 4.23). The finding reveals that the interaction between fertilizer @ 100% RDF (F_3) and Zinc @ 30 kg ha^{-1} (Z_3) registered the significantly highest total uptake of nitrogen in maize plants during 2016 (110.85), 2017 (138.06) and in pooled data (124.45).

In the present study the combined effect of Zinc and fertilizer application on the total nitrogen uptake was very much evident. This could be due to the concomitant availability of Zn, Nitrogen and Phosphorus to the crop roots. This is supported by the fact that fertilization along with RDF in corn increased the N concentration and uptake by corn grain and stover. A similar positive effect of Zn and fertilizer application was reported by Lakshmanan *et al.* (2005); Pooniya and Shivay (2013); Wu *et al*. (2010).

4.2.15 Phosphorus uptake on grain (kg ha^{-1})

4.2.15.1 Effect of organic manure

The data pertaining to the uptake of phosphorus in grains of maize is presented in the Table 4.24. The data indicated towards the significant difference in the response of application of three types of organic manure in the uptake of phosphorus in maize grains.

The significantly highest uptake of phosphorus in grain was recorded with the application of poultry manure during 2016 (13.77), 2017 (22.22) and pooled data (18.00). This was followed by vermicompost during 2016 (12.92) and pooled data (15.61). The trend during all the years and pooled data remained the same where, poultry manure resulted in the highest uptake of phosphorus followed by vermicompost.

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of phosphorus in soil compared to other form of organic manures. The positive effect on uptake of phosphorus by plants in PM treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.15.2 Effect of level of fertilizer

The results of the present experiment regarding the effects of the application of fertilizer in the uptake of phosphorus in the maize grain is presented in the Table 4.24. The significantly highest phosphorus uptake in maize grain was recorded from the application of fertilizer @ 100 % RDF during 2016 (18.05), 2017 (27.13) and pooled data (22.59). The overall trend showed an increasing response of the fertilizer application where, increase in the levels of fertilizer the average phosphorus uptake in grain also increased.

Phosphorus is very important for the plants as without it the plants cannot initiate the transition from the vegetative stage to the reproductive stage. Phosphorus absorption and utilization in the plants is greatly improved under sufficient N and K fertilization (Bindraban *et al*., 2020). NPK treatment significantly increase phosphatase activity in soil there by increasing p mobility and uptake, and reduces the residual phosphorus at the site.

4.2.15.3 Effect of Zinc application

The results regarding the effect of Zinc application on the uptake of phosphorus in maize grain is presented in the Table 4.24. Highest significant uptake of phosphorus in maize grain were recorded from the application of Zinc @ 30 kg ha^{-1} during 2016 (14.13), 2017 (22.34) and pooled data (18.23).

Table 4.24: Effect of manure, fertilizer and zinc on mean phosphorus uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

Treatment	Grain uptake (kg ha^{-1})			Stover uptake (kg ha^{-1})			Total uptake (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	12.54	18.47	15.50	8.68	12.84	10.76	21.22	31.31	26.26
M_2 - Poultry	13.77	22.22	18.00	10.27	14.58	12.42	24.04	36.80	30.42
M_3 - Vermicompost	12.92	18.29	15.61	9.36	13.06	11.21	22.27	31.35	26.81
Sem ±	0.28	0.55	0.44	0.31	0.27	0.29	0.53	0.77	0.66
CD (P=0.05)	0.77	1.53	1.00	0.87	0.76	0.68	1.48	2.15	1.53
Level of fertilizers									
F_1 - 0% RDF	8.01	11.86	9.93	6.48	9.00	7.74	14.48	20.87	17.67
F_2 - 50% RDF	13.17	19.99	16.58	9.46	12.99	11.23	22.63	32.98	27.80
F_3 - 100% RDF	18.05	27.13	22.59	12.37	18.49	15.43	30.42	45.62	38.02
Sem ±	0.30	0.48	0.40	0.31	0.29	0.30	0.47	0.60	0.54
CD (P=0.05)	0.65	1.06	0.83	0.68	0.64	0.62	1.02	1.32	1.11
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	12.10	15.25	13.67	8.99	11.63	10.31	21.08	26.88	23.98
Z_2- 15 kg ha^{-1} Zn	13.00	21.40	17.20	9.61	13.69	11.65	22.61	35.09	28.85
Z_3- 30 kg ha^{-1} Zn	14.13	22.34	18.23	9.71	15.16	12.43	23.84	37.50	30.67
Sem ±	0.31	0.40	0.36	0.20	0.26	0.23	0.35	0.53	0.45
CD (P=0.05)	0.62	0.81	0.71	0.41	0.53	0.47	0.72	1.07	0.89

Table 4.25: Interaction effects of fertilizer and zinc on mean phosphorus uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

Treatment		Grain uptake (kg ha^{-1})			Stover uptake (kg ha^{-1})			Total uptake (kg ha^{-1})		
		2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
F_1Z_1		7.72	9.39	8.56	6.25	7.49	6.87	13.97	16.89	15.43
F_1Z_2		8.04	13.09	10.56	6.50	9.15	7.83	14.54	22.23	18.39
F_1Z_3		8.26	13.11	10.68	6.67	10.38	8.52	14.93	23.48	19.21
F_2Z_1		12.41	15.38	13.90	8.97	11.12	10.04	21.38	26.50	23.94
F_2Z_2		13.18	22.24	17.71	9.62	13.26	11.44	22.80	35.50	29.15
F_2Z_3		13.92	22.34	18.13	9.80	14.58	12.19	23.72	36.93	30.32
F_3Z_1		16.16	20.97	18.56	11.75	16.28	14.01	27.90	37.25	32.58
F_3Z_2		17.78	28.87	23.32	12.71	18.67	15.69	30.48	47.54	39.01
F_3Z_3		20.21	31.56	25.89	12.66	20.51	16.58	32.87	52.07	42.47
Comparison:										
>A	**Sem ±**	0.53	0.69	0.62	0.35	0.46	0.41	0.61	0.91	0.78
	CD (P=0.05)	1.08	1.40	1.23	NS	NS	NS	1.24	1.85	1.55
>B	**Sem ±**	0.53	0.74	0.72	0.42	0.47	0.52	0.68	0.96	1.01
	CD (P=0.05)	2.08	2.09	2.02	NS	NS	NS	2.10	2.09	2.02

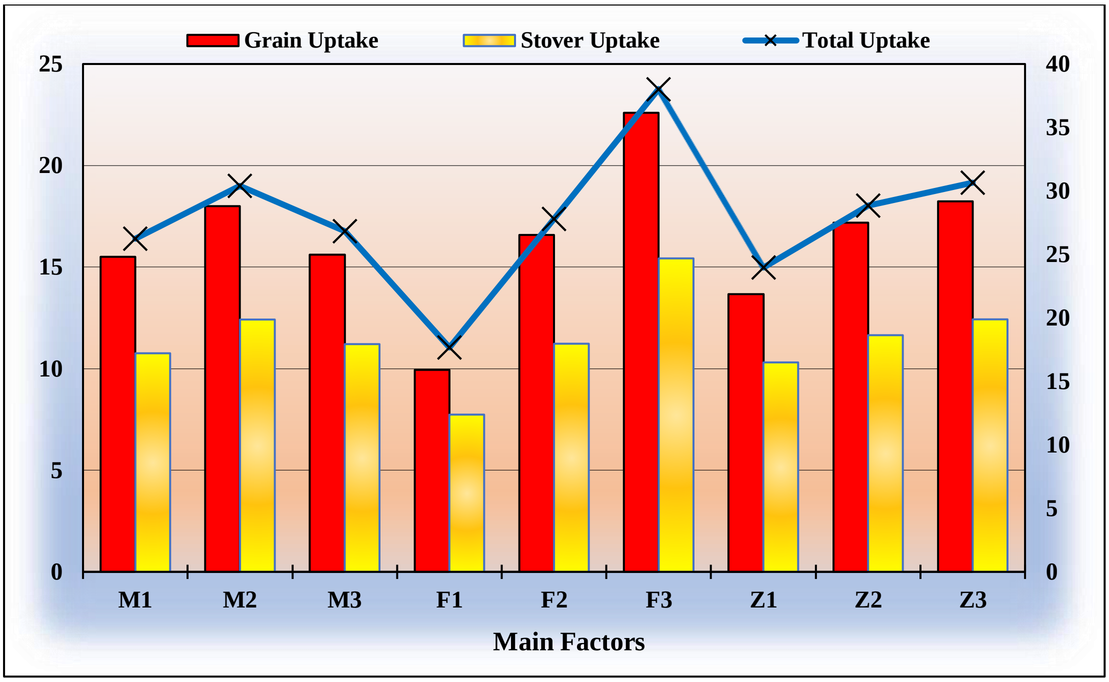


Fig 4.24: Effect of manure, fertilizer and zinc on mean phosphorus uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

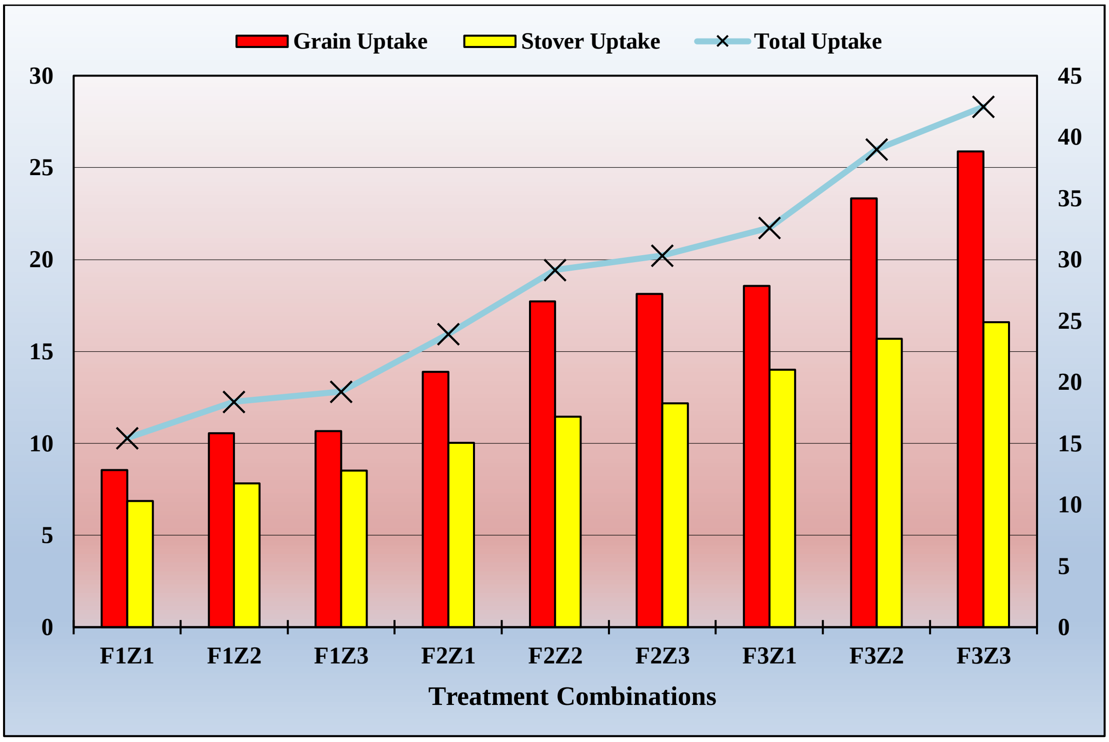


Fig 4.25: Interaction effects of fertilizer and zinc on mean phosphorus uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

This was followed by Z_2 (15 kg ha^{-1}) which was statistically at par with Z_3 during 2016 (13.00), 2017 (21.40) and in pooled data (17.20). Close examination of the results indicated towards a positive trend in the uptake of phosphorus with increasing level of Zinc application.

This could be due to the increased availability of the nutrients in the presence of high Zn content in soil as a result of Zinc application. The utilisation of nitrogen, phosphorus, and potassium by plants in the production of yield and protein synthesis depends critically on zinc. In the rhizosphere, zinc helps to mobilise phosphorus. Zinc application increases phosphorus uptake because more nutrients are available to plants from the soil reservoir and more nutrients are provided by organic manures. The results are in line with the findings of Safaya (1976) and Bukvić *et al.* (2003).

4.2.15.4 Interaction of Zinc and fertilizer level

The interaction effect between Zinc application and fertilizer application on phosphorus uptake in maize grains was found significant during both the years as well as on pooled data (Table 4.25). The finding reveals that the interaction between fertilizer @ 100% RDF (F3) and Zinc @ 30 kg ha^{-1} (Z3) registered the significantly higher uptake of phosphorus in maize grains during 2016 (20.21), 2017 (31.56) and in pooled data (25.89).

Orabi *et al.* (1981) postulated that the application of phosphorus through inorganic fertilizers and Zinc through $ZnSO_4$ results in increased phosphorus uptake due to the result of positive interaction between Zn and phosphorus.

4.2.16 Phosphorus uptake on stover (kg ha^{-1})

4.2.16.1 Effect of organic manure

The data pertaining to the uptake of phosphorus in stover of maize is presented in the Table 4.24. The data indicated towards the significant difference in the response of application of three types of organic manure in the uptake of phosphorus in maize plant stover. The significantly highest uptake of phosphorus in stover was recorded with the application of poultry manure during 2016 (10.27), 2017 (14.58) and pooled data (12.42). This was followed by vermicompost during 2016 (9.36), 2017 (9.74) and pooled data (9.55). The trend during all the years and pooled data remained the same where, poultry manure resulted in the highest uptake of phosphorus followed by vermicompost.

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of phosphorus in soil compared to other form of organic manures. The positive effect on uptake of phosphorus by plants in PM treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.16.2 Effect of level of fertilizer

The results of the present experiment regarding the effects of the application of fertilizer in the uptake of phosphorus in the maize plant stover is presented in the Table 4.25. The significantly highest phosphorus uptake in maize stover was recorded from the application of fertilizer @ 100 % RDF during 2016 (12.37), 2017 (18.49) and pooled data (15.43). The overall trend showed an increasing response of the fertilizer where, increase in the levels of fertilizer application the average phosphorus uptake in maize plant stover also increased.

Phosphorus is very important for the plants as without it the plants cannot initiate the transition from the vegetative stage to the reproductive stage. Phosphorus absorption and utilization in the plants is greatly improved under sufficient N and K fertilization (Bindraban *et al*., 2020). NPK treatment significantly increase phosphatase activity in soil there by increasing p mobility and uptake, and reduces the residual phosphorus at the site.

4.2.16.3 Effect of Zinc application

The results regarding the effect of Zinc application on the uptake of phosphorus in maize stover is presented in the Table 4.25. Highest significant uptake of phosphorus in maize stover were recorded from the application of Zinc @ 30 kg ha^{-1} during 2016 (9.71), 2017 (10.11) and pooled data (9.91). This was followed by Z2 (15 kg ha^{-1}) which was statistically at par with Z3 (30 kg ha^{-1}) during 2016 (9.61), 2017 (9.88) and in pooled data (9.74). Close examination of the results indicated towards a positive trend in the uptake of phosphorus in stover with increasing level of Zinc application.

This can be as a result of higher nutrient availability in soil with high Zn concentration as a result of zinc application. Zinc is essential for plats' use of nitrogen, phosphorus, and potassium in yield and protein synthesis. In the rhizosphere, zinc helps to mobilise phosphorus. Zinc application increases phosphorus uptake because more nutrients are available to plants from the soil reservoir and more nutrients are provided by organic manures. The results are in line with the findings of Safaya (1976) and Bukvić *et al.* (2003).

4.2.17 Total phosphorus uptake (kg ha^{-1})

4.2.17.1 Effect of organic manure

The data pertaining to the total uptake of the Phosphorus in maize plant is presented in the Table 4.25. The data from 2016 shows that the significantly highest total Phosphorus uptake was recorded from application of poultry manure (24.04). During 2017, the highest significant total Phosphorus uptake in maize plants was recorded from the application of poultry manure (36.80). The data of pooled analysis shows that the highest total phosphorus uptake was recorded from the maize plants subjected to the poultry manure (30.42) application as the source of the organic manure, which was followed by FYM (21.51).

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of phosphorus in soil compared to other form of organic manures. The positive effect on uptake of phosphorus by plants in PM treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.17.2 Effect of level of fertilizer

The results show that the presence of the positive association of the fertilizer application with the total Phosphorus uptake in the maize plants. Where, with the increasing levels of fertilizer the subsequent increase in the total Phosphorus uptake was evident. The highest total Phosphorus uptake was recorded form the application of fertilizer @100% RDF during 2016 (30.42), 2017 (45.62) and pooled data (38.02). Which was followed by 50% RDF during 2016 (22.63), 2017 (23.54) and pooled data (23.08) This trend was followed throughout the period of the experiment.

Phosphorus is very important for the plants as without it the plants cannot initiate the transition from the vegetative stage to the reproductive stage. Phosphorus absorption and utilization in the plants is greatly improved under sufficient N and K fertilization (Bindraban *et al*., 2020). NPK treatment significantly increase phosphatase activity in soil there by increasing p mobility and uptake, and reduces the residual phosphorus at the site.

4.2.17.3 Effect of the application of Zinc

The data presented in the Table 4.24 regarding the total phosphorus uptake suggest that the increase in the levels of the Zinc applied resulted in the subsequent increase in total uptake of phosphorus in the maize. The highest significant total uptake of phosphorus during 2016 was recorded from application of Zinc @ 30 kg ha^{-1} (23.84). While during 2017 it was from application of Zinc @ 30 kg ha^{-1} (24.05) which was statistically at par with Z_2 (23.12). Similarly, the highest significant total phosphorus uptake was recorded from Z_3 (23.84) which was statistically at par with the (37.50).

This can be as a result of higher nutrient availability in soil with high Zn concentration as a result of zinc application. Zinc is essential for plats' use of nitrogen, phosphorus, and potassium in yield and protein synthesis. In the rhizosphere, zinc helps to mobilise phosphorus. Zinc application increases phosphorus uptake because more nutrients are available to plants from the soil reservoir and more nutrients are provided by organic manures. The results are in line with the findings of Safaya (1976) and Bukvić *et al.* (2003).

4.2.17.4 Interaction of Zinc and fertilizer level

The interaction effect between Zinc application and fertilizer application on total phosphorus uptake in maize was found significant during both the years as well as on pooled data (Table 4.25). The finding reveals that the interaction between fertilizer @ 100% RDF (F_3) and Zinc @ 30 kg ha^{-1} (Z_3) registered the significantly higher uptake of phosphorus in maize plants during 2016 (32.87), 2017 (52.07) and in pooled data (42.47).

Orabi *et al.* (2001) postulated that the application of phosphorus through inorganic fertilizers and Zinc through $ZnSO_4$ results in increased phosphorus uptake due to the result of positive interaction between Zn and phosphorus.

4.2.18 Potassium uptake in grain (kg ha^{-1})

4.2.18.1 Effect of source of organic manure

The data pertaining to the effect of various types of organic manure on the Potassium uptake in the grain is presented in the Table 4.26. The result indicated towards the presence of the significant difference in the responses of the various organic manure. The highest mean Potassium uptake in grain was recorded from the application of poultry manure @ 4 t ha^{-1} during year 2016 (17.24), 2017 (21.79) and pooled data (19.52). However, the response of the FYM application was statistically at par with the response of the poultry manure. This response was similar in both the year as well as the pooled data.

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of potassium in soil compared to other form of organic manures. The positive effect on uptake of potassium by plants in poultry manure treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.18.2 Effect of level of fertilizer

The data pertaining to the effect of various levels of fertilizer application on the mean Potassium uptake in the grain is presented in the Table 4.26. The highest mean potassium uptake was recorded from the application of fertilizer @100 % RDF during 2016 (21.56), 2017 (26.94) and pooled data (24.25).

The overall trend observed shows a positive association between the fertilizer application and the mean Potassium uptake of the grain where, by increasing the levels of fertilizer the subsequent increase in the mean Potassium uptake in the grain was evident. Application of fertilizer @ 100% RDF gave a substantial increase in the total uptake of potassium in the maize plants from the soil. Similar findings were also reporter earlier by Karki *et al.* (2005) and Fageria (2001).

4.2.18.3 Effect of the application of Zinc

The results of the effect of the application of the Zinc on the Potassium uptake in grain is presented in the Table 4.27.

Table 4.26: Effect of manure, fertilizer and zinc on mean potassium uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

Treatment	Grain uptake (kg ha^{-1})			Stover uptake (kg ha^{-1})			Total uptake (kg ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	15.45	19.11	17.28	57.70	94.03	75.87	73.15	113.15	93.15
M_2 - Poultry	17.24	21.79	19.52	63.51	120.27	91.89	80.75	142.06	111.40
M_3 - Vermicompost	15.41	19.08	17.24	58.39	86.74	72.56	73.80	105.81	89.81
Sem ±	0.32	0.54	0.45	2.00	2.22	2.11	2.14	2.05	2.09
CD (P=0.05)	0.89	1.51	1.03	5.55	6.16	4.87	5.93	5.69	4.83
Level of fertilizers									
F_1 - 0% RDF	10.10	12.27	11.19	45.58	72.87	59.23	55.68	85.14	70.41
F_2 - 50% RDF	16.44	20.77	18.61	62.30	97.89	80.09	78.74	118.66	98.70
F_3 - 100% RDF	21.56	26.94	24.25	71.72	130.28	101.00	93.28	157.21	125.25
Sem ±	0.40	0.42	0.41	1.44	1.56	1.50	1.55	1.63	1.59
CD (P=0.05)	0.86	0.92	0.84	3.15	3.39	3.10	3.38	3.55	3.28
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	14.99	18.02	16.50	58.20	87.49	72.84	73.19	105.50	89.34
Z_2- 15 kg ha^{-1} Zn	16.01	19.91	17.96	59.77	96.74	78.26	75.78	116.65	96.22
Z_3- 30 kg ha^{-1} Zn	17.11	22.05	19.58	61.63	116.81	89.22	78.73	138.86	108.80
Sem ±	0.40	0.45	0.42	1.21	1.50	1.36	1.28	1.58	1.44
CD (P=0.05)	0.81	0.90	0.84	2.45	3.05	2.72	2.60	3.19	2.86

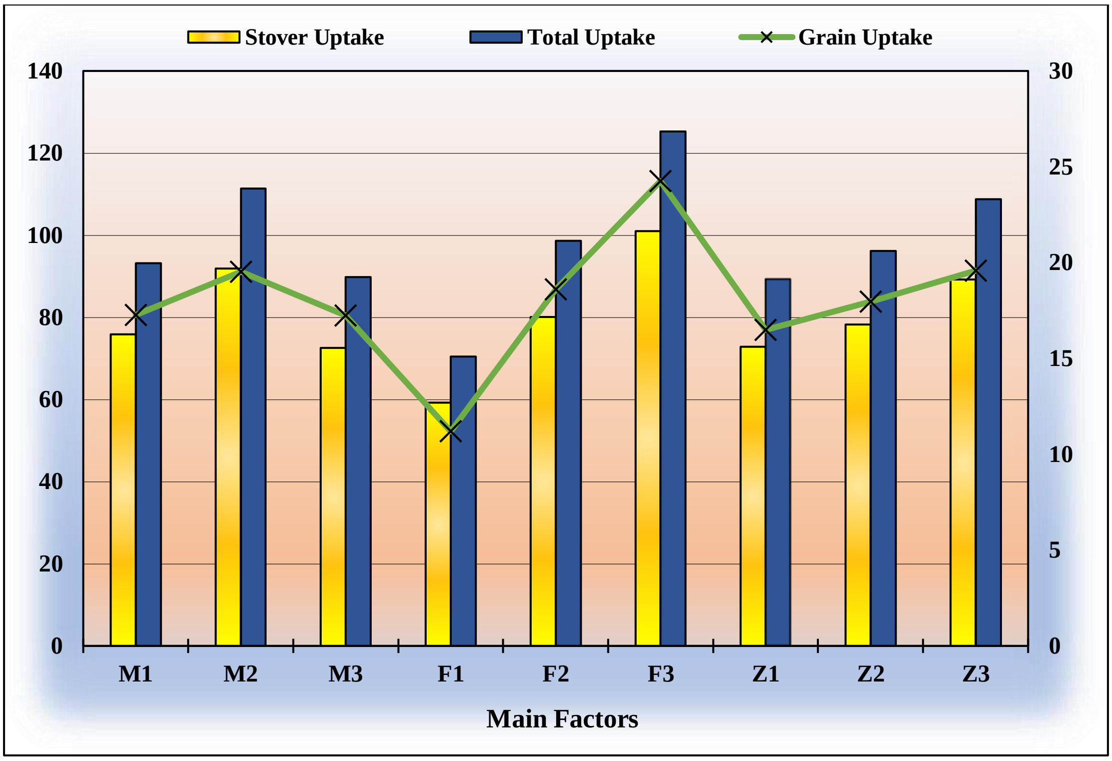


Fig 4.26: Effect of manure, fertilizer and zinc on mean potassium uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

The highest Potassium uptake in grain was recorded with the application of Zinc @ 30 kg ha^{-1} during 2016 (17.11), 2017 (22.05) and pooled data (19.58). The overall trend evident from the result was same in all the year and the pooled data as well, where with the increasing levels of Zinc application the uptake of Potassium in maize grain also increased.

The result indicated towards a positive association with the grain total Zinc and the potassium uptake. Similar result was also reported by Karki *et al.* (2005) and Paramasivan (2010).

4.2.19 Potassium uptake in Stover (kg ha^{-1})

4.2.19.1 Effect of various organic manure

The data pertaining to the effect of various types of organic manure on the Potassium uptake in the stover is presented in the Table 4.26. The result indicated towards the presence of the significant difference in the responses of the various organic manure. The response varied in each year. Where, the highest Potassium uptake was recorded from the application of the poultry manure during 2016 (63.51) and 2017 (120.27) but, during 2016 the effects produced by poultry manure and vermicompost were at par with each other. The pooled data shows that the highest mean Potassium uptake in the maize stover was recorded by the application of poultry manure (91.89). During 2017 and in the pooled data, vermicompost application resulted in the lesser mean potassium uptake in the maize stover.

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of potassium in soil compared to other form of organic manures. The positive effect on uptake of potassium by plants in PM treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.19.2 Effect of the level of fertilizer

The results of the present experiment regarding the effects of the application of the fertilizer in the uptake of potassium in the maize stover is presented in the Table 4.27. The significantly highest potassium uptake in maize stover was recorded from the application of fertilizer @ 100 % RDF during 2016 (71.72), 2017 (130.28) and pooled data (101.00). The overall trend showed an increasing response of the fertilizer application where, increase in the levels of fertilizers the average potassium uptake in stover also increased.

Application of fertilizers gave a substantial increase in the total uptake of potassium in the maize plants from the soil. Similar findings were also reporter earlier by Karki *et al.* (2005) and Fageria (2001).

4.2.19.3 Effect of the application of Zinc

The results presented in the Table 4.27 shows that the highest value of mean potassium uptake in the maize stover were recorded from the application of Zinc @ 30 kg ha^{-1} during 2016 (61.63), 2017 (116.81) and pooled data (89.22). This was followed by the application of the zinc application @ 15 kg ha^{-1} during 2016 (59.77), 2017 (96.74) and in pooled data (78.26). There was the increase response of the zinc application evident from the results. Where with increase in each level of the applied Zinc the uptake of Potassium in the maize stover also increased subsequently.

The result indicated towards a positive association with the grain total Zinc and the potassium uptake. Similar result was also reported by Karki *et al*. (2005) and Paramasivan (2010).

4.2.20 Potassium total uptake (kg ha^{-1})

4.2.20.1 Effect of organic manure

The data pertaining to the total uptake of the Potassium in maize plant is presented in the Table 4.26. The data showed the significant differences in the response of different types of organic manure. The highest significant total potassium uptake was recorded by poultry manure during 2016 (80.75), 2017 (142.06) and pooled data (111.40). The response of FYM and vermicompost were at par with each other.

Poultry manure is a potential source of not only for the macro nutrients but also of the several micro nutrients. Several studies have revealed that this property of poultry manure render them more effective in increasing the availability of potassium in soil compared to other form of organic manures. The positive effect on uptake of potassium by plants in PM treated soils is believed to be due to the better mineralization of organic matter in alternate oxidation-reduction condition and its subsequent uptake by plants. Sims and Wolf (1994) stated higher content of nutrients and more rapid mineralization rate of poultry manure compared to other animal manures. Whalen *et al.* (2000) reported significantly higher concentration of plant available phosphorus and potassium in manure amended soils compared to non-amended soils.

4.2.20.2 Effect of level of fertilizer

The result shows that the presence of the positive association of fertilizer application with the total Potassium uptake in the maize plants. Where, with the increasing levels of fertilizer the subsequent increase in the total Potassium uptake was evident. The highest total Potassium uptake was recorded form the application of fertilizer @ 100% RDF during 2016 (93.28), 2017 (157.21) and pooled data (125.25). Which was followed by 50% RDF during 2016 (93.28), 2017 (157.21) and pooled data (125.25). This trend was followed throughout the period of the experiment.

Application of fertilizer gave a substantial increase in the total uptake of potassium in the maize plants from the soil. Similar findings were also reporter earlier by Karki *et al.* (2005) and Fageria (2001).

4.2.20.3 Effect of the application of Zinc

The data presented in the Table 4.26 regarding the total potassium uptake suggest that the increase in the levels of the Zinc applied resulted in the subsequent increase in total uptake of potassium in the maize. The highest significant total uptake of potassium during 2016 was recorded from application of Zinc @ 30 kg ha^{-1} (78.73). While during 2017 it was from application of Zinc @ 30 Kg ha^{-1} (138.86). Similarly, in the pooled data the highest significant total potassium uptake was recorded from Z_3 (108.80).

The result indicated towards a positive association with the grain total Zinc and the potassium uptake. Similar result was also reported by Karki *et al.* (2005) and Paramasivan (2010).

4.2.21 Zinc uptake in grains of maize (g ha^{-1})

4.2.21.1 Effect of organic manure

The data pertaining to the uptake of Zinc in grains of maize is presented in the Table 4.27.

The data indicated towards the significant difference in the response of application of three types of organic manure in the uptake of Zinc in maize grains. The significantly highest uptake of Zinc in grain was recorded with the application of poultry manure during 2016 (15.25), 2017 (16.95) and pooled data (16.10). This was followed by FYM during 2016 (14.63), 2017 (15.35) and pooled data (14.99). The trend during all the years and pooled data remained the same where, poultry manure resulted in the highest uptake of Zinc followed by FYM.

The uptake of nutrient is a function of yield and its concentration in crop. Poultry manure is one of the potential organic sources of major, secondary and micro nutrients. The application of poultry manures therefore increases the availability of these micro nutrients which in turn increases the absorption of available Zinc by the roots. `

4.2.21.2 Effect of level of fertilizer

The results of the present experiment regarding the effects of the application of the fertilizer in the uptake of Zinc in the maize grain is presented in the Table 4.27. The significantly highest Zinc uptake in maize grain was recorded from the application of fertilizer @ 100 % RDF during 2016 (21.90), 2017 (23.30) and pooled data (22.60). The overall trend showed an increasing response of the RDF where, increase in the levels of fertilizer the average Zinc uptake in grain also increased. This effect is attributed to the synergistic effect of nitrogen and phosphorus on the absorption of available Zinc from the soil solution.

Table 4.27: Effect of manure, fertilizer and zinc on mean zinc uptake (g ha^{-1}) on grain, stover and total uptake of maize.

Treatment	Grain Uptake (g ha^{-1})			Stover Uptake (g ha^{-1})			Total Uptake (g ha^{-1})		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 - FYM	14.63	15.35	14.99	76.48	91.82	84.15	91.12	107.17	99.14
M_2 - Poultry	15.25	16.95	16.10	78.02	94.90	86.46	93.27	111.85	102.56
M_3 - Vermicompost	13.75	14.35	14.05	72.64	87.83	80.23	86.38	102.17	94.28
Sem ±	0.15	0.23	0.19	0.87	1.33	1.12	0.94	1.28	1.12
CD (P=0.05)	0.41	0.63	0.44	2.41	3.69	2.59	2.61	3.55	2.59
Level of fertilizers									
F_1 - 0% RDF	7.50	7.73	7.61	48.01	52.86	50.44	55.51	60.59	58.05
F_2 - 50% RDF	14.22	15.63	14.92	75.97	89.87	82.92	90.20	105.49	97.84
F_3 - 100% RDF	21.90	23.30	22.60	103.15	131.81	117.48	125.06	155.11	140.08
Sem ±	0.34	0.36	0.35	1.38	1.55	1.47	1.61	1.73	1.67
CD (P=0.05)	0.74	0.79	0.72	3.01	3.38	3.03	3.50	3.76	3.44
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	12.50	13.04	12.77	67.98	81.90	74.94	80.49	94.94	87.72
Z_2- 15 kg ha^{-1} Zn	15.14	16.44	15.79	78.13	93.78	85.96	93.27	110.23	101.75
Z_3- 30 kg ha^{-1} Zn	15.98	17.16	16.57	81.02	98.86	89.94	97.00	116.03	106.51
Sem ±	0.28	0.27	0.28	1.17	1.35	1.26	1.21	1.42	1.32
CD (P=0.05)	0.57	0.55	0.55	2.37	2.74	2.51	2.46	2.87	2.63

Furthermore, high concentration of N and P also enhances the translocation of the absorbed Zinc in shoot to the grains during grain filling stage. Like that of our finding, Karki *et al.* (2005) reported an increase in Zn content as well as uptake in grains and stover of maize with application of 100% RDF over 50% RDF and control.

4.2.21.3 Effect of Zinc application

The results regarding the effect of Zinc application on the uptake of Zinc in maize grain is presented in the Table 4.27. Highest significant uptake of Zinc in maize grain were recorded from the application of Zinc @ 30 kg ha^{-1} during 2016 (15.98), 2017 (17.16) and pooled data (16.57). This was followed by Z_2 (15 kg ha^{-1}) which during 2016, 2017 and in pooled data was 15.14, 16.44 and 15.79 respectively. Close examination of the results indicated towards a positive trend in the uptake of Zinc with increasing level of Zinc application.

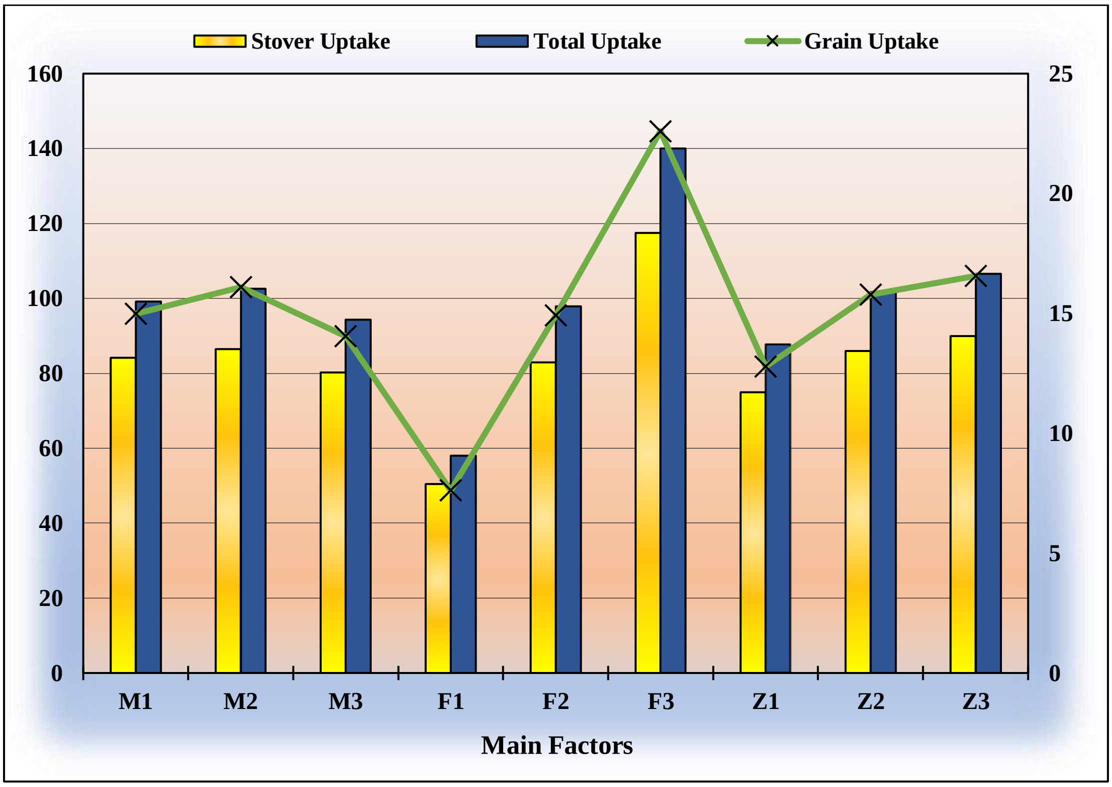


Fig 4.27: Effect of manure, fertilizer and zinc on mean zinc uptake (g ha^{-1}) on grain, stover and total uptake of maize.

Applying zinc by $ZnSO_4$ may increase its availability in the soil close to roots; as a result, roots may take up more zinc, which would then increase its accumulation in maize shoots and grains. These results are entirely consistent with those of Zhang *et al.* (2013). Similar to this, studies by Harris *et al.* (2007) and Hossain *et al.* (2008) demonstrated that applying zinc through $ZnSO_4$ to plants can boost their uptake of zinc relative to the control.

4.2.21.4 Interaction of Zinc and fertilizer level

The interaction effect between Zinc application and fertilizer application on zinc uptake in maize grains was found significant during both the years as well as on pooled data (Table 4.28). The finding reveals that the interaction between fertilizer @ 100% RDF (F_3) and Zinc @ 30 kg ha^{-1} (Z_3) registered the significantly higher uptake of Zinc in maize grains during 2016 (23.88), 2017 (25.88) and in pooled data (24.88).

The increase in Zn uptake in grains might be due to synergistic effect between nitrogen and phosphorus application and zinc as adequate supply of N and P enhanced the translocation of Zn from roots to other parts of plants. Further better root and shoot growth with the application of N might have led to better utilization of the zinc and other cations from the soil solution. Similar results were reported by and Safaya (1976) and Bukvić *et al.* (2003).

4.2.22 Zinc uptake in stover (g ha^{-1})

4.2.22.1 Effect of organic manure

The data pertaining to the uptake of Zinc in stover of maize is presented in the Table 4.27. The data indicated towards the significant difference in the response of application of three types of organic manure in the uptake of Zinc in maize plant stover. The significantly highest uptake of Zinc in stover was recorded with the application of poultry manure during 2016 (78.02 g ha^{-1}), 2017 (94.90 g ha^{-1}) and pooled data (86.46 g ha^{-1}). This was at par with FYM during 2016 (76.48 g ha^{-1}), 2017 (91.82 g ha^{-1}) and pooled data (84.15 g ha^{-1}). The trend during all the years and pooled data remained the same where, poultry manure resulted in the highest uptake of Zinc followed by FYM.

Table 4.28: Interaction effects of fertilizer and zinc on mean zinc uptake (kg ha^{-1}) on grain, stover and total uptake of maize.

Treatment		Grain Uptake (g ha^{-1})			Stover Uptake (g ha^{-1})			Total Uptake (g ha^{-1})		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
F_1Z_1		6.61	6.68	6.64	43.12	46.67	44.90	49.72	53.36	51.54
F_1Z_2		7.77	8.20	7.98	49.77	54.45	52.11	57.54	62.65	60.10
F_1Z_3		8.13	8.30	8.21	51.13	57.47	54.30	59.26	65.76	62.51
F_2Z_1		11.97	12.82	12.39	67.16	79.32	73.24	79.13	92.14	85.64
F_2Z_2		14.78	16.74	15.76	78.57	92.33	85.45	93.34	109.07	101.21
F_2Z_3		15.93	17.32	16.62	82.19	97.94	90.07	98.12	115.26	106.69
F_3Z_1		18.94	19.63	19.28	93.67	119.70	106.69	112.61	139.33	125.97
F_3Z_2		22.88	24.39	23.64	106.05	134.56	120.31	128.93	158.96	143.95
F_3Z_3		23.88	25.88	24.88	109.73	141.18	125.45	133.62	167.05	150.34
Comparison:										
>A	**Sem ±**	0.49	0.47	0.48	2.02	2.34	2.18	2.10	2.45	2.29
	CD (P=0.05)	0.99	0.95	0.95	NS	NS	NS	4.27	4.98	4.56
>B	**Sem ±**	0.52	0.53	0.53	2.15	2.46	2.36	2.35	2.64	2.61
	CD (P=0.05)	2.09	2.10	2.02	NS	NS	NS	2.10	2.09	2.02

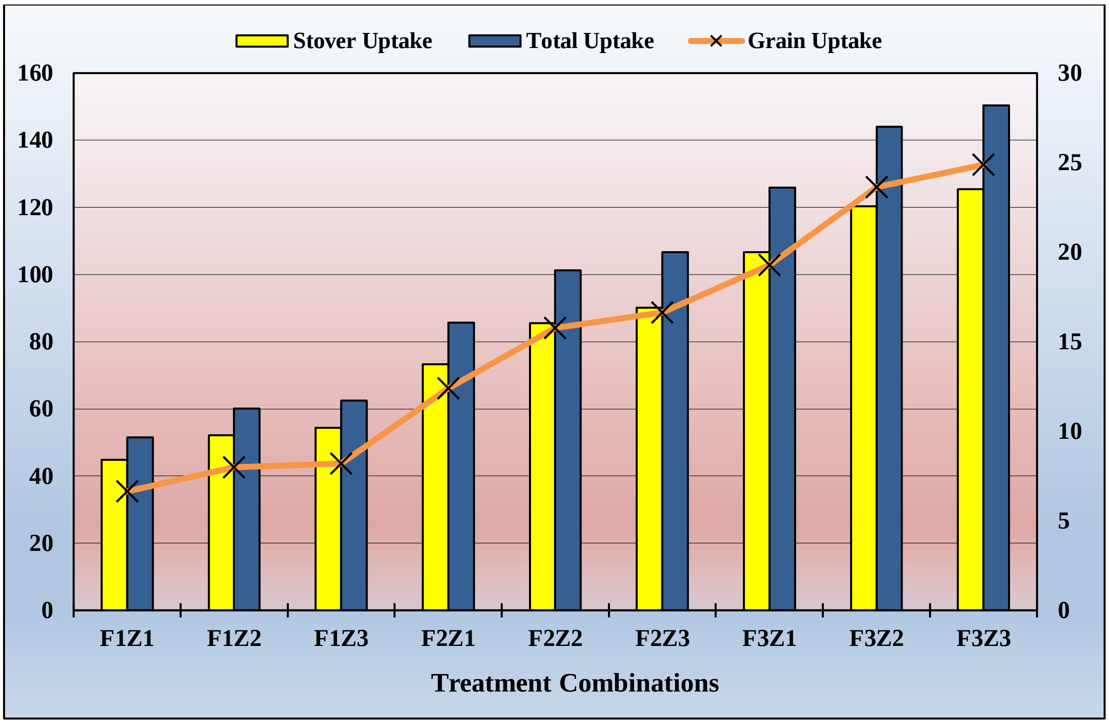


Fig 4.28: Interaction effects of fertilizer and zinc on mean zinc uptake (g ha^{-1}) on grain, stover and total uptake of maize.

The uptake of nutrient is a function of yield and its concentration in crop. Poultry manure is one of the potential organic sources of major, secondary and micro nutrients. The application of poultry manures therefore increases the availability of these micro nutrients which in turn increases the absorption of available Zinc by the roots. The current findings are in accordance with Adeniyan and Ojeniyi (2005) and Saleem *et al.* (2017).

4.2.22.2 Effect of level of fertilizer

The results of the present experiment regarding the effects of the application of the RDF in the uptake of Zinc in the maize plant stover is presented in the Table 4.27. The significantly highest Zinc uptake in maize stover was recorded from the application of fertilizer @ 100 % RDF during 2016 (103.15 g ha^{-1}), 2017 (131.81 g ha^{-1}) and pooled data (117.48 g ha^{-1}). The overall trend showed an increasing response of the RDF where, increase in the levels of fertilizer the average Zinc uptake in maize plant stover also increased.

This effect is attributed to the synergistic effect of nitrogen and phosphorus on the absorption of available Zinc from the soil solution. Furthermore, high concentration of N and P also enhances the translocation of the absorbed Zinc in shoot to the grains during grain filling stage. Like that of our finding, Karki *et al*. (2005) reported an increase in Zn content as well as uptake in grains and stover of maize with application of 100% RDF over 50% RDF and control.

4.2.22.3 Effect of Zinc application

The results regarding the effect of Zinc application on the uptake of Zinc in maize stover is presented in the Table 4.27. Highest significant uptake of Zinc in maize stover were recorded from the application of Zinc @ 30 kg ha^{-1} (Z_1) during 2016 (81.02 g ha^{-1}), 2017 (98.86 g ha^{-1}) and pooled data (89.94 g ha^{-1}). This was followed by Z_2 (15 kg ha^{-1}) during 2016 (78.13 g ha^{-1}), 2017 (93.78 g ha^{-1}) and in pooled data (85.96 g ha^{-1}). Close examination of the results indicated towards a positive trend in the uptake of Zinc in stover with increasing level of Zinc application.

Applying zinc by $ZnSO_4$ may increase its availability in the soil close to roots; as a result, roots may take up more zinc, which would then increase its accumulation in maize shoots and grains. These results are entirely consistent with those of Zhang *et al.* (2013). Similar to this, studies by Harris *et al.* (2007) and Hossain *et al.* (2008) demonstrated that applying zinc through $ZnSO_4$ to plants can boost their uptake of zinc relative to the control.

4.2.23 Total Zinc uptake in maize (g ha^{-1})

4.2.23.1 Effect of organic manure

The data pertaining to the total uptake of the Zinc in maize plant is presented in the Table 4.27. The data from 2016 shows that the significantly highest total Zinc uptake was recorded from application of poultry manure (93.27 g ha^{-1}) which was statistically at par with the FYM (91.12 g ha^{-1}). During 2017, the highest significant total Zinc uptake in maize plants was recorded from the application of poultry manure (111.85 g ha^{-1}) which was followed by FYM (107.17 g ha^{-1}). The data of pooled analysis shows that the highest total Zinc uptake was recorded from the maize plants subjected to the poultry manure (102.56 g ha^{-1}) application as the source of the organic manure, which was followed by FYM (99.14 g ha^{-1}).

The uptake of nutrient is a function of yield and its concentration in crop. Poultry manure is one of the potential organic sources of major, secondary and micro nutrients. The application of poultry manure therefore increase the availability of these micro nutrients which in turn increases the absorption of available Zinc by the roots. The current findings are in accordance with Adeniyan and Ojeniyi (2005) and Saleem *et al.* (2017).

4.2.23.2 Effect of level of fertilizer

The result shows that the presence of the positive association of the fertilizer application with the total Zinc uptake in the maize plants. Where, with the increasing levels of fertilizer the subsequent increase in the total Zinc uptake was evident. The highest total Zinc uptake was recorded form the application of fertilizer @ 100% RDF during 2016 (125.06 g ha^{-1}), 2017 (155.11 g ha^{-1}) and pooled data (140.08 g ha^{-1}). Which was followed by fertilizer @ 50% RDF during 2016 (90.20 g ha^{-1}), 2017 (105.49 g ha^{-1}) and pooled data (97.84 g ha^{-1}) This trend was followed throughout the period of the experiment.

This effect is attributed to the synergistic effect of nitrogen and phosphorus on the absorption of available Zinc from the soil solution. Furthermore, high concentration of N and P also enhances the translocation of the absorbed Zinc in shoot to the grains during grain filling stage. Like that of our finding, Karki *et al.* (2005) reported an increase in Zn content as well as uptake in grains and stover of maize with application of 100% RDF over 50% RDF and control.

4.2.23.3 Effect of the application of Zinc

The data presented in the Table 4.27 regarding the total Zinc uptake suggest that the increase in the levels of the Zinc applied resulted in the subsequent increase in total uptake of Zinc in the maize. The highest significant total uptake of Zinc was recorded from application of Zinc @ 30 kg ha^{-1} during 2016 (97.00 g ha^{-1}), 2017 (116.03 g ha^{-1}) and in pooled data (106.51 g ha^{-1}). This was followed by the Z_2 (@ 15 g ha^{-1}) during 2016 (93.27 g ha^{-1}), 2017 (110.23 g ha^{-1}) and in pooled data (101.75 g ha^{-1}).

Applying zinc by $ZnSO_4$ may increase its availability in the soil close to roots; as a result, roots may take up more zinc, which would then increase its accumulation in maize shoots and grains. These results are entirely consistent with those of Zhang *et al.* (2013). Similar to this, studies by Harris *et al.* (2007) and Hossain *et al.* (2008) demonstrated that applying zinc through $ZnSO_4$ to plants can boost their uptake of zinc relative to the control.

4.2.23.4 Interaction of Zinc and fertilizer level

The interaction effect between Zinc application and fertilizer application on total zinc uptake in maize was found significant during both the years as well as on pooled data (Table 4.28). The finding reveals that the interaction between 100% RDF (F_3) and Zinc @ 30 kg ha^{-1} (Z_3) registered the significantly higher uptake of Zinc in maize grains during 2016 (133.62 g ha^{-1}), 2017 (167.05 g ha^{-1}) and in pooled data (150.34 g ha^{-1}).

The increase in Zn uptake in grains might be due to synergistic effect between nitrogen and phosphorus application and zinc as adequate supply of N and P enhanced the translocation of Zn from roots to other parts of plants. Further better root and shoot growth with the application of N might have led to better utilization of the zinc and other cations from the soil solution. Similar results were reported by and Adeniyan and Ojeniyi (2005).

4.2.24 Protein content of maize grains (%)

The results of the experiment regarding the effects of manure, level of fertilizers and zinc application in protein content of maize plants are well presented in Table 4.29.

4.2.24.1 Effect of various sources of organic manures

The statistical analysis of the data on protein content of maize grains indicated that there were significant differences in the responses of three types of organic manure used in this study i.e., FYM, Poultry manure and Vermicompost. Close examination of the results showed that incorporation of poultry manure (M_2) results in significantly higher grain yield during 2016 (9.77), 2017 (10.66) and in pooled data (10.21). It was also revealed that application of FYM (M_1) results to be at par with application of poultry manure (M_2) during the year 2016 (9.64) well as in pooled data (9.92).

The increase in the protein content of maize grains post application of poultry manure might be due to better availability of desired and required quantity of nutrients for longer period in root zone of the growing plants resulting from the mineralization caused by the organic acids produced from the decaying of poultry manure and chelation of available nutrients. The enhanced synthesis of protein may also be facilitated by the addition of enzymes and growth regulators to the soil system received from the organic manure (Vasanthi and Subramanian, 2004) and stable soil health (Farhad *et al.*, 2009). The beneficial effect of organic material on protein content was also reported due to increased nitrogen content in seeds (Khiriya *et al.*, 2003) and nitrogen is an integral part of protein and the phosphorus is a structural element of certain co-enzyme involved in protein synthesis. Similar findings have also been reported by Singh *et al.* (2009) and Aduloju and Abdulmalik (2013).

4.2.24.2 Effect of levels of fertilizer

The data related to the effects of different treatments of fertilizers on protein content of maize is presented in the Table 4.29. The study of the data indicated towards the presence of significant difference among the responses of the various fertilizer treatments for protein content in maize. The significantly higher protein content was recorded from the F_3 (100% RDF) during 2016 (10.29), 2017 (11.26) and in pooled data (10.77). The trend suggests a positive association of fertilizer application with the protein content in maize, where with increase in the levels of fertilizer the overall protein content in the maize grain also increased. The beneficial effect of the increased fertilizer may be ascribed to the enhanced content of Nitrogen and Phosphorus in the grains and stover of the plants. As nitrogen is integral part of the protein while phosphorus is a structural element of certain co-enzyme involved in protein synthesis.

Table 4.29: Effect of manure, fertilizer and zinc on mean protein content (%) of maize grains.

Treatment	2016	2017	Pooled
Manures			
M_1 - FYM	9.64	10.20	9.92
M_2 - Poultry	9.77	10.66	10.21
M_3 - Vermicompost	9.26	9.88	9.57
Sem ±	0.13	0.15	0.14
CD (P=0.05)	0.36	0.40	0.32
Level of fertilizers			
F_1 - 0% RDF	8.81	9.46	9.14
F_2 - 50% RDF	9.56	10.02	9.79
F_3 - 100% RDF	10.29	11.26	10.77
Sem ±	0.12	0.13	0.12
CD (P=0.05)	0.26	0.28	0.25
Zinc Level			
Z_1- 0 kg ha^{-1} Zn	9.34	9.85	9.59
Z_2- 15 kg ha^{-1} Zn	9.47	10.17	9.82
Z_3- 30 kg ha^{-1} Zn	9.86	10.73	10.29
Sem ±	0.14	0.09	0.12
CD (P=0.05)	0.28	0.19	0.24

Table 4.30: Interaction effects of fertilizer and zinc on mean protein content (%) of maize grains.

Treatment		**2016**	**2017**	**Pooled**
F_1Z_1		8.72	9.26	8.99
F_1Z_2		8.84	9.45	9.15
F_1Z_3		8.88	9.68	9.28
F_2Z_1		9.45	9.70	9.58
F_2Z_2		9.50	10.01	9.76
F_2Z_3		9.74	10.34	10.04
F_3Z_1		9.86	10.57	10.21
F_3Z_2		10.06	11.03	10.55
F_3Z_3		10.95	12.17	11.56
Comparison:				
>A	**Sem ±**	0.24	0.16	0.20
	CD (P=0.05)	0.48	0.33	0.41
>B	**Sem ±**	0.23	0.18	0.22
	CD (P=0.05)	2.07	2.10	2.02

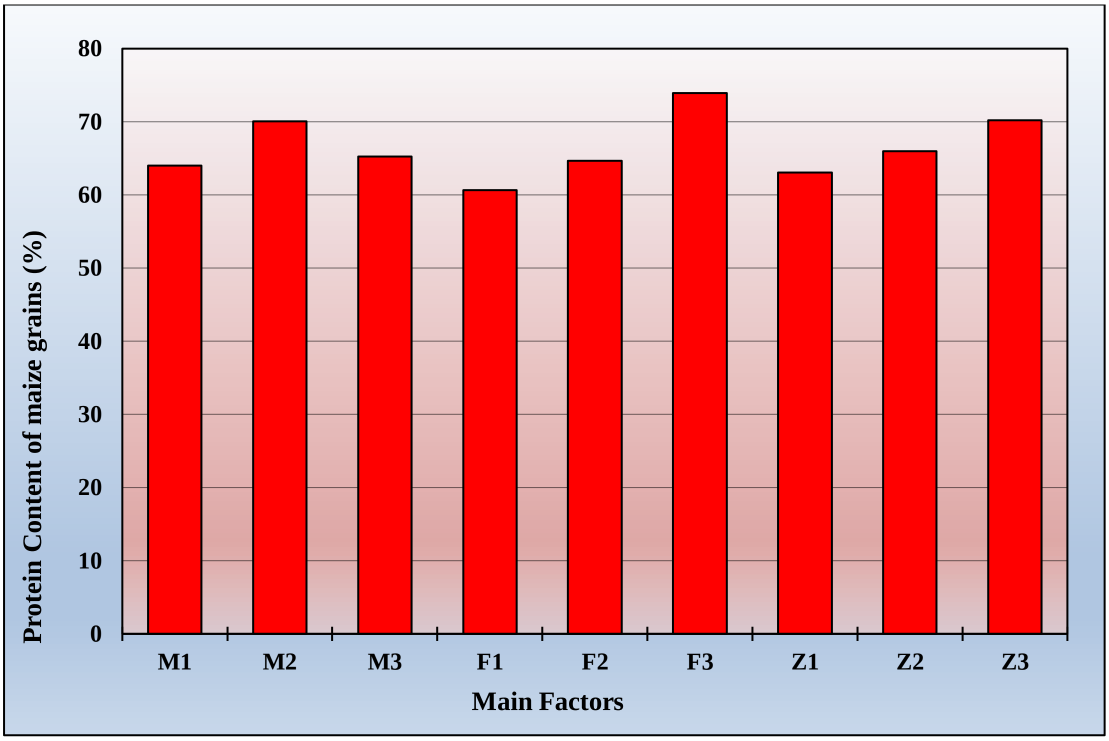


Fig 4.29: Effect of manure, fertilizer and zinc on mean protein content (%) of maize grains.

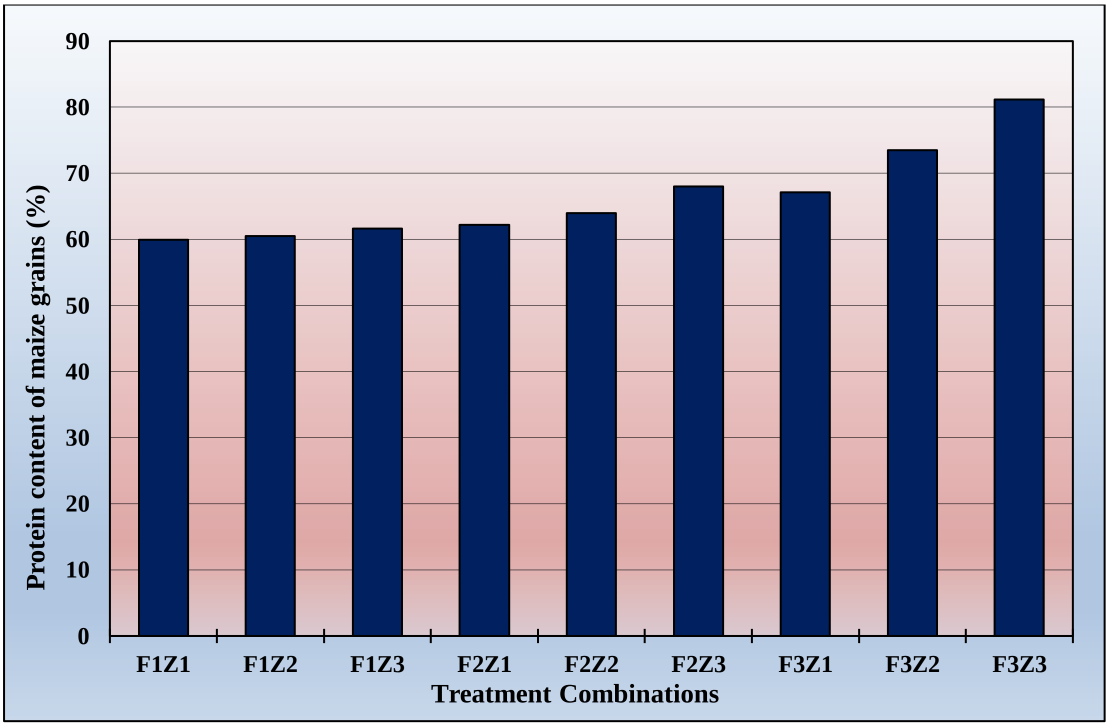


Fig 4.30: Interaction effects of fertilizer and zinc on mean protein content (%) of maize grains.

The increase of their content in the grain will indirectly increase the protein content of the grains. The outcomes are comparable to that of Ashoka *et al.* (2009) and Zende *et al.* (2009).

4.2.24.3 Effect of Zinc application

The data presented in the Table 4.29 indicated that the effect of Z on protein content of maize showed significant increase. It is observed that application of zinc @ 30 kg ha^{-1} to maize significantly increased the protein content when compared with no Zinc or 0 kg ha^{-1} application. Though application of Zinc @ 30 kg ha^{-1} gave highest protein content in both the year as well as pooled data with the value of 9.86 during the first year, 10.73 during the second year and 10.29 in pooled data respectively.

It is possible to attribute applied zinc's beneficial impact on the protein content of maize grains to its catalytic or stimulatory effects on the majority of plant physiological and metabolic processes. In addition to the transformation of carbohydrates, the creation of chlorophyll, and the synthesis of proteins, zinc has numerous other catalytic activities in plants (Menzeke *et al.*, 2014). Besides this, zinc also enhances the absorption of N, P, K and Zn (Ashoka *et al.*, 2008) where, N and P are directly involved in the protein synthesis. Similar results were also reported by Singh *et al.* (2009); and Farhad *et al.* (2009).

4.2.24.4 Effect of interaction between fertilizer and Zinc application

The data pertaining to the interaction effect of fertilizer and zinc are presented in Table 4.30. Analyzing the data critically revealed that fertiliser and zinc treatment together had a considerable impact on maize's protein content during both year and pooled data.

It is observed that increase level of fertilizer and Zinc increased protein content of maize at diminishing rate. The treatment combination with the highest protein concentration was recorded from F_3Z_3 (10.95) in the year 2016; 2017 (12.17) and even in pooled data maximum protein content was observed in F_3Z_3 (11.56) treatment combination. The result revealed that increase level of fertilizer @ 100% RDF and Zinc @ 30 kg ha^{-1} enhanced protein content significantly compared to other treatment. This may be attributed to the enhanced absorption, translocation and assimilation of nutrients to various parts of the plant which increased the protein accumulation in the grains at higher level. Similar findings of the beneficial combined effects of fertilizer and Zn application were previously reported by Kumar and Bohra (2014).

4.2.25 Carbohydrate content of maize grains (%)

4.2.25.1 Effect of sources of organic manure

The results presented in the Table 4.31 regarding the effect of sources of organic manure on the carbohydrate content in the maize grains, reveals the significance differences among the responses of the various source of organic manure on increasing the carbohydrate content of maize. Application of poultry manure showed significantly highest carbohydrate content in maize during 2016 (69.91), 2017 (70.22) and in pooled data (70.06). However, the effect of vermicompost during 2016 was at par with that of poultry manure (65.13).

4.2.25.2 Effect of level of fertilizer

The data on effect of level of fertilizers on carbohydrates content in the seed are presented in Table 4.31. The data revealed that different level of fertilizer affect carbohydrate concentration in the grains. Application of fertilizer @ 100% RDF was recorded to give significantly highest carbohydrate concentration during both the year as well as in pooled data with the value of 72.96 % in 2016, 74.96 % in 2017 and 73.91 % in pooled data. It is quite evident from the data that carbohydrate content significantly increased with increasing fertilization. This might be due to the function of NPK that are involved in many physico-chemical reactions in the plant, which can enhance the values of carbohydrates and sugar. Current finding is in accordance with Singh *et al.* (2009).

4.2.25.3 Effect of Zinc

The data indicated towards a synergistic effect of Zinc application where with increasing levels of Zn application the carbohydrate content increased significantly ($> P=0.05$).

Table 4.31: Effect of manure, fertilizer and zinc on mean carbohydrate content (%) of maize grains.

Treatment	2016	2017	Pooled
Manures			
M_1 - FYM	63.02	64.96	63.99
M_2 - Poultry	69.91	70.22	70.06
M_3 - Vermicompost	65.13	65.32	65.22
Sem ±	1.78	1.27	1.54
CD (P=0.05)	4.93	3.53	3.56
Level of fertilizers			
F_1 - 0% RDF	61.10	60.24	60.67
F_2 - 50% RDF	64.00	65.41	64.70
F_3 - 100% RDF	72.96	74.85	73.91
Sem ±	1.96	1.95	1.96
CD (P=0.05)	4.27	4.26	4.04
Zinc Level			
Z_1- 0 kg ha^{-1} Zn	63.27	62.88	63.08
Z_2- 15 kg ha^{-1} Zn	65.66	66.27	65.97
Z_3- 30 kg ha^{-1} Zn	69.12	71.35	70.23
Sem ±	1.41	1.73	1.58
CD (P=0.05)	2.87	3.51	3.15

Table 4.32: Interaction effects of fertilizer and zinc on mean carbohydrate content (%) of maize grains.

Treatment		**2016**	**2017**	**Pooled**
F_1Z_1		60.67	59.18	59.93
F_1Z_2		60.56	60.41	60.49
F_1Z_3		62.05	61.14	61.60
F_2Z_1		62.42	61.93	62.17
F_2Z_2		63.14	64.77	63.95
F_2Z_3		66.43	69.52	67.98
F_3Z_1		66.73	67.54	67.13
F_3Z_2		73.28	73.64	73.46
F_3Z_3		78.87	83.38	81.13
Comparison:				
>A	**Sem ±**	2.45	3.00	2.74
	CD (P=0.05)	4.96	6.08	5.45
>B	**Sem ±**	2.80	3.13	3.17
	CD (P=0.05)	2.10	2.09	2.02

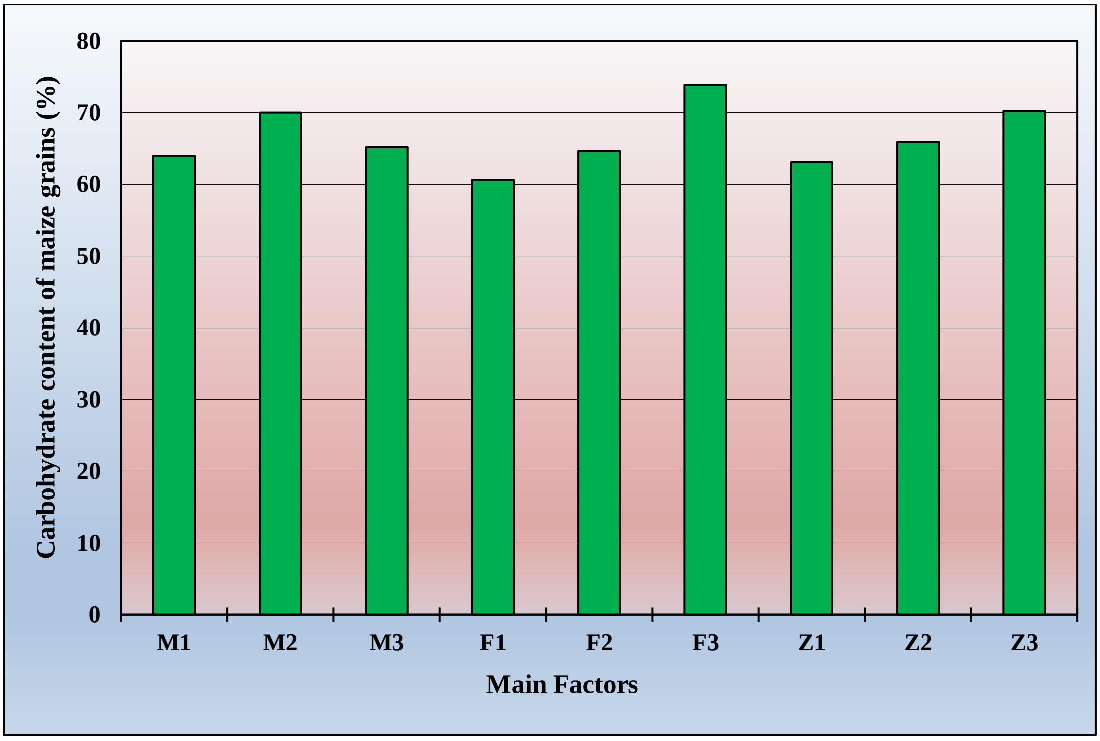


Fig 4.31: Effect of manure, fertilizer and zinc on mean carbohydrate content (%) of maize grains.

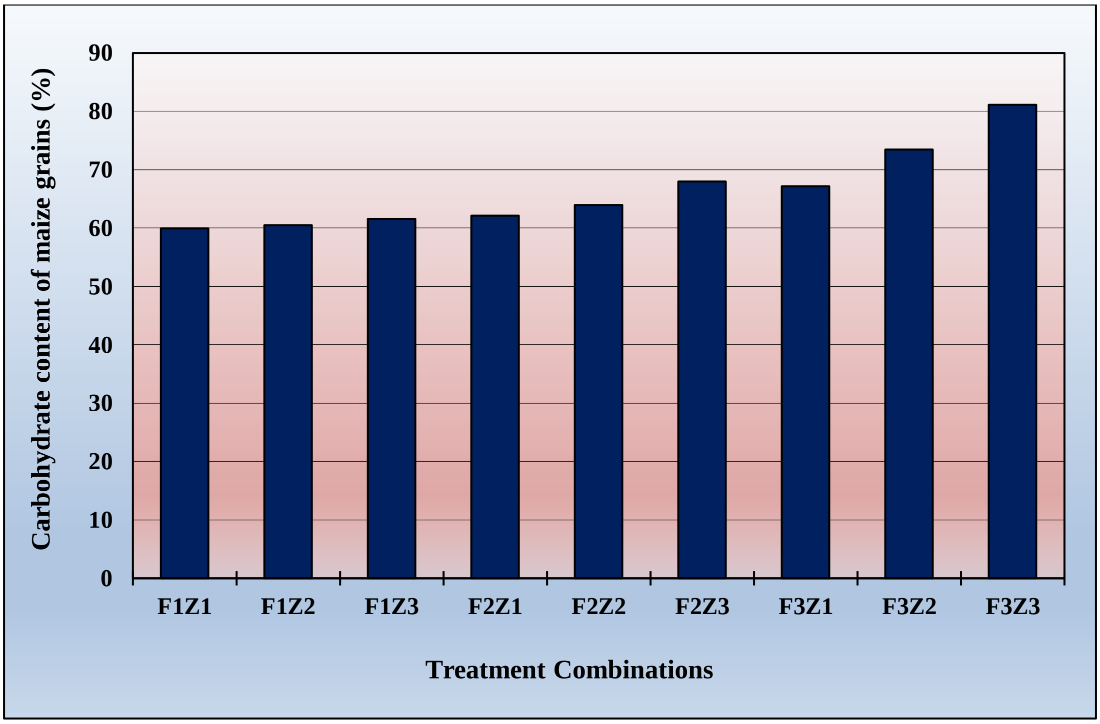


Fig 4.32: Interaction effects of fertilizer and zinc on mean carbohydrate content (%) of maize grains.

Here the highest level of Zn *i.e*. 30 kg ha^{-1} $ZnSO_4$ produced highest concentration of carbohydrate. This effect was consistent in both the year as well as in pooled data. However, during year 2017 Z_2 (15 kg ha^{-1}) was comparable to Z_3 (30 kg ha^{-1}). The value recorded was 69.12 in 2016, 71.35 in 2017 and 70.23 in pooled data.

The data suggest that carbohydrate content was positively affected by increasing levels of Zinc. This might be due to the greater balanced absorption and translocation of nutrients to different plant parts resulting in higher carbohydrate accumulation at higher levels of Zinc. Current findings are in agreement with Singh *et al.* (2009).

4.2.25.4 Interaction effect of fertilizer and Zinc application

The data regarding the interaction effect between fertilizer and Zinc application on carbohydrate content is presented in Table 4.32. The finding reveals that the interaction between fertilizer @ 100% RDF (F_3) and Zinc @ 30 kg ha^{-1} (Z_3) registered the significantly higher carbohydrate content in maize grains during 2016 (78.87), 2017 (83.38) and in pooled data (81.13).

This trend in the carbohydrate content of the maize grain might be due to the synergistic effect between NPK and Zn which bring a greater balanced absorption and translocation of the nutrients to different plant parts resulting in the higher carbohydrate accumulation at higher levels of NPK and Zn. Similar findings were reported by Ashoka *et al.* (2009).

4.3 SOIL PHYSICO CHEMICAL PROPERTIES

4.3.1 Soil organic carbon (%)

The data pertaining to the effect of manure, fertilizer and Zinc application on soil organic carbon content is presented in the Table 4.33. The analysis of variance studies suggests that only the responses of various types of organic manure showed significant differences in improving the overall soil organic carbon.

4.3.1.1 Effect of manure

Data given in Table 4.33 indicated that application of different organic manure affected the organic carbon content in soil. A perusal of data further indicated that application of poultry manure @ 4 t ha^{-1} was found to be significantly increasing the soil organic carbon during both the year as well as pooled data the value recorded was 1.46 % in 2016, 1.51 % in 2017 and 1.49 in pooled data.

The organic carbon content and C:N ratio in the organic manure is an important consideration that determines the release and availability of nutrients to the crops. Carbon was considered as the major constituent of organic matter and the estimation of organic matter are carried out through organic carbon which is considered to be about 58% of soil organic matter. Current finding is in accordance with Saleem *et al.* (2017) and Sanjivkumar (2014), who reported that integration of organic manure in the soil using of poultry manure increases soil organic matter.

4.3.2 Soil pH

The data pertaining to the effect of application of manure, fertilizer and zinc in soil is presented in the Table 4.33. The analysis of variation studies conducted to partition and check the significance of various source of variation showed no significance effect on soil pH after application.

4.3.3 Soil EC

The results of the effect of the application of manure, fertilizer and zinc in soil is presented in the Table 4.34. No significance difference in the responses among the treatments was evident.

4.3.4 Soil bulk density

The data pertaining to the effect of application of manure, fertilizer and zinc in soil is presented in the Table 4.34. The analysis of variation studies conducted to partition and check the significance of various source of variation showed no significance effect on soil bulk density after application.

Table 4.33: Effect of manure, fertilizer and zinc on mean soil organic carbon content (%) and soil pH.

Treatment	**Soil OC (%)**			**Soil pH**		
	2016	**2017**	**Pooled**	**2016**	**2017**	**Pooled**
Manures						
M_1 – FYM	1.41	1.44	1.42	4.42	4.84	4.63
M_2 - Poultry	1.46	1.51	1.49	4.54	4.85	4.69
M_3 - Vermicompost	1.29	1.41	1.35	4.50	4.90	4.70
Sem ±	0.01	0.03	0.02	0.25	0.16	0.21
CD (P=0.05)	0.04	0.07	0.05	NS	NS	NS
Level of fertilizers						
F_1 - 0% RDF	1.42	1.47	1.45	4.48	4.84	4.66
F_2 - 50% RDF	1.37	1.44	1.40	4.51	4.83	4.67
F_3 - 100% RDF	1.38	1.44	1.41	4.46	4.92	4.69
Sem ±	0.02	0.02	0.02	0.10	0.07	0.09
CD (P=0.05)	NS	NS	NS	NS	NS	NS
Zinc Level						
Z_1- 0 kg ha^{-1} Zn	1.38	1.44	1.41	4.49	4.91	4.70
Z_2- 15 kg ha^{-1} Zn	1.39	1.46	1.42	4.57	4.88	4.73
Z_3- 30 kg ha^{-1} Zn	1.39	1.46	1.42	4.39	4.80	4.59
Sem ±	0.015	0.022	0.019	0.15	0.08	0.12
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Table 4.34: Effect of manure, fertilizer and zinc on mean soil EC (mS cm^{-1}), bulk density (g mL^{-1}) and water holding capacity.

Treatment	Soil EC (mS cm^{-1})			Bulk Density (g mL^{-1})			Water Holding Capacity		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
Manures									
M_1 – FYM	0.22	0.22	0.22	1.33	1.32	1.33	33.44	33.77	33.60
M_2 - Poultry	0.21	0.22	0.22	1.34	1.33	1.33	32.36	32.49	32.42
M_3- Vermicompost	0.22	0.23	0.23	1.35	1.34	1.35	32.44	32.90	32.67
Sem ±	0.01	0.01	0.01	0.01	0.01	0.01	0.50	0.75	0.64
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Level of fertilizers									
F_1 - 0% RDF	0.22	0.22	0.22	1.36	1.36	1.36	30.93	31.24	31.09
F_2 - 50% RDF	0.21	0.22	0.22	1.35	1.34	1.34	33.05	33.32	33.19
F_3 - 100% RDF	0.22	0.22	0.22	1.31	1.30	1.30	34.26	34.59	34.42
Sem ±	0.01	0.01	0.01	0.01	0.01	0.01	0.48	0.59	0.54
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Zinc Level									
Z_1- 0 kg ha^{-1} Zn	0.21	0.22	0.22	1.34	1.33	1.33	31.96	32.27	32.12
Z_2- 15 kg ha^{-1} Zn	0.22	0.23	0.22	1.34	1.33	1.34	32.55	32.83	32.69
Z_3- 30 kg ha^{-1} Zn	0.21	0.22	0.22	1.34	1.33	1.33	33.73	34.05	33.89
Sem ±	0.01	0.01	0.01	0.01	0.01	0.01	0.54	0.55	0.55
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

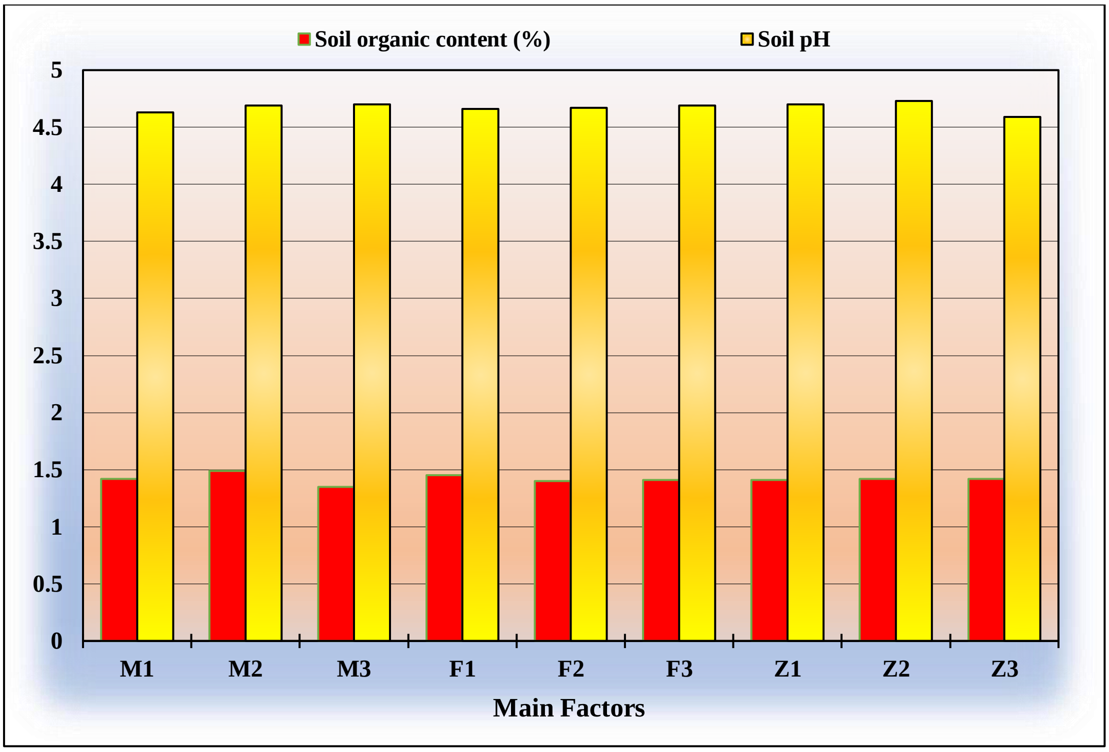


Fig 4.33: Effect of manure, fertilizer and zinc on mean soil organic content (%) and soil pH.

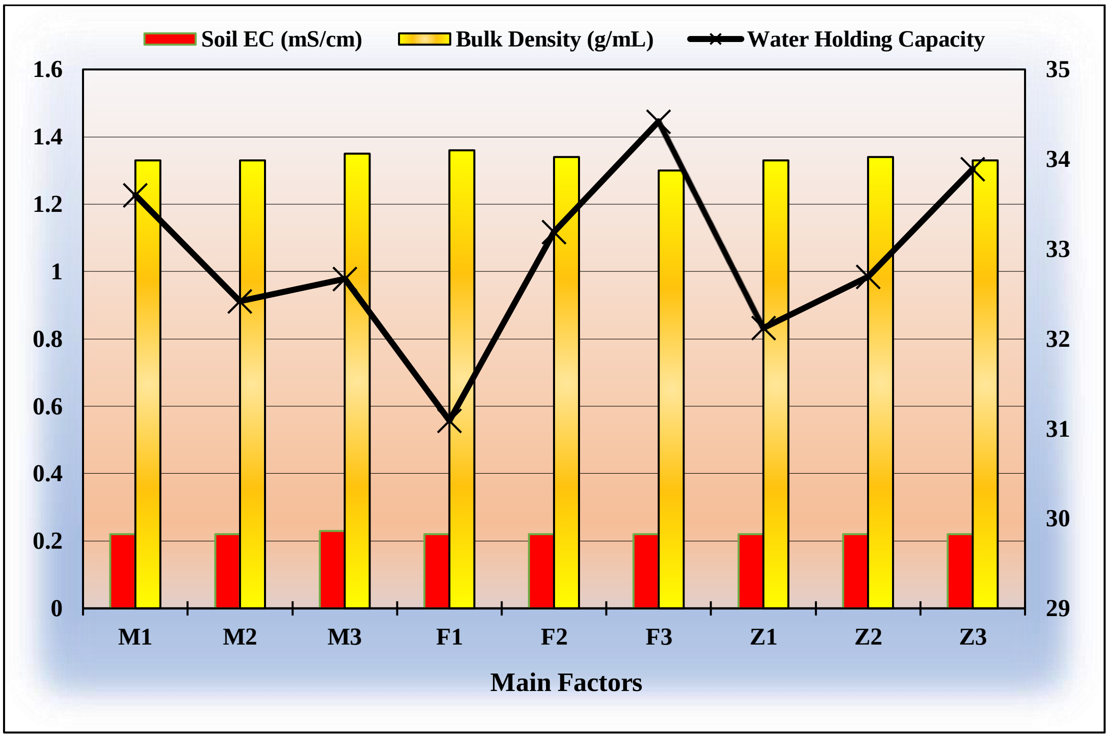


Fig 4.34: Effect of manure, fertilizer and zinc on mean soil EC (mS cm^{-1}), bulk density (g mL^{-1}) and water holding capacity.

4.3.5 Soil water holding capacity

The results of the effect of the application of manure, fertilizer and zinc in soil water holding capacity is presented in the Table 4.34. No significance difference in the responses among the treatments was evident.

4.4 ECOMOMICS

There were differences in the total cost of cultivation of maize production among the various treatments and the highest cost of cultivation (₹54223.5 ha^{-1}) was recorded in T_{27} ($M_3F_3Z_3$) while T_1 ($M_1F_1Z_1$) showed the lowest cost of cultivation.

4.4.1 Gross Income

The estimate of the, gross income was calculated and presented in Table 4.35. In 2016, T_{18} ($M_2F_3Z_3$) with ₹110908.33 ha^{-1} exhibited the largest gross return. Same trend was observed in 2017 and pooled data with the respective value of ₹112400.00 ha^{-1} and ₹111654.17 ha^{-1}. The lowest gross income pooled data (₹52404.17 ha^{-1}) was recorded in Treatment T_{21} ($M_3F_1Z_3$).

4.4.2 Net Income

The presented data in Table 4.35 was carefully examined, and it became clear that T18 (₹60684.83 ha^{-1}) had the highest net return for the year 2016. Similarly, in 2017 and pooled data treatment T_{18} recorded highest net return with the respective value of ₹62176.50 ha^{-1} and ₹61430.67 ha^{-1}.

4.4.2 B:C Ratio

T8 (M1F3Z2) recorded the highest Pooled maximum benefit cost ratio (B:C) with a value of 2.52, followed by T5 (M1F2Z2) with a value of 2.54.

Table 4.35: Effect of integrated nutrient management on economics of maize.

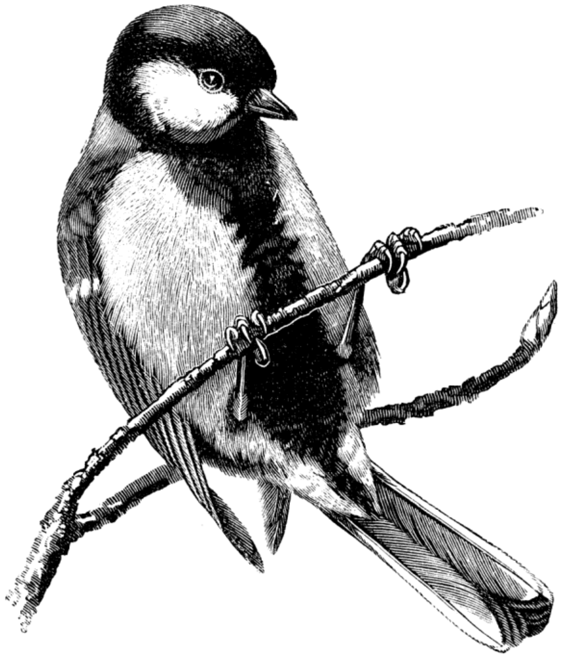
Treatment	Gross Income			Net Income			B:C ratio		
	2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
$M_1F_1Z_1$	53666.67	51908.33	52787.50	26451.67	24693.33	25572.50	1.97	1.91	1.94
$M_1F_1Z_2$	55458.33	54283.33	54870.83	26843.61	25668.61	26256.11	1.94	1.90	1.92
$M_1F_1Z_3$	56300.00	52541.67	54420.83	26285.28	22526.95	24406.11	1.88	1.75	1.81
$M_1F_2Z_1$	77666.67	78908.33	78287.50	45347.11	46588.77	45967.94	2.40	2.44	2.42
$M_1F_2Z_2$	85241.67	86316.67	85779.17	51522.39	52597.39	52059.89	2.53	2.51	2.52
$M_1F_2Z_3$	83916.67	86075.00	84995.83	48797.39	50955.72	49876.55	2.39	2.45	2.42
$M_1F_3Z_1$	91166.67	90408.33	90787.50	53742.89	52984.55	53363.72	2.44	2.42	2.43
$M_1F_3Z_2$	99391.67	98133.33	98762.50	60568.17	59309.83	59939.00	2.56	2.53	2.54
$M_1F_3Z_3$	100091.67	100333.33	100212.50	59868.17	60109.83	59989.00	2.49	2.49	2.49
$M_2F_1Z_1$	54416.67	54158.33	54287.50	17201.67	16943.33	17072.50	1.45	1.47	1.46
$M_2F_1Z_2$	55191.67	55683.33	55437.50	16576.95	17068.61	16822.78	1.42	1.44	1.43
$M_2F_1Z_3$	57366.67	59608.33	58487.50	17351.95	19593.61	18472.78	1.43	1.49	1.46
$M_2F_2Z_1$	78916.67	80908.33	79912.50	36597.11	38588.77	37592.94	1.86	1.91	1.89
$M_2F_2Z_2$	82541.67	88533.33	85537.50	38822.39	44814.05	41818.22	1.89	2.03	1.96
$M_2F_2Z_3$	89341.67	93333.33	91337.50	44222.39	48214.05	46218.22	1.98	2.07	2.02
$M_2F_3Z_1$	96666.67	96158.33	96412.50	49242.89	48734.55	48988.72	2.04	2.03	2.03
$M_2F_3Z_2$	107833.33	106075.00	106954.17	59009.83	57251.50	58130.67	2.21	2.17	2.19
$M_2F_3Z_3$	110908.33	112400.00	111654.17	60684.83	62176.50	61430.67	2.21	2.24	2.22
$M_3F_1Z_1$	54166.67	51408.33	52787.50	12951.67	10193.33	11572.50	1.31	1.25	1.28
$M_3F_1Z_2$	55991.67	52733.33	54362.50	13376.95	10118.61	11747.78	1.31	1.24	1.28
$M_3F_1Z_3$	55450.00	49358.33	52404.17	11435.28	10343.61	11389.45	1.26	1.12	1.19
$M_3F_2Z_1$	76791.67	76283.33	76537.50	30472.11	29963.77	30217.94	1.66	1.65	1.65
$M_3F_2Z_2$	79866.67	83358.33	81612.50	32147.39	35639.05	33893.22	1.67	1.75	1.71
$M_3F_2Z_3$	81566.67	79558.33	80562.50	32447.39	30439.05	31443.22	1.66	1.62	1.64
$M_3F_3Z_1$	92666.67	87658.33	90162.50	41242.89	36234.55	38738.72	1.80	1.70	1.75
$M_3F_3Z_2$	97841.67	95333.33	96587.50	45018.17	42509.83	43764.00	1.85	1.80	1.83
$M_3F_3Z_3$	97958.33	94033.33	95995.83	43734.83	39809.83	41772.33	1.81	1.73	1.77

Plate 4.1: Field preparation and layout designing of the experimental plot.

Plate 4.2: Field view of the standing crop in the experimental plot.

Plate 4.3: Field view of the standing crop in the experimental plot.

Plate 4.4: Five cobs of the best three treatments.



CHAPTER V

SUMMARY AND CONCLUSION

SUMMARY AND CONCLUSION

5.1 Summary

A field experiment entitled "Zinc Biofortification of maize (*Zea mays* L.) and integrated nutrient management in foothill condition of Nagaland'' was conducted during *Kharif* season of 2016 and 2017 at the experimental farm of School of Agricultural Sciences and rural development (SASRD), Nagaland University, Campus: Medziphema, Nagaland with the following objective:

1. To find out the effect of Zinc levels on growth, yield and quality of maize.
2. To find out the suitable source of organic manure and level of Recommended dose of fertilizer.
3. To find out the interaction effect and economics of the treatment combinations.

The experiment was laid out in Split-Split Plot design with twenty-seven treatments and three replications. The soil of the experimental site was sandy clay loam with pH 4.5. Observations on growth, yield, yield attributes, soil chemical analysis, nutrient uptake by plant and quality of maize were recorded. The salient findings of the investigation are summarized in this chapter.

Growth parameters

The various growth parameters taken into consideration for the present experiment *viz.* plant height (cm), number of green leaves plant^{-1}, stem diameter (cm), shoot dry weight, Leaf Area Index, Crop Growth Rate, days to 50 % tasseling and days to 50% silking were studied at different growth stages i.e. 30 DAS, 60 DAS and 90 DAS. The results of the study indicate that the different types of organic manures differed in their responses for various growth parameters except for the stem diameter. It was found that maize plants of the treatments receiving poultry manure (M_2) as a source of organic manure produced the highest plant height (cm), number of green leaves plant^{-1}, stem diameter (cm), shoot dry weight, Leaf Area Index, Crop Growth Rate, while it significantly reduced the days taken to attain 50% tasseling and silking.

However, the response of the FYM (M_1) in case of number of green leaves plant^{-1}, LAI, dry matter, CGR, days to 50 % tasseling and days to 50% silking were found to be statistically at par with that of poultry manure. The exceptional higher performance of poultry for all the growth characters of the maize can be credited to its higher content of phosphorus and other beneficial micronutrient, which encourages early root development required for better growth ultimately resulting in increased and vigorous growth in maize plants.

The results of the application fertilizers at various levels indicated the positive impact of fertilization on maize plants for various growth characters under study. The general trend observed was that with increasing the level of RDF application resulted in subsequent improvement in all the growth characters of maize. Where 100% RDF (F_3) was found to be producing the highest value for every growth character studied which was followed by 50% RDF (F_2). 100% RDF ensured better nutrient availability and nitrogen use efficiency which might enhance the rate of cell division and elongation thereby providing better overall growth of maize plants.

Application of the Zinc did not show any significant difference in early growth stages until 60 DAS where onwards with the increase in levels of the Zinc a positive influence in all the growth characters was evident except for stem diameter. In present study we found out that application of $ZnSO_4$ @ 30 kg ha^{-1} (Z_3) helped maize plants to gain significant improvement in plant height, number of green leaves plant^{-1}, LAI, dry matter, CGR, days to 50 % tasseling and days to 50% silking of maize plants. However, the improvement generated through application of $ZnSO_4$ @ 15 kg ha^{-1} (Z_2) was at par with that of $ZnSO_4$ @ 30 kg ha^{-1} (Z_3). This positive influence of zinc on maize plants might be due to the fact that it plays a vital role in photosynthesis and nitrogen metabolism and it also helps in regulating auxin concentration in plants which ultimately contributes to faster and higher plant growth and development in compared to no zinc application.

Among the growth parameters the interaction effect of manure and fertilizer was found to be significant for dry matter accumulation, number of days to silking and Yield. The maximum dry matter and yield were recorded with the combination of poultry manure @ 4t ha^{-1} with 100% RDF (i.e., M_2F_3). While maize plants receiving treatment M_2F_3 took lesser days to attain silking.

While the interaction between dose of fertilizers and Zinc application showed significant effect on dry matter accumulation, CGR and Yield. Where, the highest values were recorded with the treatments receiving 100% RDF in combination with 30 kg ha^{-1} Zinc application (F_3Z_3).

Yield and yield contributing attributes

The yield attributes *viz.* number of cob $plant^{-1}$, length of cob (cm), weight of cob (g), cob diameter (cm), number of grain cob^{-1}, grain weight cob^{-1} (g), test weight (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) were studied to determine the effect of manures and RDF and Zinc application. The results indicated that the poultry manure (M_2) was found produce significantly higher number of cob $plant^{-1}$, length of cob (cm), weight of cob (g), cob diameter (cm), number of grain cob^{-1}, grain weight cob^{-1} (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) than rest of the organic manures.

Application of 100% RDF (F_3) significantly improved the number of cob $plant^{-1}$, length of cob (cm), weight of cob (g), cob diameter (cm), number of grain cob^{-1}, grain weight cob^{-1} (g), test weight (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}) of maize when compared to 50% RDF (F_2) and 0% RDF (F_1). Similarly, Zinc application @ 30 kg ha^{-1} (Z_3) produced higher the number of cob $plant^{-1}$, length of cob (cm), weight of cob (g), cob diameter (cm), number of grain cob^{-1}, grain weight cob^{-1} (g), grain yield (kg ha^{-1}) and stover yield (kg ha^{-1}). However, the effect of $ZnSO_4$ @ 15 kg ha^{-1} (Z_2) on yield and yield attributing characters were at par with that of the Z_3.

With regards to the combined effect, interaction between manure and fertilizer and fertilizer and Zinc was found to be significantly affecting grain yield of maize plants. Where treatment combination M_2F_3 (poultry manure @ 4 t ha^{-1} with 100% RDF) and F_3Z_3 (100% RDF in combination with 30 kg ha^{-1} Zinc application) produced highest grain yield among the other treatment combinations.

Quality parameters

In case of quality parameters under study application of poultry manure @ 4 t ha^{-1} (M_2) significantly improved the quality status of the maize grain and stover in comparison with FYM and Vermicompost. With regard to the dose of fertilizers, maize plants supplied with 100% RDF (F3) resulted in improved quality maize grains, which in turn resulted in remunerative returns. Among the different levels of Zinc tried, application of 30 kg ha^{-1} of Zinc to the HQPM-1 maize registered highest increase in the quality parameters when compared to the other control *i.e*. 0 kg ha^{-1} Zinc.

Only fertilizer levels and Zinc application could exert significant influence on nitrogen content and uptake, phosphorus content and uptake; zinc content and uptake; protein and carbohydrate content in the HQPM-1 maize. The treatment combination involving 100 % RDF and 30 kg ha^{-1} Zinc (F_3Z_3) exerted the best results among all the combinations.

Economics

Total cost of cultivation in production of Maize was found varied among the different treatments and the highest cost of cultivation (₹54223.5 ha^{-1}) was recorded in T27 ($M_3F_3Z_3$) while the lowest was observed in T1 ($M_1F_1Z_1$). Highest gross return was obtained from the T18 ($M_2F_3Z_3$) during both the years as well as in pooled data, while the lowest gross income was obtained from T21 ($M_2F_1Z_3$). Maximum net return during both the year as well as in the pooled data was recorded in T18 ($M_2F_3Z_3$). The pooled maximum benefit cost ration (B:C) was recorded in T8 ($M_1F_3Z_2$).

5.2 Conclusion

Among different sources of organic manure poultry manure was found to produce significantly better results in almost all the growth, yield and yield attributing characters. RDF with higher levels i.e., 100% RDF dominated in producing significantly better results growth, yield and yield attributing characters. Highest levels of Zinc i.e., 30 kg ha^{-1} recorded highest value in all the growth and yield and yield attributing characters. But it was found to be at par with Zinc application at the rate of 15 kg ha^{-1} in all the characters recorded.

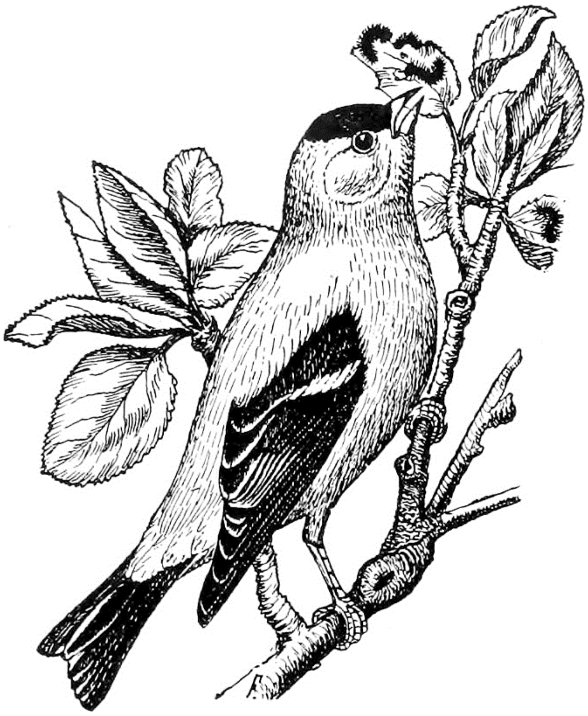
Among the interactions, the treatment combinations of M_2F_3 (poultry manure @ 4t ha^{-1} with 100% RDF) and F_3Z_3 (100% RDF in combination with 30 kg ha^{-1} Zinc application) produced the best effects in growth, yield and quality aspects of the maize.

Economic analysis of maize production indicated that integrated nutrient management significantly increased the overall profitability of the maize production. $M_2F_3Z_3$ with B:C ratio and net return of 2.22 and ₹60684.83 ha^{-1} respectively, was the best treatment due to significantly higher grain and stover yield of maize plants.

5.3 Future line of research

From the findings of the present study, the following line of research can be suggested for better understanding of agronomic biofortification and integrated nutrient management in maize to enhance sustainable maize production with better nutrient profile.

- Further research is required to better understand about the effect and relative distribution of zinc on different plant parts of maize.
- To understand the genotypic efficiency and potential to extract the available zinc more efficiently.
- To identify the maize genotype with higher concentration of bioavailable zinc in grain and stover.
- To understand the response of agronomic biofortification in different maize based cropping system.
- In depth analysis on dynamics of zinc in soil and plant and how zinc biofortification interacts with other micronutrients, thereby affecting their absorption by the maize plant and bioavailability for human (gains) and animals (Fodder).



CHAPTER VI
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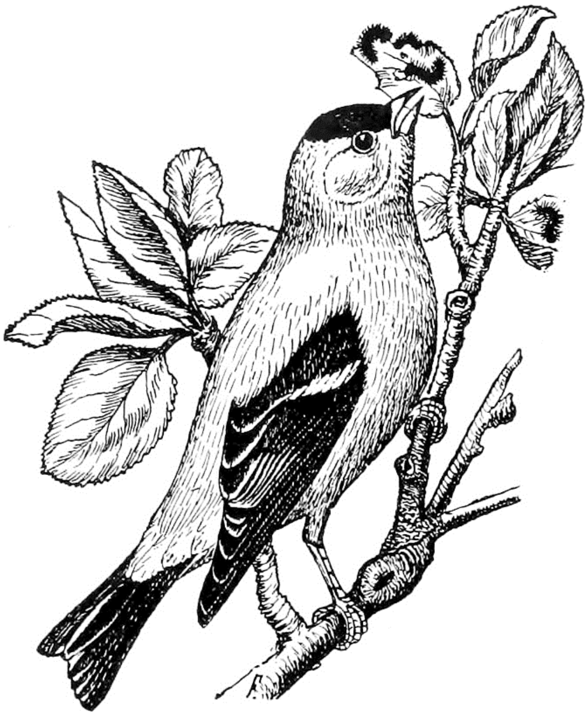

APPENDICES

APPENDICES

Appendix-I: Fixed cost of cultivation (₹ /ha).

Sl. No	Particulars	No. of Units	Rate (₹ /unit)	Cost (₹ /ha)
1	**Land preparation**			
	Ploughing by tractor	1	1200	1200
	Power tiller	1	1000	1000
	Layout and seed bed preparation	10	225	2250
	Manure and fertilizer application	6	225	1350
2	**Maize seed cost**	25	45	1125
3	**Sowing**	10	225	2250
4	**Intercultural operations**	10	225	2250
5	**Plant protection measures and herbicide**			
	Malathion	8	100	800
	Furadan granules	8	105	840
	Application of chemical	4	225	900
	Harvesting	10	225	2250
6	**Miscellaneous**	1	1000	1000
	Total			**17215**

Appendix-II: Cost of cultivation (₹ /ha) as influenced by various treatment combinations.

Treatment	Inputs	Fixed cost	Cost of cultivation
10 t ha^{-1} FYM +0% RDF + 0 kg ha^{-1} Zn	10000	17,215	27215
10 t ha^{-1} FYM + 0% RDF + 15 kg ha^{-1} Zn	11399.72	17,215	28614.72
10 t ha^{-1} FYM + 0% RDF + 30 kg ha^{-1} Zn	12799.72	17,215	30014.72
4 t ha^{-1} PM + 0% RDF + 0 kg ha^{-1} Zn	20000	17,215	37215
4 t ha^{-1} PM + 0% RDF + 15 kg ha^{-1} Zn	21399.72	17,215	38614.72
4 t ha^{-1} PM + 0% RDF + 30 kg ha^{-1}Zn	22799.72	17,215	40014.72
2 t ha^{-1} VC + 0% RDF + 0 kg ha^{-1} Zn	24000	17,215	41215
2 t/ha VC + 0% RDF + 15 kg ha^{-1}Zn	25399.72	17,215	42614.72
2 t/ha VC+ 0% RDF + 30 kg ha^{-1} Zn	26799.72	17,215	44014.72
10 t ha^{-1} FYM + 50% RDF + 0 kg ha^{-1} Zn	15104.56	17,215	32319.56
10 t ha^{-1} FYM + 50% RDF + 15 kg ha^{-1} Zn	16504.28	17,215	33719.28
10 t ha^{-1} FYM + 50% RDF + 30 kg ha^{-1} Zn	17904.28	17,215	35119.28
4 t ha^{-1} PM + 50% RDF + 0 kg ha^{-1} Zn	25104.56	17,215	42319.56
4 t ha^{-1} PM + 50% RDF + 15 kg ha^{-1} Zn	26504.28	17,215	43719.28
4 t ha^{-1} PM + 50% RDF + 30 kg ha^{-1} Zn	27904.28	17,215	45119.28
2 t ha^{-1} VC + 50% RDF + 0 kg ha^{-1} Zn	29104.56	17,215	46319.56
2 t ha^{-1} VC + 50% RDF + 15 kg ha^{-1} Zn	30504.28	17,215	47719.28
2 t ha^{-1} VC+ 50% RDF + 30 kg ha^{-1} Zn	31904.28	17,215	49119.28
10 t ha^{-1} FYM + 100% RDF + 0 kg ha^{-1} Zn	20208.78	17,215	37423.78
10 t ha^{-1} FYM + 100% RDF + 15 kg ha^{-1} Zn	21608.5	17,215	38823.5
10 t ha^{-1} FYM + 100% RDF + 30 kg ha^{-1} Zn	23008.5	17,215	40223.5
4 t ha^{-1} PM + 100% RDF + 0 kg ha^{-1} Zn	30208.78	17,215	47423.78
4 t ha^{-1} PM + 100% RDF + 15 kg ha^{-1} Zn	31608.5	17,215	48823.5
4 t ha^{-1} PM + 100% RDF + 30 kg ha^{-1} Zn	33008.5	17,215	50223.5
2 t ha^{-1} VC + 100% RDF + 0 kg ha^{-1} Zn	34208.78	17,215	51423.78
2 t ha^{-1} VC + 100% RDF + 15 kg ha^{-1} Zn	35608.5	17,215	52823.5
2 t ha^{-1} VC + 100% RDF + 30 kg ha^{-1} Zn	37008.5	17,215	54223.5

Appendix-III: Effect of manure, fertilizer and zinc on mean plant height (cm) at 60 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	50.553	25.276		64.251	32.126		
FACTOR M	2	1119.061	559.530	6.835	1264.239	632.119	6.998	6.944
ERROR(a)	4	327.456	81.864		361.300	90.325		
FACTOR F	2	10409.728	5204.864	71.979	9016.223	4508.112	56.590	3.885
M x F	4	644.446	161.112	2.228	156.070	39.018	0.490	3.259
ERROR(b)	12	867.730	72.311		955.959	79.663		
FACTOR Z	2	776.066	388.033	6.751	516.200	258.100	3.613	3.259
MxZ	4	222.006	55.502	0.966	12.530	3.132	0.044	2.634
FxZ	4	130.092	32.523	0.566	6.164	1.541	0.022	2.634
MxFxZ	8	125.265	15.658	0.272	10.732	1.342	0.019	2.209
ERROR(c)	36	2069.269	57.480		2571.847	71.440		
TOTAL	80	16741.673	209.271		14935.516	186.694		

Appendix-IV: Effect of manure, fertilizer and zinc on mean plant height (cm) at 90 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	516.984	258.492		24.671	12.335		
FACTOR M	2	2349.959	1174.979	7.149	1665.684	832.842	7.144	6.944
ERROR(a)	4	657.425	164.356		466.295	116.574		
FACTOR F	2	23088.620	11544.310	74.932	23498.951	11749.476	118.545	3.885
M x F	4	446.745	111.686	0.725	22.865	5.716	0.058	3.259
ERROR(b)	12	1848.769	154.064		1189.366	99.114		
FACTOR Z	2	1997.615	998.808	8.167	1294.565	647.283	7.722	3.259
MxZ	4	98.095	24.524	0.201	5.777	1.444	0.017	2.634
FxZ	4	22.888	5.722	0.047	173.993	43.498	0.519	2.634
MxFxZ	8	59.967	7.496	0.061	20.771	2.596	0.031	2.209
ERROR(c)	36	4402.657	122.296		3017.698	83.825		
TOTAL	80	35489.725	443.622		31380.635	392.258		

Appendix-IV: Pooled effect of manure, fertilizer and zinc on mean plant height (cm) at 60 DAS and 90 DAS of maize.

		60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	3275.372	3275.372	114.120	5191.760	5191.760	38.340	7.709
REP WITHIN YEAR	4	114.804	28.701		541.655	135.414		
MAIN FACTOR (A)	2	2379.225	1189.613	13.818	3969.584	1984.792	14.130	4.459
LxA	2	4.074	2.037	0.024	46.058	23.029	0.164	4.459
POOLED ERROR (a)	8	688.756	86.094		1123.720	140.465		
SUBPLOT FACTOR (B)	2	19355.497	9677.748	127.360	46544.851	23272.426	183.842	3.403
LxB	2	70.455	35.228	0.464	42.720	21.360	0.169	3.403
AxB	4	622.155	155.539	2.047	263.492	65.873	0.520	2.776
LxBxA	4	178.362	44.591	0.587	206.118	51.529	0.407	2.776
POOLED ERROR (b)	24	1823.690	75.987		3038.135	126.589		
SUB-SUBPLOT FACTOR (C)	2	1272.501	636.250	9.870	3214.280	1607.140	15.594	3.124
AxC	4	80.934	20.234	0.314	33.894	8.473	0.082	2.499
BxC	4	48.021	12.005	0.186	150.770	37.692	0.366	2.499
LxC	2	19.765	9.883	0.153	77.901	38.950	0.378	3.124
AxBxC	8	49.314	6.164	0.096	27.532	3.442	0.033	2.070
AxLxC	4	153.602	38.400	0.596	69.979	17.495	0.170	2.499
BxCxL	4	88.236	22.059	0.342	46.111	11.528	0.112	2.499
AxBxCxL	8	86.683	10.835	0.168	53.205	6.651	0.065	2.070
POOLED ERROR (C)	72	4641.116	64.460		7420.355	103.060		
TOTAL	161							

Appendix-V: Effect of manure, fertilizer and zinc on mean LAI at 30 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	516.984	258.492		0.029	0.015		
FACTOR M	2	2349.959	1174.979	7.149	0.131	0.065	3.781	6.944
ERROR(a)	4	657.425	164.356		0.069	0.017		
FACTOR F	2	23088.620	11544.310	74.932	0.834	0.417	32.079	3.885
M x F	4	446.745	111.686	0.725	0.001	0.001	0.010	3.259
ERROR(b)	12	1848.769	154.064		0.156	0.013		
FACTOR Z	2	1997.615	998.808	8.167	0.048	0.024	1.885	3.259
MxZ	4	98.095	24.524	0.201	0.001	0.001	0.003	2.634
FxZ	4	22.888	5.722	0.047	0.001	0.001	0.008	2.634
MxFxZ	8	59.967	7.496	0.061	0.001	0.001	0.002	2.209
ERROR(c)	36	4402.657	122.296		0.460	0.013		
TOTAL	80	35489.725	443.622		1.729	0.022		

Appendix-V: Effect of manure, fertilizer and zinc on mean LAI at 60 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.009	0.005		0.041	0.021		
FACTOR M	2	0.290	0.145	7.998	0.194	0.097	2.295	6.944
ERROR(a)	4	0.073	0.018		0.169	0.042		
FACTOR F	2	3.643	1.822	103.766	3.377	1.688	110.082	3.885
M x F	4	0.176	0.044	2.505	0.111	0.028	1.812	3.259
ERROR(b)	12	0.211	0.018		0.184	0.015		
FACTOR Z	2	0.084	0.042	3.322	0.116	0.058	3.947	3.259
MxZ	4	0.004	0.001	0.076	0.003	0.001	0.054	2.634
FxZ	4	0.004	0.001	0.087	0.003	0.001	0.047	2.634
MxFxZ	8	0.009	0.001	0.086	0.004	0.001	0.031	2.209
ERROR(c)	36	0.457	0.013		0.528	0.015		
TOTAL	80	4.960	0.062		4.730	0.059		

Appendix-V: Effect of manure, fertilizer and zinc on mean LAI at 90 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.082	0.041		0.469	0.234		
FACTOR M	2	0.558	0.279	7.472	0.573	0.287	7.135	6.944
ERROR(a)	4	0.149	0.037		0.161	0.040		
FACTOR F	2	2.410	1.205	40.234	2.863	1.432	38.559	3.885
M x F	4	0.115	0.029	0.962	0.055	0.014	0.369	3.259
ERROR(b)	12	0.359	0.030		0.446	0.037		
FACTOR Z	2	0.190	0.095	3.278	0.193	0.096	3.789	3.259
MxZ	4	0.007	0.002	0.060	0.002	0.001	0.021	2.634
FxZ	4	0.022	0.005	0.186	0.022	0.006	0.218	2.634
MxFxZ	8	0.012	0.001	0.050	0.016	0.002	0.078	2.209
ERROR(c)	36	1.045	0.029		0.917	0.025		
TOTAL	80	4.949	0.062		5.716	0.071		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean LAI at 30 DAS, 60 DAS and 90 DAS of maize.

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	0.155	0.155	9.528	0.278	0.278	22.056	0.001	0.001	0.004	7.709
REP WITHIN YEAR	4	0.065	0.016		0.050	0.013		0.550	0.138		
MAIN FACTOR (A)	2	0.183	0.092	4.370	0.472	0.236	7.816	1.124	0.562	14.505	4.459
LxA	2	0.009	0.005	0.221	0.012	0.006	0.201	0.007	0.004	0.091	4.459
POOLED ERROR (a)	8	0.168	0.021		0.242	0.030		0.310	0.039		
SUBPLOT FACTOR (B)	2	2.089	1.044	78.131	6.993	3.497	212.612	5.263	2.631	78.464	3.403
LxB	2	0.026	0.013	0.987	0.027	0.013	0.810	0.010	0.005	0.149	3.403
AxB	4	0.012	0.003	0.232	0.059	0.015	0.891	0.147	0.037	1.099	2.776
LxBxA	4	0.008	0.002	0.146	0.228	0.057	3.473	0.023	0.006	0.168	2.776
POOLED ERROR (b)	24	0.321	0.013		0.395	0.016		0.805	0.034		
SUB-SUBPLOT FACTOR (C)	2	0.055	0.027	2.094	0.193	0.097	7.057	0.373	0.186	6.838	3.124

AxC	4	0.001	0.001	0.017	0.003	0.001	0.064	0.005	0.001	0.047	2.499
BxC	4	0.001	0.001	0.011	0.007	0.002	0.126	0.031	0.008	0.284	2.499
LxC	2	0.006	0.003	0.236	0.007	0.004	0.258	0.011	0.005	0.195	3.124
AxBxC	8	0.001	0.001	0.008	0.006	0.001	0.054	0.016	0.002	0.075	2.070
AxLxC	4	0.001	0.001	0.021	0.004	0.001	0.065	0.004	0.001	0.037	2.499
BxCxL	4	0.001	0.001	0.001	0.001	0.001	0.005	0.013	0.003	0.119	2.499
AxBxCxL	8	0.001	0.001	0.011	0.007	0.001	0.060	0.011	0.001	0.052	2.070
POOLED ERROR (C)	72	0.938	0.013		0.985	0.014		1.961	0.027		
TOTAL	161										

Appendix-V: Effect of manure, fertilizer and zinc on mean number of leaf at 30 DAS of maize.

		2016			**2017**			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.336	0.168		4.493	2.246		
FACTOR M	2	1.014	0.507	2.734	4.108	2.054	6.423	6.944
ERROR(a)	4	0.741	0.185		1.279	0.320		
FACTOR F	2	37.589	18.795	30.836	1.474	0.737	2.972	3.885
M x F	4	0.006	0.002	0.003	0.494	0.123	0.498	3.259
ERROR(b)	12	7.314	0.610		2.975	0.248		
FACTOR Z	2	0.185	0.092	0.405	0.048	0.024	0.083	3.259
MxZ	4	0.004	0.001	0.004	1.492	0.373	1.282	2.634
FxZ	4	0.007	0.002	0.008	0.882	0.220	0.757	2.634
MxFxZ	8	0.004	0.001	0.002	1.284	0.160	0.551	2.209
ERROR(c)	36	8.221	0.228		10.480	0.291		
TOTAL	80	55.422	0.693		29.008	0.363		

Appendix-V: Effect of manure, fertilizer and zinc on mean number of leaf at 60 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.735	0.367		1.345	0.673		
FACTOR M	2	3.038	1.519	2.431	5.396	2.698	5.577	6.944
ERROR(a)	4	2.500	0.625		1.935	0.484		
FACTOR F	2	80.569	40.284	69.608	89.284	44.642	98.016	3.885
M x F	4	1.141	0.285	0.493	2.669	0.667	1.465	3.259
ERROR(b)	12	6.945	0.579		5.465	0.455		
FACTOR Z	2	1.534	0.767	2.435	1.982	0.991	3.169	3.259
MxZ	4	0.023	0.006	0.018	0.044	0.011	0.035	2.634
FxZ	4	0.052	0.013	0.041	0.106	0.026	0.085	2.634
MxFxZ	8	0.051	0.006	0.020	0.101	0.013	0.040	2.209
ERROR(c)	36	11.338	0.315		11.256	0.313		
TOTAL	80	107.926	1.349		119.582	1.495		

Appendix-V: Effect of manure, fertilizer and zinc on mean number of leaf at 90 DAS of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	1.025	0.512		0.835	0.418		
FACTOR M	2	4.522	2.261	5.818	6.430	3.215	5.863	6.944
ERROR(a)	4	1.554	0.389		2.193	0.548		
FACTOR F	2	117.152	58.576	94.195	130.180	65.090	146.236	3.885
M x F	4	6.643	1.661	2.671	6.825	1.706	3.833	3.259
ERROR(b)	12	7.462	0.622		5.341	0.445		
FACTOR Z	2	1.947	0.974	3.868	1.587	0.793	3.132	3.259
MxZ	4	0.149	0.037	0.148	0.028	0.007	0.028	2.634
FxZ	4	1.049	0.262	1.042	1.369	0.342	1.351	2.634
MxFxZ	8	0.096	0.012	0.048	0.041	0.005	0.020	2.209
ERROR(c)	36	9.062	0.252		9.117	0.253		
TOTAL	80	150.662	1.883		163.946	2.049		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean number of leaf at 30 DAS, 60 DAS and 90 DAS of maize.

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	45.442	45.442	37.644	9.592	9.592	18.446	0.021	0.021	0.044	7.709
REP WITHIN YEAR	4	4.829	1.207	0.001	2.080	0.520	0.001	1.860	0.465	0.001	
MAIN FACTOR (A)	2	1.140	0.570	2.257	8.264	4.132	7.454	10.868	5.434	11.599	4.459
LxA	2	3.981	1.991	7.882	0.170	0.085	0.153	0.084	0.042	0.089	4.459
POOLED ERROR (a)	8	2.020	0.253		4.434	0.554		3.748	0.468		
SUBPLOT FACTOR (B)	2	26.679	13.340	31.116	169.736	84.868	164.125	246.999	123.499	231.498	3.403
LxB	2	12.384	6.192	14.443	0.116	0.058	0.113	0.333	0.167	0.312	3.403
AxB	4	0.235	0.059	0.137	3.611	0.903	1.746	13.425	3.356	6.291	2.776
LxBxA	4	0.265	0.066	0.155	0.200	0.050	0.097	0.043	0.011	0.020	2.776
POOLED ERROR (b)	24	10.289	0.429		12.410	0.517		12.803	0.533		
SUB-SUBPLOT FACTOR (C)	2	0.195	0.097	0.375	3.500	1.750	5.577	3.502	1.751	6.934	3.124
AxC	4	0.736	0.184	0.709	0.052	0.013	0.042	0.131	0.033	0.130	2.499
BxC	4	0.413	0.103	0.397	0.143	0.036	0.114	2.405	0.601	2.382	2.499
LxC	2	0.039	0.019	0.074	0.015	0.008	0.024	0.032	0.016	0.063	3.124
AxBxC	8	0.652	0.081	0.314	0.129	0.016	0.051	0.051	0.006	0.025	2.070
AxLxC	4	0.760	0.190	0.732	0.014	0.003	0.011	0.046	0.011	0.045	2.499
BxCxL	4	0.476	0.119	0.459	0.015	0.004	0.012	0.013	0.003	0.013	2.499
AxBxCxL	8	0.636	0.080	0.306	0.023	0.003	0.009	0.086	0.011	0.043	2.070
POOLED ERROR (C)	72	18.701	0.260		22.595	0.314		18.179	0.252		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean dry matter (g plant^{-1}) at 30 DAS stage of maize

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	1.356	0.678		1.356	0.678		
FACTOR M	2	3.285	1.642	5.054	13.633	6.816	20.975	6.944
ERROR(a)	4	1.300	0.325		1.300	0.325		
FACTOR F	2	282.675	141.337	469.198	357.648	178.824	593.643	3.885
M x F	4	3.544	0.886	2.941	3.544	0.886	2.941	3.259
ERROR(b)	12	3.615	0.301		3.615	0.301		
FACTOR Z	2	6.709	3.354	22.757	6.709	3.354	22.757	3.259
MxZ	4	0.146	0.037	0.248	0.146	0.037	0.248	2.634
FxZ	4	1.178	0.295	1.998	1.178	0.295	1.998	2.634
MxFxZ	8	0.803	0.100	0.681	0.803	0.100	0.681	2.209
ERROR(c)	36	5.306	0.147		5.306	0.147		
TOTAL	80	309.917	3.874		395.239	4.940		

Appendix-VI: Effect of manure, fertilizer and zinc on mean dry matter (g plant^{-1}) at 60 DAS stage of maize

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	45.228	22.614		31.398	15.699		
FACTOR M	2	615.054	307.527	15.529	793.835	396.917	10.556	6.944
ERROR(a)	4	79.215	19.804		150.407	37.602		
FACTOR F	2	11677.310	5838.655	372.033	16229.158	8114.579	353.296	3.885
M x F	4	207.720	51.930	3.309	153.803	38.451	1.674	3.259
ERROR(b)	12	188.327	15.694		275.619	22.968		
FACTOR Z	2	584.956	292.478	13.935	455.970	227.985	7.536	3.259
MxZ	4	27.932	6.983	0.333	14.107	3.527	0.117	2.634
FxZ	4	254.909	63.727	3.036	230.692	57.673	1.906	2.634
MxFxZ	8	36.653	4.582	0.218	42.509	5.314	0.176	2.209
ERROR(c)	36	755.612	20.989		1089.078	30.252		
TOTAL	80	14472.918	180.911		19466.575	243.332		

Appendix-VI: Effect of manure, fertilizer and zinc on mean dry matter (g plant^{-1}) at 90 DAS stage of maize

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	227.435	113.718		344.698	172.349		
FACTOR M	2	2082.332	1041.166	8.003	1324.148	662.074	9.073	6.944
ERROR(a)	4	520.368	130.092		291.888	72.972		
FACTOR F	2	62948.751	31474.375	261.175	50163.562	25081.781	181.656	3.885
M x F	4	1600.986	400.247	3.321	134.968	33.742	0.244	3.259
ERROR(b)	12	1446.127	120.511		1656.875	138.073		
FACTOR Z	2	3214.882	1607.441	13.196	6363.746	3181.873	25.065	3.259
MxZ	4	146.871	36.718	0.301	61.991	15.498	0.122	2.634
FxZ	4	1645.287	411.322	3.377	1708.375	427.094	3.364	2.634
MxFxZ	8	674.296	84.287	0.692	438.894	54.862	0.432	2.209
ERROR(c)	36	4385.255	121.813		4570.072	126.946		
TOTAL	80	78892.590	986.157		67059.216	838.240		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean dry matter (g plant^{-1}) at 30 DAS, 60 DAS and 90 DAS of maize.

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	68.094	68.094	100.412	110.889	110.889	5.789	78.428	78.428	0.548	7.709
REP WITHIN YEAR	4	2.713	0.678	0.001	76.626	19.157	0.001	572.133	143.033	0.001	
MAIN FACTOR (A)	2	14.668	7.334	22.567	1400.567	700.283	24.398	2584.417	1292.209	12.727	4.459
LxA	2	2.250	1.125	3.462	8.322	4.161	0.145	822.063	411.031	4.048	4.459
POOLED ERROR (a)	8	2.600	0.325		229.622	28.703		812.256	101.532		
SUBPLOT FACTOR (B)	2	637.699	318.849	1058.486	27643.317	13821.659	714.998	112632.516	56316.258	435.575	3.403
LxB	2	2.624	1.312	4.356	263.151	131.576	6.806	479.796	239.898	1.855	3.403
AxB	4	7.087	1.772	5.882	353.499	88.375	4.572	1296.454	324.114	2.507	2.776
LxBxA	4	0.001	0.001	0.001	8.025	2.006	0.104	439.500	109.875	0.850	2.776
POOLED ERROR (b)	24	7.230	0.301		463.945	19.331		3103.002	129.292		
SUB-SUBPLOT FACTOR (C)	2	13.418	6.709	45.514	932.650	466.325	18.201	9152.226	4576.113	36.792	3.124
AxC	4	0.293	0.073	0.497	33.793	8.448	0.330	13.305	3.326	0.027	2.499
BxC	4	2.356	0.589	3.996	483.724	120.931	4.720	3334.920	833.730	6.703	2.499

LxC	2	0.001	0.001	0.001	108.277	54.138	2.113	426.402	213.201	1.714	3.124
AxBxC	8	1.607	0.201	1.362	64.001	8.000	0.312	983.490	122.936	0.988	2.070
AxLxC	4	0.001	0.001	0.001	8.247	2.062	0.080	195.556	48.889	0.393	2.499
BxCxL	4	0.001	0.001	0.001	1.877	0.469	0.018	18.742	4.685	0.038	2.499
AxBxCxL	8	0.001	0.001	0.001	15.160	1.895	0.074	129.700	16.212	0.130	2.070
POOLED ERROR (C)	72	10.613	0.147		1844.690	25.621		8955.327	124.380		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at 30 DAS stage of maize.

		2016			**2017**			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.298	0.149		0.316	0.158		
FACTOR M	2	0.405	0.203	1.312	0.196	0.098	1.024	6.944
ERROR(a)	4	0.617	0.154		0.383	0.096		
FACTOR F	2	38.712	19.356	217.307	34.292	17.146	230.010	3.885
M x F	4	0.098	0.025	0.275	0.247	0.062	0.827	3.259
ERROR(b)	12	1.069	0.089		0.895	0.075		
FACTOR Z	2	0.275	0.137	2.143	0.474	0.237	4.149	3.259
MxZ	4	0.033	0.008	0.127	0.041	0.010	0.181	2.634
FxZ	4	0.083	0.021	0.323	0.057	0.014	0.251	2.634
MxFxZ	8	0.208	0.026	0.406	0.074	0.009	0.161	2.209
ERROR(c)	36	2.308	0.064		2.057	0.057		
TOTAL	80	44.105	0.551		39.032	0.488		

Appendix-VI: Effect of manure, fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at 60 DAS stage of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.298	0.149		0.013	0.007		
FACTOR M	2	0.405	0.203	1.312	0.032	0.016	0.107	6.944
ERROR(a)	4	0.617	0.154		0.597	0.149		
FACTOR F	2	17.194	8.597	96.520	9.429	4.715	67.672	3.885
M x F	4	0.098	0.025	0.275	0.062	0.016	0.223	3.259
ERROR(b)	12	1.069	0.089		0.836	0.070		
FACTOR Z	2	1.311	0.656	10.224	0.925	0.462	8.931	3.259
MxZ	4	0.033	0.008	0.127	0.052	0.013	0.250	2.634
FxZ	4	0.083	0.021	0.323	0.067	0.017	0.325	2.634
MxFxZ	8	0.208	0.026	0.406	0.214	0.027	0.518	2.209
ERROR(c)	36	2.308	0.064		1.863	0.052		
TOTAL	80	23.624	0.295		14.091	0.176		

Appendix-VI: Effect of manure, fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at 90 DAS stage of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.071	0.036		0.103	0.051		
FACTOR M	2	0.145	0.073	0.397	0.201	0.100	3.084	6.944
ERROR(a)	4	0.731	0.183		0.130	0.033		
FACTOR F	2	26.017	13.009	52.882	21.791	10.895	197.600	3.885
M x F	4	0.480	0.120	0.487	0.297	0.074	1.345	3.259
ERROR(b)	12	2.952	0.246		0.662	0.055		
FACTOR Z	2	1.153	0.576	20.712	0.891	0.445	5.685	3.259
MxZ	4	0.207	0.052	1.862	0.384	0.096	1.226	2.634
FxZ	4	0.276	0.069	2.478	0.624	0.156	1.991	2.634
MxFxZ	8	0.392	0.049	1.761	0.369	0.046	0.589	2.209
ERROR(c)	36	1.002	0.028		2.820	0.078		
TOTAL	80	33.427	0.418		28.270	0.353		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean CGR (g m^{-2} day^{-1}) at 30 DAS, 60 DAS and 90 DAS of maize.

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	0.183	0.183	1.191	0.185	0.185	2.384	0.173	0.173	3.975	7.709
REP WITHIN YEAR	4	0.614	0.154	0.001	0.311	0.078	0.001	0.174	0.043	0.001	
MAIN FACTOR (A)	2	0.582	0.291	2.327	0.331	0.166	1.092	0.324	0.162	1.502	4.459
LxA	2	0.019	0.010	0.077	0.105	0.053	0.347	0.022	0.011	0.103	4.459
POOLED ERROR (a)	8	1.000	0.125		1.214	0.152		0.862	0.108		
SUBPLOT FACTOR (B)	2	72.935	36.467	445.770	26.033	13.016	163.996	47.473	23.737	157.651	3.403
LxB	2	0.069	0.034	0.419	0.591	0.295	3.723	0.334	0.167	1.110	3.403
AxB	4	0.321	0.080	0.982	0.033	0.008	0.105	0.607	0.152	1.008	2.776
LxBxA	4	0.024	0.006	0.072	0.127	0.032	0.400	0.169	0.042	0.281	2.776
POOLED ERROR (b)	24	1.963	0.082		1.905	0.079		3.614	0.151		
SUB-SUBPLOT FACTOR (C)	2	0.658	0.329	5.428	2.176	1.088	18.777	2.019	1.010	19.020	3.124
AxC	4	0.059	0.015	0.242	0.058	0.014	0.250	0.555	0.139	2.614	2.499
BxC	4	0.133	0.033	0.550	0.131	0.033	0.565	0.837	0.209	3.942	2.499
LxC	2	0.091	0.045	0.748	0.060	0.030	0.516	0.024	0.012	0.228	3.124
AxBxC	8	0.196	0.025	0.405	0.368	0.046	0.793	0.644	0.081	1.517	2.070
AxLxC	4	0.015	0.004	0.063	0.027	0.007	0.114	0.036	0.009	0.171	2.499
BxCxL	4	0.007	0.002	0.027	0.019	0.005	0.082	0.063	0.016	0.295	2.499
AxBxCxL	8	0.085	0.011	0.176	0.055	0.007	0.118	0.117	0.015	0.275	2.070
POOLED ERROR (C)	72	4.365	0.061		4.172	0.058		3.822	0.053		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean 50% tasselling of maize.

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	6.889	3.444		7.630	3.815		
FACTOR M	2	39.407	19.704	7.141	36.392	18.196	9.448	6.944
ERROR(a)	4	11.037	2.759		7.704	1.926		
FACTOR F	2	375.407	187.704	83.538	392.868	196.434	86.239	3.885
M x F	4	6.963	1.741	0.775	28.721	7.180	3.152	3.259
ERROR(b)	12	26.963	2.247		27.333	2.278		
FACTOR Z	2	33.556	16.778	4.752	24.889	12.444	4.634	3.259
MxZ	4	2.815	0.704	0.199	3.556	0.889	0.331	2.634
FxZ	4	8.593	2.148	0.608	3.926	0.981	0.366	2.634
MxFxZ	8	3.259	0.407	0.115	2.963	0.370	0.138	2.209
ERROR(c)	36	127.111	3.531		96.667	2.685		
TOTAL	80	642.000	8.025		632.647	7.908		

Appendix-VI: Effect of manure, fertilizer and zinc on mean 50% silking of maize.

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	8.469	4.235		22.296	11.148		
FACTOR M	2	28.840	14.420	7.584	50.889	25.444	16.554	6.944
ERROR(a)	4	7.605	1.901		6.148	1.537		
FACTOR F	2	555.284	277.642	128.509	420.222	210.111	109.096	3.885
M x F	4	31.235	7.809	3.614	35.556	8.889	4.615	3.259
ERROR(b)	12	25.926	2.160		23.111	1.926		
FACTOR Z	2	19.358	9.679	3.760	27.630	13.815	3.996	3.259
MxZ	4	1.160	0.290	0.113	0.593	0.148	0.043	2.634
FxZ	4	1.383	0.346	0.134	2.370	0.593	0.171	2.634
MxFxZ	8	8.099	1.012	0.393	8.296	1.037	0.300	2.209
ERROR(c)	36	92.667	2.574		124.444	3.457		
TOTAL	80	780.025	9.750		721.556	9.019		

Appendix-VI: Effect of manure, fertilizer and zinc on cob length (cm) of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	11.882	5.941		0.512	0.256		
FACTOR M	2	23.777	11.888	6.998	34.937	17.468	7.710	6.944
ERROR(a)	4	6.795	1.699		9.063	2.266		
FACTOR F	2	97.937	48.969	30.151	109.330	54.665	55.689	3.885
M x F	4	4.014	1.003	0.618	1.770	0.443	0.451	3.259
ERROR(b)	12	19.490	1.624		11.779	0.982		
FACTOR Z	2	11.925	5.962	3.276	5.107	2.553	4.005	3.259
MxZ	4	0.456	0.114	0.063	0.410	0.103	0.161	2.634
FxZ	4	0.196	0.049	0.027	0.585	0.146	0.229	2.634
MxFxZ	8	0.577	0.072	0.040	0.396	0.050	0.078	2.209
ERROR(c)	36	65.528	1.820		22.951	0.638		
TOTAL	80	242.576	3.032		196.840	2.460		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean 50% tasselling, 50% silking and cob length of maize.

		50% tasselling			50% Silking			Cob length (cm)			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	26.330	26.330	7.254	26.080	26.080	3.391	1.142	1.142	0.368	7.709
REP WITHIN YEAR	4	14.519	3.630		30.765	7.691		12.394	3.099	0.001	
MAIN FACTOR (A)	2	66.568	33.284	14.208	4.457	2.228	1.296	57.428	28.714	14.486	4.459
LxA	2	9.231	4.615	1.970	75.272	37.636	21.892	1.285	0.643	0.324	4.459
POOLED ERROR (a)	8	18.741	2.343		13.753	1.719		15.858	1.982		
SUBPLOT FACTOR (B)	2	764.326	382.163	168.923	970.235	485.117	237.429	204.947	102.474	78.652	3.403
LxB	2	3.950	1.975	0.873	5.272	2.636	1.290	2.320	1.160	0.890	3.403
AxB	4	14.872	3.718	1.643	30.247	7.562	3.701	4.736	1.184	0.909	2.776
LxBxA	4	20.811	5.203	2.300	36.543	9.136	4.471	1.048	0.262	0.201	2.776
POOLED ERROR (b)	24	54.296	2.262		49.037	2.043	0.001	31.269	1.303		
SUB-SUBPLOT FACTOR (C)	2	56.333	28.167	9.063	45.420	22.710	7.531	16.285	8.142	6.626	3.124
AxC	4	4.185	1.046	0.337	0.173	0.043	0.014	0.657	0.164	0.134	2.499
BxC	4	6.222	1.556	0.500	0.840	0.210	0.070	0.433	0.108	0.088	2.499
LxC	2	2.111	1.056	0.340	1.568	0.784	0.260	0.747	0.373	0.304	3.124

AxBxC	8	3.259	0.407	0.131	6.790	0.849	0.281	0.288	0.036	0.029	2.070
AxLxC	4	2.185	0.546	0.176	1.580	0.395	0.131	0.209	0.052	0.043	2.499
BxCxL	4	6.296	1.574	0.506	2.914	0.728	0.242	0.348	0.087	0.071	2.499
AxBxCxL	8	2.963	0.370	0.119	9.605	1.201	0.398	0.685	0.086	0.070	2.070
POOLED ERROR (C)	72	223.778	3.108		217.111	3.015		88.479	1.229		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean cob girth (cm) at different growth stages of maize.

		2016			**2017**			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	1.077	0.538		4.024	2.012		
FACTOR M	2	16.232	8.116	7.031	17.604	8.802	5.139	6.944
ERROR(a)	4	4.617	1.154		6.852	1.713		
FACTOR F	2	22.471	11.235	15.532	48.000	24.000	15.318	3.885
M x F	4	0.626	0.156	0.216	0.979	0.245	0.156	3.259
ERROR(b)	12	8.681	0.723		18.801	1.567		
FACTOR Z	2	3.753	1.876	3.278	4.229	2.114	2.734	3.259
MxZ	4	0.247	0.062	0.108	0.221	0.055	0.071	2.634
FxZ	4	0.117	0.029	0.051	0.264	0.066	0.085	2.634
MxFxZ	8	0.212	0.027	0.046	0.385	0.048	0.062	2.209
ERROR(c)	36	20.606	0.572		27.846	0.773		
TOTAL	80	78.639	0.983		129.205	1.615		

Appendix-VI: Effect of manure, fertilizer and zinc on mean grain weight cob^{-1} (g) at different growth stages of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	1079.557	539.779		1474.737	737.368		
FACTOR M	2	3082.493	1541.246	11.978	4550.067	2275.033	13.466	6.944
ERROR(a)	4	514.691	128.673		675.769	168.942		
FACTOR F	2	15836.668	7918.334	81.847	21138.785	10569.393	66.099	3.885
M x F	4	57.845	14.461	0.149	486.060	121.515	0.760	3.259
ERROR(b)	12	1160.944	96.745		1918.821	159.902		
FACTOR Z	2	1763.225	881.612	9.269	2615.442	1307.721	10.781	3.259
MxZ	4	99.042	24.761	0.260	92.624	23.156	0.191	2.634
FxZ	4	277.055	69.264	0.728	465.239	116.310	0.959	2.634
MxFxZ	8	122.108	15.264	0.160	270.264	33.783	0.279	2.209
ERROR(c)	36	3424.139	95.115		4366.678	121.297		
TOTAL	80	27417.767	342.722		38054.484	475.681		

Appendix-VI: Effect of manure, fertilizer and zinc on mean number of grain cob^{-1} at different growth stages of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	9681.213	4840.607		16490.659	8245.330		
FACTOR M	2	18235.442	9117.721	7.254	26319.414	13159.707	7.089	6.944
ERROR(a)	4	5027.741	1256.935		7425.140	1856.285		
FACTOR F	2	90743.669	45371.834	33.568	115962.881	57981.440	38.445	3.885
M x F	4	4077.722	1019.431	0.754	2948.131	737.033	0.489	3.259
ERROR(b)	12	16219.913	1351.659		18098.064	1508.172		
FACTOR Z	2	11449.889	5724.944	5.184	8111.180	4055.590	4.831	3.259
MxZ	4	519.092	129.773	0.118	1079.176	269.794	0.321	2.634
FxZ	4	244.541	61.135	0.055	3650.638	912.659	1.087	2.634
MxFxZ	8	1289.911	161.239	0.146	3730.763	466.345	0.556	2.209
ERROR(c)	36	39754.344	1104.287		30220.105	839.447		
TOTAL	80	197243.478	2465.543		234036.149	2925.452		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean cob girth (cm), grain weight cob^{-1} (g) and number of grain cob^{-1} at different growth stages of maize.

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	0.734	0.734	0.575	4398.975	4398.975	6.889	5897.221	5897.221	0.901	7.709
REP WITHIN YEAR	4	5.101	1.275		2554.294	638.573		26171.872	6542.968	0.001	
MAIN FACTOR (A)	2	33.619	16.810	11.725	7560.566	3780.283	25.404	43924.094	21962.047	14.109	4.459
LxA	2	0.217	0.109	0.076	71.993	35.997	0.242	630.762	315.381	0.203	4.459
POOLED ERROR (a)	8	11.469	1.434		1190.460	148.807		12452.882	1556.610		
SUBPLOT FACTOR (B)	2	67.866	33.933	29.634	36716.618	18358.309	143.063	205907.857	102953.928	72.000	3.403
LxB	2	2.605	1.303	1.138	258.835	129.417	1.009	798.693	399.346	0.279	3.403
AxB	4	1.273	0.318	0.278	311.690	77.922	0.607	2088.435	522.109	0.365	2.776
LxBxA	4	0.331	0.083	0.072	232.215	58.054	0.452	4937.418	1234.354	0.863	2.776
POOLED ERROR (b)	24	27.482	1.145		3079.765	128.324	0.001	34317.977	1429.916		
SUB-SUBPLOT FACTOR (C)	2	7.958	3.979	5.913	4328.876	2164.438	20.003	19412.345	9706.172	9.987	3.124
AxC	4	0.305	0.076	0.113	189.933	47.483	0.439	1350.559	337.640	0.347	2.499
BxC	4	0.180	0.045	0.067	650.307	162.577	1.502	2459.958	614.990	0.633	2.499
LxC	2	0.024	0.012	0.018	49.791	24.895	0.230	148.724	74.362	0.077	3.124
AxBxC	8	0.251	0.031	0.047	224.555	28.069	0.259	2147.990	268.499	0.276	2.070
AxLxC	4	0.162	0.041	0.060	1.734	0.433	0.004	247.709	61.927	0.064	2.499
BxCxL	4	0.201	0.050	0.075	91.987	22.997	0.213	1435.220	358.805	0.369	2.499
AxBxCxL	8	0.346	0.043	0.064	167.817	20.977	0.194	2872.684	359.085	0.369	2.070
POOLED ERROR (C)	72	48.452	0.673		7790.817	108.206		69974.449	971.867		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean test weight (g) at different growth stages of maize.

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	34.485	17.243		4.868	2.434		
FACTOR M	2	50.955	25.478	5.459	31.199	15.600	2.837	6.944
ERROR(a)	4	18.669	4.667		21.995	5.499		
FACTOR F	2	275.200	137.600	29.837	299.586	149.793	24.109	3.885
M x F	4	6.351	1.588	0.344	3.875	0.969	0.156	3.259
ERROR(b)	12	55.340	4.612		74.558	6.213		
FACTOR Z	2	16.984	8.492	3.215	23.325	11.662	3.042	3.259
MxZ	4	5.544	1.386	0.525	0.820	0.205	0.053	2.634
FxZ	4	12.811	3.203	1.213	1.777	0.444	0.116	2.634
MxFxZ	8	1.116	0.139	0.053	3.996	0.499	0.130	2.209
ERROR(c)	36	95.086	2.641		138.038	3.834		
TOTAL	80	572.541	7.157		604.037	7.550		

Appendix-VI: Effect of manure, fertilizer and zinc on mean shelling % at different growth stages of maize.

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	5.337	2.668		16.962	8.481		
FACTOR M	2	521.359	260.679	7.060	725.871	362.935	12.064	6.944
ERROR(a)	4	147.687	36.922		120.334	30.083		
FACTOR F	2	1394.041	697.021	26.701	1684.479	842.239	33.192	3.885
M x F	4	19.183	4.796	0.184	39.970	9.993	0.394	3.259
ERROR(b)	12	313.251	26.104		304.501	25.375		
FACTOR Z	2	167.709	83.854	4.396	163.675	81.837	3.273	3.259
MxZ	4	6.152	1.538	0.081	7.939	1.985	0.079	2.634
FxZ	4	42.398	10.599	0.556	24.128	6.032	0.241	2.634
MxFxZ	8	4.162	0.520	0.027	8.975	1.122	0.045	2.209
ERROR(c)	36	686.772	19.077		900.110	25.003		
TOTAL	80	3308.050	41.351		3996.942	49.962		

Appendix-VI: Effect of manure, fertilizer and zinc on mean grain yield (kg ha^{-1}) at different growth stages of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	66438.543	33219.272		169261.951	84630.975		
FACTOR M	2	480157.728	240078.864	7.495	1579479.580	789739.790	12.745	6.944
ERROR(a)	4	128121.531	32030.383		247856.864	61964.216		
FACTOR F	2	42483889.951	21241944.975	653.298	44029464.025	22014732.012	592.953	3.885
M x F	4	370930.568	92732.642	2.852	237843.012	59460.753	1.602	3.259
ERROR(b)	12	390179.259	32514.938		445527.630	37127.302		
FACTOR Z	2	937937.506	468968.753	13.617	1153660.543	576830.272	18.202	3.259
MxZ	4	133426.790	33356.698	0.969	319966.272	79991.568	2.524	2.634
FxZ	4	244177.235	61044.309	1.772	348871.383	87217.846	2.752	2.634
MxFxZ	8	78268.469	9783.559	0.284	14810.914	1851.364	0.058	2.209
ERROR(c)	36	1239835.333	34439.870		1140859.556	31690.543		
TOTAL	80	46553362.914	581917.036		49687601.728	621095.022		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean test weight (g), shelling % and grain yield (kg ha^{-1}) at different growth stages of maize.

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	66.858	66.858	6.796	740.270	740.270	132.793	12517.136	12517.136	0.212	7.709
REP WITHIN YEAR	4	39.353	9.838		22.299	5.575		235700.494	58925.123	0.001	
MAIN FACTOR (A)	2	79.557	39.778	7.826	1238.710	619.355	18.487	1894196.704	947098.352	20.152	4.459
LxA	2	2.597	1.299	0.256	8.519	4.260	0.127	165440.605	82720.302	1.760	4.459
POOLED ERROR (a)	8	40.663	5.083		268.021	33.503		375978.395	46997.299		
SUBPLOT FACTOR (B)	2	572.564	286.282	52.893	3071.090	1535.545	59.657	86330274.481	43165137.241	1239.625	3.403
LxB	2	2.222	1.111	0.205	7.430	3.715	0.144	183079.494	91539.747	2.629	3.403
AxB	4	6.699	1.675	0.309	54.333	13.583	0.528	591583.481	147895.870	4.247	2.776
LxBxA	4	3.527	0.882	0.163	4.820	1.205	0.047	17190.099	4297.525	0.123	2.776

POOLED ERROR (b)	24	129.898	5.412		617.753	25.740	0.001	835706.889	34821.120		
SUB-SUBPLOT FACTOR (C)	2	38.841	19.420	5.998	326.889	163.445	7.416	2079591.148	1039795.574	31.447	3.124
AxC	4	5.136	1.284	0.397	13.288	3.322	0.151	416582.593	104145.648	3.150	2.499
BxC	4	9.619	2.405	0.743	62.649	15.662	0.711	566700.370	141675.093	4.285	2.499
LxC	2	1.468	0.734	0.227	4.494	2.247	0.102	12006.901	6003.451	0.182	3.124
AxBxC	8	3.528	0.441	0.136	7.421	0.928	0.042	61577.333	7697.167	0.233	2.070
AxLxC	4	1.228	0.307	0.095	0.802	0.201	0.009	36810.469	9202.617	0.278	2.499
BxCxL	4	4.969	1.242	0.384	3.877	0.969	0.044	26348.247	6587.062	0.199	2.499
AxBxCxL	8	1.583	0.198	0.061	5.716	0.715	0.032	31502.049	3937.756	0.119	2.070
POOLED ERROR (C)	72	233.124	3.238		1586.881	22.040		2380694.889	33065.207		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean stover yield (kg ha^{-1}) at different growth stages of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	61195.136	30597.568		107261.802	53630.901		
FACTOR M	2	526366.321	263183.160	2.779	414505.214	207252.607	1.733	6.944
ERROR(a)	4	378774.346	94693.586		478441.012	119610.253		
FACTOR F	2	37133745.358	18566872.679	239.382	39217497.525	19608748.762	257.162	3.885
M x F	4	28457.679	7114.420	0.092	28457.679	7114.420	0.093	3.259
ERROR(b)	12	930740.519	77561.710		915007.185	76250.599		
FACTOR Z	2	350941.802	175470.901	2.607	282869.802	141434.901	1.963	3.259
MxZ	4	7761.012	1940.253	0.029	7761.012	1940.253	0.027	2.634
FxZ	4	17232.864	4308.216	0.064	17232.864	4308.216	0.060	2.634
MxFxZ	8	8067.654	1008.457	0.015	8067.654	1008.457	0.014	2.209
ERROR(c)	36	2423428.000	67317.444		2593428.000	72039.667		
TOTAL	80	41866710.691	523333.884		44070529.751	550881.622		

Appendix-VI: Effect of manure, fertilizer and zinc on mean nitrogen content of maize grain (%).

SOV	DF	2016			2017			F table
		SS	MSS	F cal	SS	MSS	F cal	
REPLICATION	2	0.013	0.007		0.012	0.006		
FACTOR M	2	0.096	0.048	8.097	0.210	0.105	14.393	6.944
ERROR(a)	4	0.024	0.006		0.029	0.007		
FACTOR F	2	0.753	0.376	78.326	1.169	0.584	104.334	3.885
M x F	4	0.013	0.003	0.666	0.021	0.005	0.917	3.259
ERROR(b)	12	0.058	0.005		0.067	0.006		
FACTOR Z	2	0.100	0.050	7.656	0.278	0.139	44.704	3.259
MxZ	4	0.001	0.001	0.035	0.002	0.001	0.173	2.634
FxZ	4	0.071	0.018	2.707	0.101	0.025	8.148	2.634
MxFxZ	8	0.003	0.001	0.063	0.005	0.001	0.211	2.209
ERROR(c)	36	0.236	0.007		0.112	0.003		
TOTAL	80	1.367	0.017		2.007	0.025		

Appendix-VI: Effect of manure, fertilizer and zinc on mean nitrogen content of stover (%) of maize.

SOV	DF	2016			2017			F table
		SS	MSS	F cal	SS	MSS	F cal	
REPLICATION	2	444.208	222.104		3574.064	1787.032		
FACTOR M	2	5582.276	2791.138	7.005	16944.423	8472.212	6.963	6.944
ERROR(a)	4	1593.753	398.438		4866.785	1216.696		
FACTOR F	2	50605.077	25302.539	66.402	56048.439	28024.220	53.882	3.885
M x F	4	292.967	73.242	0.192	2014.272	503.568	0.968	3.259
ERROR(b)	12	4572.624	381.052		6241.228	520.102		
FACTOR Z	2	915.899	457.949	3.412	3231.396	1615.698	3.811	3.259
MxZ	4	24.004	6.001	0.045	2096.895	524.224	1.237	2.634
FxZ	4	34.910	8.728	0.065	610.520	152.630	0.360	2.634
MxFxZ	8	54.247	6.781	0.051	1513.844	189.231	0.446	2.209
ERROR(c)	36	4832.493	134.236		15261.672	423.935		
TOTAL	80	68952.459	861.906		112403.538	1405.044		

Appendix-VI: Effect of manure, fertilizer and zinc on mean nitrogen content of available soil nitrogen (kg ha^{-1}).

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	0.008	0.004		0.017	0.008		
FACTOR M	2	0.019	0.009	7.215	0.707	0.354	190.469	6.944
ERROR(a)	4	0.005	0.001		0.007	0.002		
FACTOR F	2	0.089	0.045	37.332	0.390	0.195	118.441	3.885
M x F	4	0.002	0.001	0.437	0.003	0.001	0.411	3.259
ERROR(b)	12	0.014	0.001		0.020	0.002		
FACTOR Z	2	0.005	0.002	3.563	0.145	0.072	44.318	3.259
MxZ	4	0.001	0.001	0.263	0.001	0.001	0.116	2.634
FxZ	4	0.001	0.001	0.047	0.008	0.002	1.299	2.634
MxFxZ	8	0.001	0.001	0.217	0.001	0.001	0.039	2.209
ERROR(c)	36	0.023	0.001		0.059	0.002		
TOTAL	80	0.167	0.002		1.357	0.017		

Appendix-VI: Effect of manure, fertilizer and zinc on mean nitrogen content of grain (%), stover (%) of maize and available soil nitrogen (kg ha^{-1}).

SOV	DF	30 DAS SS	30 DAS MSS	30 DAS F cal	60 DAS SS	60 DAS MSS	60 DAS F cal	90 DAS SS	90 DAS MSS	90 DAS F cal	F table
YEAR (L)	1	0.498	0.498	77.044	3486.526	3486.526	3.471	1.892	1.892	305.083	7.709
REP WITHIN YEAR	4	0.026	0.006		4018.271	1004.568		0.025	0.006	0.001	
MAIN FACTOR (A)	2	0.285	0.142	21.526	2653.071	1326.535	1.643	0.442	0.221	140.735	4.459
LxA	2	0.021	0.011	1.614	19873.628	9936.814	12.305	0.284	0.142	90.343	4.459
POOLED ERROR (a)	8	0.053	0.007		6460.538	807.567		0.013	0.002		
SUBPLOT FACTOR (B)	2	1.875	0.938	180.188	105906.378	52953.189	117.523	0.423	0.212	148.785	3.403
LxB	2	0.046	0.023	4.459	747.138	373.569	0.829	0.056	0.028	19.746	3.403
AxB	4	0.027	0.007	1.310	774.408	193.602	0.430	0.003	0.001	0.478	2.776
LxBxA	4	0.006	0.002	0.292	1532.831	383.208	0.850	0.002	0.001	0.366	2.776
POOLED ERROR (b)	24	0.125	0.005		10813.853	450.577	0.001	0.034	0.001		
SUB-SUBPLOT FACTOR (C)	2	0.355	0.177	36.745	3791.620	1895.810	6.793	0.099	0.050	43.864	3.124

AxC	4	0.001	0.001	0.048	1018.150	254.538	0.912	0.001	0.001	0.062	2.499
BxC	4	0.170	0.042	8.782	233.809	58.452	0.209	0.004	0.001	0.980	2.499
LxC	2	0.023	0.012	2.432	355.674	177.837	0.637	0.050	0.025	21.952	3.124
AxBxC	8	0.003	0.001	0.088	721.215	90.152	0.323	0.001	0.001	0.056	2.070
AxLxC	4	0.002	0.001	0.111	1102.749	275.687	0.988	0.001	0.001	0.252	2.499
BxCxL	4	0.003	0.001	0.137	411.621	102.905	0.369	0.004	0.001	0.917	2.499
AxBxCxL	8	0.005	0.001	0.133	846.876	105.859	0.379	0.001	0.001	0.122	2.070
POOLED ERROR (C)	72	0.348	0.005		20094.166	279.086		0.082	0.001		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean potassium content (%) of grain of maize

		2016			**2017**			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.016	0.008		0.003	0.001		
FACTOR M	2	0.013	0.007	7.185	0.018	0.009	13.685	6.944
ERROR(a)	4	0.004	0.001		0.003	0.001		
FACTOR F	2	0.098	0.049	34.262	0.179	0.089	104.093	3.885
M x F	4	0.005	0.001	0.943	0.004	0.001	1.044	3.259
ERROR(b)	12	0.017	0.001		0.010	0.001		
FACTOR Z	2	0.009	0.005	3.363	0.075	0.038	50.839	3.259
MxZ	4	0.001	0.001	0.192	0.001	0.001	0.295	2.634
FxZ	4	0.002	0.001	0.324	0.003	0.001	0.899	2.634
MxFxZ	8	0.003	0.001	0.226	0.001	0.001	0.135	2.209
ERROR(c)	36	0.051	0.001		0.027	0.001		
TOTAL	80	0.219	0.003		0.322	0.004		

Appendix-VI: Effect of manure, fertilizer and zinc on mean potassium content (%) of stover of maize.

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	319.801	159.901		369.621	184.810		
FACTOR M	2	3273.062	1636.531	17.291	4632.500	2316.250	19.620	6.944
ERROR(a)	4	378.586	94.646		472.233	118.058		
FACTOR F	2	20891.557	10445.778	176.246	23401.037	11700.519	131.952	3.885
M x F	4	81.743	20.436	0.345	356.481	89.120	1.005	3.259
ERROR(b)	12	711.216	59.268		1064.072	88.673		
FACTOR Z	2	444.408	222.204	6.211	959.714	479.857	7.652	3.259
MxZ	4	22.221	5.555	0.155	102.351	25.588	0.408	2.634
FxZ	4	12.099	3.025	0.085	33.057	8.264	0.132	2.634
MxFxZ	8	41.661	5.208	0.146	22.488	2.811	0.045	2.209
ERROR(c)	36	1287.936	35.776		2257.601	62.711		
TOTAL	80	27464.290	343.304		33671.154	420.889		

Appendix-VI: Effect of manure, fertilizer and zinc on mean potassium content (%) of available soil potassium (kg ha^{-1}).

SOV	DF	2016 SS	2016 MSS	2016 F cal	2017 SS	2017 MSS	2017 F cal	F table
REPLICATION	2	0.002	0.001		0.005	0.003		
FACTOR M	2	0.096	0.048	7.152	5.308	2.654	460.224	6.944
ERROR(a)	4	0.027	0.007		0.023	0.006		
FACTOR F	2	0.277	0.138	38.073	3.600	1.800	511.900	3.885
M x F	4	0.002	0.001	0.113	0.007	0.002	0.510	3.259
ERROR(b)	12	0.044	0.004		0.042	0.004		
FACTOR Z	2	0.017	0.008	3.286	3.980	1.990	1046.263	3.259
MxZ	4	0.001	0.001	0.041	0.001	0.001	0.085	2.634
FxZ	4	0.001	0.001	0.041	0.002	0.001	0.294	2.634
MxFxZ	8	0.001	0.001	0.069	0.003	0.001	0.222	2.209
ERROR(c)	36	0.092	0.003		0.068	0.002		
TOTAL	80	0.558	0.007		13.041	0.163		

Appendix-VI: Pooled effect of manure, fertilizer and zinc on mean potassium content (%) of grain, stover of maize and available soil potassium (kg ha ^{1}).

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	0.643	0.643	140.835	1256.793	1256.793	7.292	23.986	23.986	12645.520	7.709
REP WITHIN YEAR	4	0.018	0.005		689.422	172.355		0.008	0.002	0.001	
MAIN FACTOR (A)	2	0.030	0.015	18.620	7839.575	3919.787	36.857	3.318	1.659	265.506	4.459
LxA	2	0.002	0.001	1.190	65.988	32.994	0.310	2.087	1.044	167.032	4.459
POOLED ERROR (a)	8	0.006	0.001		850.819	106.352		0.050	0.006		
SUBPLOT FACTOR (B)	2	0.269	0.135	117.502	43747.696	21873.848	295.711	2.837	1.419	396.842	3.403
LxB	2	0.008	0.004	3.342	544.898	272.449	3.683	1.040	0.520	145.412	3.403
AxB	4	0.006	0.002	1.359	217.533	54.383	0.735	0.005	0.001	0.359	2.776
LxBxA	4	0.003	0.001	0.603	220.691	55.173	0.746	0.004	0.001	0.258	2.776
POOLED ERROR (b)	24	0.027	0.001		1775.289	73.970	0.001	0.086	0.004		
SUB-SUBPLOT FACTOR (C)	2	0.069	0.035	32.159	1347.477	673.738	13.682	2.251	1.125	505.005	3.124
AxC	4	0.001	0.001	0.151	51.784	12.946	0.263	0.001	0.001	0.102	2.499
BxC	4	0.003	0.001	0.755	11.193	2.798	0.057	0.001	0.001	0.155	2.499
LxC	2	0.016	0.008	7.377	56.645	28.322	0.575	1.746	0.873	391.691	3.124
AxBxC	8	0.001	0.001	0.151	37.483	4.685	0.095	0.003	0.001	0.176	2.070
AxLxC	4	0.001	0.001	0.304	72.788	18.197	0.370	0.001	0.001	0.018	2.499
BxCxL	4	0.001	0.001	0.291	33.962	8.491	0.172	0.001	0.001	0.143	2.499
AxBxCxL	8	0.002	0.001	0.238	26.665	3.333	0.068	0.002	0.001	0.093	2.070
POOLED ERROR (C)	72	0.077	0.001		3545.537	49.244		0.160	0.002		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean phosphorus content (%) of grain of Maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.004	0.002		0.004	0.002		
FACTOR M	2	0.007	0.003	7.075	0.072	0.036	58.866	6.944
ERROR(a)	4	0.002	0.001		0.002	0.001		
FACTOR F	2	0.114	0.057	63.981	0.260	0.130	219.983	3.885
M x F	4	0.001	0.001	0.178	0.001	0.001	0.540	3.259
ERROR(b)	12	0.011	0.001		0.007	0.001		
FACTOR Z	2	0.011	0.006	6.315	0.481	0.241	924.530	3.259
MxZ	4	0.001	0.001	0.185	0.001	0.001	0.228	2.634
FxZ	4	0.010	0.002	2.738	0.007	0.002	6.729	2.634
MxFxZ	8	0.001	0.001	0.122	0.001	0.001	0.125	2.209
ERROR(c)	36	0.032	0.001		0.009	0.001		
TOTAL	80	0.192	0.002		0.844	0.011		

Appendix-VI: Effect of manure, fertilizer and zinc on mean phosphorus content (%) of stover of Maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	4.310	2.155		16.156	8.078		
FACTOR M	2	62.613	31.307	16.537	25.497	12.749	6.350	6.944
ERROR(a)	4	7.573	1.893		8.030	2.008		
FACTOR F	2	281.477	140.739	106.224	397.433	198.717	238.598	3.885
M x F	4	0.528	0.132	0.100	11.099	2.775	3.332	3.259
ERROR(b)	12	15.899	1.325		9.994	0.833		
FACTOR Z	2	5.077	2.538	3.264	5.871	2.936	3.549	3.259
MxZ	4	0.446	0.112	0.144	0.730	0.182	0.221	2.634
FxZ	4	0.501	0.125	0.161	1.324	0.331	0.400	2.634
MxFxZ	8	1.055	0.132	0.170	0.700	0.087	0.106	2.209
ERROR(c)	36	27.995	0.778		29.781	0.827		
TOTAL	80	407.475	5.093		506.617	6.333		

Appendix-VI: Effect of manure, fertilizer and zinc on mean phosphorus content (%) of available soil phosphorus (kg ha^{-1}).

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.002	0.001		0.004	0.002		
FACTOR M	2	0.009	0.005	9.066	0.012	0.006	62.835	6.944
ERROR(a)	4	0.002	0.001		0.001	0.001		
FACTOR F	2	0.047	0.024	68.537	0.147	0.074	379.344	3.885
M x F	4	0.001	0.001	0.463	0.001	0.001	0.885	3.259
ERROR(b)	12	0.004	0.001		0.002	0.001		
FACTOR Z	2	0.001	0.001	3.199	0.054	0.027	132.371	3.259
MxZ	4	0.001	0.001	0.165	0.001	0.001	0.243	2.634
FxZ	4	0.001	0.001	0.321	0.001	0.001	0.106	2.634
MxFxZ	8	0.001	0.001	0.258	0.001	0.001	0.106	2.209
ERROR(c)	36	0.007	0.001		0.007	0.001		
TOTAL	80	0.073	0.001		0.227	0.003		

Appendix-VI: Effect of manure, fertilizer and zinc on mean phosphorus content (%) of grain, stover of Maize and available soil phosphorus (kg ha^{-1}).

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	1.702	1.702	875.213	17.987	17.987	3.515	0.236	0.236	175.530	7.709
REP WITHIN YEAR	4	0.008	0.002		20.467	5.117		0.005	0.001	0.001	
MAIN FACTOR (A)	2	0.056	0.028	52.070	76.163	38.081	19.525	0.020	0.010	33.425	4.459
LxA	2	0.022	0.011	20.834	11.948	5.974	3.063	0.001	0.001	1.258	4.459
POOLED ERROR (a)	8	0.004	0.001		15.603	1.950		0.002	0.001		
SUBPLOT FACTOR (B)	2	0.357	0.179	240.794	673.706	336.853	312.223	0.179	0.090	334.091	3.403
LxB	2	0.017	0.009	11.515	5.205	2.602	2.412	0.015	0.007	27.460	3.403
AxB	4	0.001	0.001	0.444	6.443	1.611	1.493	0.001	0.001	1.090	2.776
LxBxA	4	0.001	0.001	0.200	5.185	1.296	1.201	0.001	0.001	0.140	2.776
POOLED ERROR (b)	24	0.018	0.001		25.893	1.079	0.001	0.006	0.001		

SUB-SUBPLOT FACTOR (C)	2	0.296	0.148	260.019	10.933	5.467	6.813	0.035	0.017	90.309	3.124
AxC	4	0.001	0.001	0.069	0.247	0.062	0.077	0.001	0.001	0.100	2.499
BxC	4	0.016	0.004	7.149	1.184	0.296	0.369	0.001	0.001	0.116	2.499
LxC	2	0.197	0.098	172.905	0.015	0.007	0.009	0.020	0.010	51.509	3.124
AxBxC	8	0.001	0.001	0.184	0.801	0.100	0.125	0.001	0.001	0.273	2.070
AxLxC	4	0.001	0.001	0.321	0.929	0.232	0.289	0.001	0.001	0.312	2.499
BxCxL	4	0.001	0.001	0.153	0.641	0.160	0.200	0.001	0.001	0.301	2.499
AxBxCxL	8	0.001	0.001	0.061	0.954	0.119	0.149	0.001	0.001	0.084	2.070
POOLED ERROR (C)	72	0.041	0.001		57.776	0.802		0.014	0.001		
TOTAL	161										

Appendix-VI: Effect of manure, fertilizer and zinc on mean zinc content (ppm) of grain of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.002	0.001		0.001	0.001		
FACTOR M	2	0.006	0.003	9.290	0.009	0.005	10.145	6.944
ERROR(a)	4	0.001	0.001		0.002	0.001		
FACTOR F	2	0.600	0.300	568.780	0.734	0.367	691.184	3.885
M x F	4	0.002	0.001	0.715	0.002	0.001	0.707	3.259
ERROR(b)	12	0.006	0.001		0.006	0.001		
FACTOR Z	2	0.074	0.037	160.272	0.112	0.056	197.039	3.259
MxZ	4	0.002	0.001	2.408	0.002	0.001	1.839	2.634
FxZ	4	0.002	0.001	2.216	0.003	0.001	2.274	2.634
MxFxZ	8	0.002	0.001	0.916	0.002	0.001	0.913	2.209
ERROR(c)	36	0.008	0.001		0.010	0.001		
TOTAL	80	0.706	0.009		0.883	0.011		

Appendix-VI: Effect of manure, fertilizer and zinc on mean zinc content (ppm) stover of maize.

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	1.210	0.605		0.141	0.071		
FACTOR M	2	4.920	2.460	0.494	11.899	5.950	1.131	6.944
ERROR(a)	4	19.906	4.977		21.033	5.258		
FACTOR F	2	697.933	348.966	154.615	932.875	466.438	223.362	3.885
M x F	4	2.270	0.567	0.251	1.124	0.281	0.135	3.259
ERROR(b)	12	27.084	2.257		25.059	2.088		
FACTOR Z	2	34.033	17.017	7.936	38.907	19.453	10.002	3.259
MxZ	4	2.198	0.549	0.256	1.699	0.425	0.218	2.634
FxZ	4	0.107	0.027	0.012	0.688	0.172	0.088	2.634
MxFxZ	8	2.623	0.328	0.153	2.370	0.296	0.152	2.209
ERROR(c)	36	77.188	2.144		70.017	1.945		
TOTAL	80	869.471	10.868		1105.813	13.823		

Appendix-VI: Effect of manure, fertilizer and zinc on mean available soil zinc (kg ha^{-1}).

		2016			2017			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
REPLICATION	2	0.014	0.007		0.009	0.004		
FACTOR M	2	0.054	0.027	9.290	0.092	0.046	10.154	6.944
ERROR(a)	4	0.012	0.003		0.018	0.005		
FACTOR F	2	5.403	2.702	568.780	13.482	6.741	1393.922	3.885
M x F	4	0.014	0.003	0.715	0.014	0.003	0.698	3.259
ERROR(b)	12	0.057	0.005		0.058	0.005		
FACTOR Z	2	0.668	0.334	160.272	1.134	0.567	253.269	3.259
MxZ	4	0.020	0.005	2.408	0.019	0.005	2.110	2.634
FxZ	4	0.018	0.005	2.216	0.019	0.005	2.100	2.634
MxFxZ	8	0.015	0.002	0.916	0.019	0.002	1.047	2.209
ERROR(c)	36	0.075	0.002		0.081	0.002		
TOTAL	80	6.350	0.079		14.944	0.187		

Appendix-VI: Effect of manure, fertilizer and zinc on mean zinc content (ppm) of grain, stover of maize and available soil zinc (kg ha^{-1}).

		30 DAS			60 DAS			90 DAS			
SOV	**DF**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**SS**	**MSS**	**F cal**	**F table**
YEAR (L)	1	0.042	0.042	63.352	4.946	4.946	14.644	3.193	3.193	569.104	7.709
REP WITHIN YEAR	4	0.003	0.001		1.351	0.338		0.022	0.006	0.001	
MAIN FACTOR (A)	2	0.013	0.006	16.387	16.027	8.013	1.566	0.139	0.069	18.513	4.459
LxA	2	0.003	0.001	3.195	0.792	0.396	0.077	0.008	0.004	1.119	4.459
POOLED ERROR (a)	8	0.003	0.001		40.939	5.117		0.030	0.004		
SUBPLOT FACTOR (B)	2	1.331	0.665	1257.146	1619.293	809.647	372.657	17.973	8.986	1874.961	3.403
LxB	2	0.003	0.002	3.152	11.515	5.757	2.650	0.912	0.456	95.144	3.403
AxB	4	0.003	0.001	1.379	3.187	0.797	0.367	0.026	0.007	1.370	2.776
LxBxA	4	0.001	0.001	0.043	0.206	0.051	0.024	0.001	0.001	0.043	2.776
POOLED ERROR (b)	24	0.013	0.001		52.143	2.173	0.001	0.115	0.005		
SUB-SUBPLOT FACTOR (C)	2	0.185	0.092	357.019	72.741	36.370	17.789	1.766	0.883	408.778	3.124
AxC	4	0.004	0.001	4.171	3.567	0.892	0.436	0.039	0.010	4.490	2.499
BxC	4	0.004	0.001	4.269	0.292	0.073	0.036	0.037	0.009	4.271	2.499
LxC	2	0.002	0.001	4.133	0.199	0.100	0.049	0.035	0.018	8.120	3.124
AxBxC	8	0.004	0.001	1.820	4.121	0.515	0.252	0.034	0.004	1.959	2.070
AxLxC	4	0.001	0.001	0.016	0.330	0.082	0.040	0.001	0.001	0.018	2.499
BxCxL	4	0.001	0.001	0.228	0.503	0.126	0.062	0.001	0.001	0.041	2.499
AxBxCxL	8	0.001	0.001	0.008	0.872	0.109	0.053	0.001	0.001	0.009	2.070
POOLED ERROR (C)	72	0.019	0.001		147.205	2.045		0.156	0.002		
TOTAL	161										