# STUDY ON ACIDITY TOLERANCE OF MAIZE AND ITS RESPONSE TO PHOSPHORUS AND BORON

Thesis

submitted to

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of

**Doctor of Philosophy**

in

**Agricultural Chemistry and Soil Science**

by

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**2020**

# DECLARATION

I, Ms. Merasenla Ao, 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.

This is being submitted to Nagaland University for the degree of Doctor of Philosophy in Agricultural chemistry and Soil Science

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## CERTIFICATE – I

This is to certify that the thesis entitled "Study on Acidity Tolerance of Maize and its Response to Phosphorus and Boron" submitted to Nagaland University in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy (Agriculture) in Agricultural Chemistry and Soil Science is the record of research work carried out by Ms. Merasenla Ao, Registration No. 760/2017 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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# CERTIFICATE – II

## VIVA VOCE ON THESIS OF DOCTOR OF PHILOSOPHY IN AGRICULTURAL CHEMISTRY AND SOIL SCIENCE

This is to certify that the thesis entitled "Study on Acidity Tolerance of Maize and its Response to Phosphorus and Boron" submitted by Miss Merasenla Ao, Admission No. 156/14, Registration No. 760/2017 to the NAGALAND UNIVERSITY in partial fulfillment of the requirements for the award of degree of Doctor of Philosophy in Agricultural Chemistry and Soil Science has been examined by the Advisory Board and External examiner on 22.03.2021.

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

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Date: 06/10/2020
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(MERASENLA AO)

## CONTENTS

## LIST OF TABLES

# LIST OF FIGURES

# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| AE | - | Agronomic efficiency |
| $Al^{3+}$ | - | Aluminium |
| @ | - | at a rate of |
| cm | - | Centimeter |
| CD | - | Critical Difference |
| B | - | Boron |
| BUE | - | Boron Use Efficiency |
| DAS | - | Days after Sowing |
| ºC | - | Degree Celsius |
| $Ca^{2+}$ | - | Calcium |
| Cmol | - | Centimol |
| $dSm^{-1}$ | - | Decisiemens per meter |
| E | - | East |
| EC | - | Electrical conductivity |
| *et al*. | - | *et allia* (and others/co-workers) |
| $Fe^{3+}$ | - | Iron |
| Fig. | - | Figure |
| g | - | Gram |
| $H^{+}$ | | Hydrogen |
| ha | - | Hectare |
| *i.e.* | - | Id est (that is) |
| kg | - | Kilogram |
| LR | - | Lime requirement |
| m | - | Meter |
| mg | - | Milligram |
| N | - | North |
| N | - | Nitrogen |
| NS | - | Non-significant |
| NU | - | Nagaland University |

| | | |
|---|---|---|
| No. | - | Number |
| % | - | Per cent |
| P | - | Phosphorus |
| PUE | - | Phosphorus Use Efficiency |
| K | - | Potassium |
| RDF | - | Recommended Dose of Fertilizers |
| SASRD | - | School of Agricultural Sciences and Rural Development |
| Sl. No. | - | Serial number |
| S | - | South |
| SEm± | - | Standard error of mean |
| *Viz.* | - | Namely |

# CHAPTER I

# INTRODUCTION

# INTRODUCTION

Maize (*Zea mays L.*) also known as corn belongs to the family of grasses (*Poaceae*) and is widely cultivated throughout the world. It is a versatile crop which is grown over a range of agro-climatic zones *viz.*, the tropical, subtropical and temperate areas of the world. It is globally recognised as the "Queen of cereals" because of its inherent capacity to give higher yield among cereals. Among the countries, the United States of America stands first in maize production with 371.52 million tonnes (mt) followed by China (256 mt), Brazil (94.50 mt), European Union (59.50 mt), Argentina (42.50 mt) and India (26.50 mt) (Maize Outlook, January 2019).

In India, maize is grown throughout the year and is predominantly a *kharif* crop with a total area of 9.18 million hectare (Agricultural Statistics at a Glance, 2019). It is the third most important cereal crop after rice and wheat and accounts for around 10% of total food grain production in the country. It has great significance as human food, animal feed and has numerous applications in various industries such as the food industries where it is used in the manufacture of starch, gluten, sugar, corn oil and syrup, corn meal and flour. Its application in pharmaceutical, cosmetic, textile and paper industries is observed as well. In addition to this, the past few decades have seen a sharp increase in maize production in the world owing to the new application of maize in bioethanol production industry with the United States emerging as the leader in this sector (Mohanty and Swain, 2018).

In the North Eastern Region of India, maize is an important cereal crop having high potentiality for large scale cultivation, but the current production is still lower in comparison to our national average. In Nagaland, maize is one of the important cereal crops next to paddy in respect of area and production. Maize is grown in almost all the districts of Nagaland. In Nagaland, it is grown in an area of 68,960 hectares with annual production of 136540 metric tonnes (Statistical Handbook of Nagaland, 2017).

Maize has been found to be grown successfully in a range of soils from loamy sand to clayey loam. However, neutral pH soils with high organic matter content and water holding capacity is considered good for higher productivity. A challenge in maize production faced by the farmers in the North Eastern Regions of India is soil acidity. The acid soils have high Aluminium (Al) content which leads to grain yield losses up to 60% (The *et al.,* 2006). Nearly 65% of the area under North East, India is under acute forms of soil acidity (pH below 5.5) (Sharma and Singh, 2002). Intense weathering associated with humid climate and heavy precipitation is the cause of soil acidity in this region (Kumar *et al.,* 2012). Some of the problems associated with soil acidity include aluminium toxicity, low nutrient status, and nutrient imbalance (Zesith, 2011). In Nagaland where most of the soils are predominantly acidic in nature, acidity is the main constraint in increasing productivity of these soils. The prevailing factors affecting maize productivity on acid soils are toxicity of aluminium (Al) and iron (Fe), fixation of phosphorus (P), low base saturation and reduction in soil biological activity (Patiram, 1991; Kumar *et al.,* 2012). The negative effect of soil acidity on crops is mainly due to P fixation in soils, where Fe and Al sesquioxides fix sizeable quantities of P, thus making it unavailable to plants. Excess $Al^{3+}$ ions due to soil acidity accumulates in the plant roots and prevents the translocation of P, Mo and other ions from the root to the top, as is evident by the inhibition of root elongation and delayed crop development (Ligeyo and Gudu, 2005). The negative effect of $H^+$ ions in acid soils is not distinctive as that of $Al^{3+}$ ions, but excess of $H^+$ ions affects plant root membrane permeability which interferes with ion transport (Ligeyo and Gudu, 2005). In acid soils where the utilization of native P or added P by plants cannot be carried out efficiently (Swift *et al.*, 1994), it becomes critical to correct soil acidity and also to apply P fertilizer.

For decreasing soil acidity, liming becomes essential along with quantification of lime, which also is an important factor. The nature of soil acidity and soil properties basically determines the lime requirement. Addition of lime increases the soil pH, which eliminates most of the major problems of acid soils. Application of lime eliminates actual and exchange acidities, minimizes hydrolytic acidity, raises the calcium content in the soil (Peoples *et al.,* 1995). Liming also increases the availability of several plant nutrients such as nitrogen, sulphur and particularly phosphorus, due to enhanced mineralization of organic matter. Only around 20% of phosphorus applied as fertilizer is taken up by the crop during the year of its application (Bhat *et al.*, 2007). The rest is fixed in the soil in different range of availability to the subsequent crops. Therefore, one of the benefits of liming acid soils is the increased utilization of residual fertilizer phosphorus by crop. Liming creates a suitable environment (pH 6.0 - 6.5) for nitrifying bacteria, increase in aerobic N fixation process and organic matter decomposition process

In P fixing acid soils, combined application of lime and P is crucial for improved plant uptake of applied P. Phosphorus is required for growth, sugar and starch utilization, photosynthesis, nucleus formation, cell division and fat and albumen formation. The energy from photosynthesis and carbohydrate metabolism is stored in phosphate compounds for growth and reproduction (Ayub *et al.,* 2002). Phosphorus can be easily transported within the plants, moving from older to younger tissues (Ali *et al.*, 2002). Sufficient levels of P in plants results in rapid growth and early maturity and enhances the quality of vegetative growth. Purple leaf coloration is commonly associated with phosphorus deficiency in maize. Phosphorus deficiency is also responsible for crooked and missing rows as kernel twist in maize. Among the cereals, maize has been found to be an exhaustive crop with high yield potential and thus absorbs large quantity of nutrients from the soil during different growth stages.

Among the essential nutrients, phosphorus is the most important nutrient that is needed in larger quantity to achieve higher yield (Chen *et al.,* 1994).

Another challenge in maize production is its sensitivity to B deficiency (Salisbury and Ross, 1992; Soylu *et al.,* 2004). Previously, maize was considered to have a relatively low boron requirement as compared to other cereals (Martens and Westermann, 1991). However, boron deficiency in maize has been reported across five continents based on field responses to boron application (Bell and Dell 2008; Shorrocks, 1997; Shorrocks and Blaza, 1973). The first observation of boron deficiency in field grown maize was in the 1960s in United States (Shorrocks and Blaza, 1973), where on application of boron, the yield increase was more than 10% (Woodruff *et al.*, 1987).

Nearly 33% of 36800 soil samples analyzed in India have been found to be deficient in boron (Singh, 2004). The problem has been reported to be more extensive in the eastern and north-eastern states of India which may be due to leaching losses by high rainfall and high soil acidity. In acid soils boron availability is decreased due to adsorption on sesquioxides, iron and aluminium hydroxy compounds. Boron deficiency affects various processes in vascular plants such as root elongation, oxidase activity, sugar translocation, carbohydrate metabolism, nucleic acid synthesis, and growth of pollen tube (Goldbach and Wimmer, 2007; Saleem *et al.,* 2011). Visual deficiency symptoms of boron in maize include foreshortened internodes, narrow white and transparent necrotic spots and smaller cobs with less tightly packed kernels. Boron plays an important role in several functions of the plant, *viz.*, meristem tissue cell division, petal and leaf bud formation, vascular tissue repair, transport and metabolism of sugars, metabolism of RNA and indoleacetic acid, stability of membranes, production and transfer of cytokinin, pollen budding and seed formation (Shelp, 1993; Marschner, 1995).

The key to accurate and profitable fertilizer recommendations is to target specific nutrients that are deficient in soils and to evaluate the response to the applied nutrients. In Nagaland due to acidity- induced soil fertility problems and traditionally minimal use of mineral fertilizers, there is a need for soil acidity management and crop productivity improvement like nutrient management for enhancing food security in the region. It is therefore necessary to determine the yield benefits due to individual as well as combined application of lime and chemical fertilizers. The effect of nutrient management is one of the most important factors that must be controlled to ensure that farmers get good quality high yields (Grazia *et al.,* 2003). Since maize is a heavy feeder that requires comparatively higher amounts of nutrients for higher production, use of inadequate quantity of fertilizers and a decrease in the native soil fertility often leads to nutrient deficiencies and reduced production of this crop.

There is substantiation of differences in acidity tolerance among crop species and among varieties of the same species. Tolerance to low P and Al toxicity has been reported (Malama *et al.,* 2000). Thus, it becomes imperative to screen maize varieties for tolerance to soil acidity which would be an efficient and permanent alternative to increase yields on acidic soils and avoiding enormous yield losses as is often observed with sensitive varieties (Horst *et al.,* 1997). The knowledge gained from the response of maize with different lime doses and chemical properties in the acid soil would help to identify efficient and economical practices for the farmers. Lastly, the combination of liming practices together with selection for more tolerant plants to Al toxicity would be an economical approach.

In this backdrop, the present investigation entitled "Study on Acidity Tolerance of Maize and its Response to Phosphorus and Boron" was carried out with the following objectives:

1. To evaluate the acidity tolerance of maize varieties and response to lime application.

2. To study the effect of P and B supply on growth, yield and nutrient uptake in case of maize under acidic soil environment.
3. To assess the treatment effect on physicochemical properties of the soil.

# CHAPTER II

# REVIEW OF LITERATURE

# REVIEW OF LITERATURE

The information pertaining to the present investigation entitled "Study on acidity tolerance in maize and its response to phosphorus and boron" and related crops have been presented in this chapter.

## 2.1 EFFECT OF SOIL pH ON PLANTS AND SOIL PROPERTIES

Marquez and Baucas (1990) reported that an increase in soil pH to 5.74, enhanced NPK absorption which in turn resulted to higher yields in various crops.

Goldberg (1997) reported that at lower soil pH, adsorption of B on sesquioxides is greater compared to adsorption of B on soil constituents other than sesquioxides at relatively higher pH. Boron adsorption occurs specifically on mineral surfaces of sesquioxides where innersphere surface complexes are formed which may enhance the irreversibility of B desorption.

Fageria and Zimmermann (1998) studied the influence of pH on nutrient uptake on various crop species and reported varied responses of the crops to soil pH reflecting the genetic diversity among species. In all of the crop species, uptake of calcium (Ca) and magnesium (Mg) decreased with a decrease in soil pH. In general, increasing soil pH decreased the uptake of nitrogen (N), phosphorus (P), and potassium (K) in rice, but uptake of these elements increased in wheat, corn, and common bean.

Alam *et al.* (1999) reported that excess $H^+$ in the growth medium affects plant growth by two processes: a) $H^+$ may cause injury to the root tissue, and b) specific effects on root ion fluxes via $H^+$ competition with base cations for uptake which causes a decrease in the rate of cation absorption as a result of the competition between the similarly charged ions for binding and carrier sites.

Gale *et al.* (2001) stated that acidic soil would result in calcium and magnesium deficiency and poor bacterial growth.

Keerthisinghe *et al.* (2001) reported that crops growing in tropical acid soils can only recover and utilize 10–25% of the P fertilizer applied due to their high P fixations by Al and Fe oxides.

Scott *et al.* (2001) stated that incorporating lime and/or use of acid-soil resistant genotypes are integral to the management of acid soils.

Giller *et al.* (2002) reported that soil acidity has also been shown to reduce the agronomic and recovery efficiencies of nutrients such as P by plants.

Nwachukwu (2002) observed that hot water soluble B content decreased with increase in soil pH.

Abreu *et al.* (2003) studied the relationship between acidity and soil chemical properties and reported that pH correlated positively with P, Ca, Mg, K, base saturation and CEC and negatively with Al saturation. The $Al^{3+}$ was the predominant exchangeable cation in 32% of the soils with pH below 5.6.

Adnan *et al.* (2003) in their study reported that the reaction of $H_2PO_4^{2-}$ and $HPO_4^{-}$ with Al and Fe ions forms a precipitate (Al or Fe phosphate minerals) which reduces diffusion of P into plant roots.

Sierra *et al.* (2003) reported that soil acidity reduces maize and other grain yields by about 10% in tropical areas.

Arora and Chahal (2005) found significant positive correlation between soil pH and available B content.

Mariano and Keltjens (2005) reported that Al had negative effects on the uptake of macro and micronutrients. Al effects were most pronounced on the uptake of Ca and Mg, with respective reductions of 61% and 72%, when averaged across the 10 genotypes. Among the micronutrients, the most pronounced effects of Al were noted on Mn and Zn.

Kifuko *et al.* (2007) stated that an increase in soil pH results in precipitation of exchangeable and soluble Al as insoluble Al hydroxides.

Ligeyo (2007) reported that Al toxicity and P deficiency reduce maize grain yield by about 16 and 28%, respectively, in acid soils.

Mallarino (2011) in a study reported that maize growth and performance is affected by soil reaction. The study revealed that the optimum performance of maize was observed at pH 6.0 and 6.5 in areas with high pH subsoil and in areas without high pH (calcareous) subsoils, respectively.

Awani (2012) stated that soil acidification leads to a decrease in soil available phosphorus.

Bruckner (2012) reported that lower soil pH indicates larger number of hydrogen ions in the soil. Hydrogen ions can appear in varying amount in the soil environment which can affect the level of electrical conductivity. Higher amount of hydrogen ions in the soil will show a higher rate of electrical conductivity. Hence, low soil pH due to large number of hydrogen ions in the soil may encourage soil electrical conductivity.

Kai *et al.* (2012) noted that crop performance is affected indirectly by low soil pH from aluminium and manganese toxicity resulting from overly acidic conditions of the soil.

Lauchli and Grattan (2012) stated that though plants differ in their tolerance to extreme pH, most agricultural plants perform optimally at a pH near neutrality.

Lin *et al.* (2012) in their study on effect of acidic growth conditions on soybean reported that low pH effects the root growth and development and absorption of water and nutrients

Dewi-Hayati *et al.* (2014) reported that grain yield reduction in acid soils varied from 2.8 to 71%.

Sahin (2014) reported that pH of soils is not effective upon the increase of boron concentration in maize with boron fertilizer implementation.

Behera and Shukla (2015) reported that soil pH is positively and significantly correlated with exchangeable $K^+$, $Ca^{2+}$ and $Mg^{2+}$ content in soils.

Tandzi *et al.* (2015) found maize yield reduction under acid soils to be up to 69%.

Khadka *et al.* (2016) in a study on relationship between soil pH and macronutrients revealed that soil pH was significantly and negatively correlated with total N, available $P_2O_5$ and extractable $K_2O$, while there was significant and positive correlation between soil pH and extractable Ca, extractable Mg and available S. In addition, with the increase in soil pH by one unit, N, $P_2O_5$ and $K_2O$ decreases by 0.056, 51.86 and 3.90 units, respectively and vice-versa. On the other hand, Ca, Mg and S increased by 382.2, 46.09, 1.2 units, respectively and vice-versa.

Kundu *et al.* (2017) reported that available boron was significantly and negative correlated with pH. The result indicates that available boron increased with decreased in pH value. Boron adsorption by soils increased as a function of solution pH in the range of pH 3 to 9 and decreased in the range of pH 10 to 11.5.

Otieno *et al.* (2018) observed positive relationships between pH and N, P and K nutrient uptake in soybean.

Kaur *et al.* (2019) stated that in acidic soils, effects of Al toxicity in plants include inhibition of root growth, inhibition of root cell division, modification of the cytoskeleton and inhibition of nutrient uptake. In most acidic soils, P ends up being fixed by Fe which degrades the condition for crop production.

Pan *et al.* (2020) studied the growth and yield of maize on two soil pH of 4.8 and 5.0 and observed that changes in soil pH below the critical soil pH, increased soil pH significantly and increased maize height and the yield of maize shoots and roots. Increase in the pH also increased N accumulation in maize, the N derived from fertilizer in maize, physiological N use efficiency, and N use efficiency (NUE) by maize. Changes in soil pH above the critical soil pH however showed no significant effect on these parameters.

## 2.2. EFFECT OF LIME ON PLANTS AND SOIL PROPERTIES

### 2.2.1 Effect on growth and yield

Venkatesh *et al.* (2002) reported that liming @ 0.25 LR increased both grain and straw yields of maize by about 10 per cent, which might be due to the increase in soil pH, exchangeable bases, available P and reduction in exchangeable Al.

Sierra *et al.* (2003) observed that grain yield, number of grains, test weight and number of rows per ear of maize was higher in limed plots than in non-limed plots. In non-limed plots, soil acidity affected aerial growth in two ways: (i) the appearance of leaves was delayed, and (ii) the individual leaf area and LAI were reduced.

Chatterjee *et al.* (2005) reported that incorporation of lime at 10, 50 and 100% LR increased the pod yield and nutrient uptake of groundnut, where maximum yield was observed at 100% LR.

Brajendra *et al.* (2006) reported that there was a significant increase in plant height, cob length, number of grains/cob and grain yield of maize in all the levels of lime addition (0.5, 1.0, 1.5 and 2.0 t/ha) over no lime.

Dixit (2006) reported that grain and stover yield of maize increased significantly due to lime and P interaction effect. The P application increased grain yield significantly up to 39 kg P $ha^{-1}$ at no lime, 26 kg P $ha^{-1}$ at half of the lime requirement and 13 Kg P $ha^{-1}$ at full lime requirement. Increase in stover yield at no lime and half of the lime requirement was up to 26 kg P $ha^{-1}$ and at full lime requirement, a significant increase was recorded at 13 kg P $ha^{-1}$.

Adhikary and Karki (2007) studied the effect of lime and fertilizer on local and improved varieties of maize and suggested that irrespective of the maize varieties application of fertilizers (60: 30: 30) with agricultural lime (4 t $ha^{-1}$) was beneficial for increased grain production.

Bhat *et al.* (2007) found that application of lime caused a significant increase in grain (GY) and straw yield (SY) of wheat. The magnitude of increase in GY and SY due to liming was 26.8 and 18.6 per cent, respectively over the no lime treatment, irrespective of the sources and levels of lime.

Busari *et al.* (2008) reported that application of lime along with poultry manure in maize, significantly improved plant height, stover and cob yield as well as highest grain yield of maize as compared to control.

Fageria and Baligar (2008) in their review stated that in acid soils with a pH ($H_2O$) < 5.0-5.5, initial lime applications result in large increases in crop growth and yield, mainly due to the amelioration of Al toxicity. Lime rates that raise the soil pH ($H_2O$) to 6 or greater are often associated with lime-induced depressions in plant growth, mostly due to micronutrient deficiencies, and sometimes deficiencies of K and Mg. Lime-induced depressions in plant P content have also been recorded.

Singh *et al.* (2009) reported that application of NPK with lime resulted in the highest grain yield of maize which produced 5.6 t $ha^{-1}$, whereas application of NPK alone (no lime) in acid soil produced 1.8 t $ha^{-1}$ grain yield of maize

Andric *et al.* (2012) found that liming resulted in maize grain yield increases of up to 33% in the first year and 35% in the second year.

Kumar *et al.* (2012) reported that liming at 300 kg $ha^{-1}$ (furrow application) caused 32% yield increase over control. Combined application of NPK+ lime further boosted the yield improvement up to 147% over control.

Kumar *et al.* (2014) reported that growth attributes like plant height and leaf area index and yield and yield attributes of ricebean were significantly higher with the application of lime at 0.6 t $ha^{-1}$ than lower levels of lime (0.2 t $ha^{-1}$ and 0.4 t $ha^{-1}$) and control.

Kumar (2015) reported that increasing levels of lime (control, 0.2, 0.4 and 0.6 t/ha) significantly increased cob length, number of row/cob, number of grain/row, number of grain/cob and 1000-grain weight than lower doses of lime. The grain, stover and biological yield of maize also significantly increased with increasing levels of lime up to 0.6 t $ha^{-1}$.

Behera *et al.* (2017) reported that liming of soil and their combined application with FYM resulted in increasing root length, cob length, diameter and seed weight $cob^{-1}$. Inorganic (lime) amelioration of acid soil resulted in 32 per cent higher yield compared to the yield of 22 q $ha^{-1}$ due to inorganic nutrition only.

Lokya *et al.* (2017) observed that combined application of soil test based recommended dose (STD) + vermicompost (VC) @ 2.5 t $ha^{-1}$+ lime @ 0.2 LR increased the concentration, uptake and recovery of the macro primary nutrients in maize crop.

Opala (2017) reported a significant effect of lime, P, and P by lime interactions on plant heights and dry matter. Without lime application, plant height and dry matter increased with increasing P rates but, with lime, it increased up to 30 kg P $ha^{-1}$ and thereafter declined from 30 to 100 kg P $ha^{-1}$.

Bekele *et al.* (2018) in a study demonstrated that highest leaf area index (5.91), plant height (3.48 m), cob length (47.83 cm), number of grain per cob (644) and above ground dry biomass yield (22 t ha-1 ) were exhibited by the application of lime along with vermicompost and mineral P fertilizer over the control.

Ferdous *et al.* (2018) reported that growth parameters, yield components and yield of rice increased with increasing lime rate (0, 0.50, 1.00, and 1.50 t $ha^{-1}$) along with fertilizer application in acidic soil. The highest grain yield (2.90 t $ha^{-1}$) was recorded from the application of 1.50 t $ha^{-1}$ lime and the lowest (2.06 t $ha^{-1}$) was from control (0 t $ha^{-1}$), irrespective of fertilizer application.

Opala *et al.* (2018) in a study on effect of lime and fertilizers on maize yield observed that maize did not respond to lime without fertilizer. Maize responded to the fertilizers containing N and P but not to application of lime without fertilizer at all experimental sites.

Adikuru *et al.* (2019) reported that lime application of 2 t $ha^{-1}$ significantly increased number of grain rows $cob^{-1}$ by 5.7 %, number of grains $row^{-1}$ by 17.9 %, number of grains $cob^{-1}$ by 24.9 %, weight of hundred seeds by 19.6 % and grain yield by 58.5 % over control.

Devkota *et al.* (2019) reported that plant and yield characters showed significant variation due to variety, lime and their interaction. The highest significant grain yield was given by Manakamana-3 maize variety followed by

Deuti variety. Application of lime at the rate of 1.5 to 1 t $ha^{-1}$ showed statistically significant highest grain yield.

Teshome and Garadew (2019) reported that in an experiment with treatments of five levels of potassium fertilizer (0, 20, 40, 60, and 80 kg $ha^{-1}$) and two levels of lime (0 and 4.6 t $ha^{-1}$), response of soybean in terms of grain yield was highest when 60 kg $K_2O$ $ha^{-1}$ and 4.6 ton lime $ha^{-1}$ was applied while the lowest yield was recorded in the control treatment.

### 2.2.2 Effect on nutrient composition and uptake

Friesen *et al.* (1980) reported that liming alleviates Al toxicity in soil leading to improvement in root growth of plants which eventually results in increased uptake of nutrients as the roots are able to explore greater volume of soil.

Gupta *et al.* (1989) conducted a study to observe the effect of lime on various crops and response to liming was variable among the crops. The uptake of N, P, K increased in all the crops where soybean recorded maximum uptake of all the three nutrients followed by maize, barley and wheat.

Quaggio *et al.* (1991) reported that liming of the surface soil promoted amelioration of the soil down to 100 cm, increased root growth and nutrient absorption in maize, mainly nitrogen, which increased about ten fold.

Su *et al.* (1994) reported an increase in B uptake in alfalfa due to liming.

Oya and Khondaker (1996)) reported the enhanced concentration of N in common millet as a result of addition of lime in acid soil.

Rosolem and Caires (1998) studied response of peanut to liming and Mo application and reported that their application increased N contents in the leaves as well as N uptake.

Jibrin *et al.* (2002) reported that application of lime at 1.35 t CaO $ha^{-1}$ significantly raised the P concentration of index leaves and the total P uptake in maize. Liming also significantly raised the concentrations of Ca and Mg concentrations of index leaves of maize by 12 and 5 %, respectively.

Busari *et al.* (2005) reported an increase in N and P uptake in maize due to liming.

Dixit (2006) reported that phosphorus uptake by grain and stover significantly increased with increase in lime dose up to full lime requirement (3.08 t $ha^{-1}$). The increase over non lime in P uptake by maize grain was to the tune of 68 and 41 % during first and second year, respectively.

Bhat *et al.* (2007) found that application of lime caused a significant increase in N and P content of crop. The mean increase of N concentration was 17.1% over no lime and phosphorus concentration was 51.5% over no lime. Application of lime did not show any specific trend of increase or decrease in concentration of K in wheat plants. The concentration of K was increased to about 0.92% in limed soils.

Ranjit *et al.* (2007) reported that in groundnut, application of 100% lime requirement recorded higher total nitrogen, phosphorus, potassium and calcium uptake than other levels of lime.

Busari *et al.* (2008) reported that lime improved the maize leaf N concentration when provided in combination with poultry manure (PM) and NPK while the combination of PM, lime and NPK gave significantly higher leaf P and K concentrations than any of the other treatments or the control.

Ossom and Rhykerd (2008) in a study reported that N concentration in tubers of sweet potato increased as a result of liming in acid soil.

Singh *et al.* (2009) studied that lime application with NPK resulted in significantly higher uptake of P, Ca, Mg, S and B by maize as compared to NPK alone in acidic soils. Uptake of K by maize in NPK and NPK + lime treated plots was at par. Hot water soluble B content showed a decreasing trend with lime + NPK compared to NPK application without lime.

Sultana *et al.* (2009) reported that the concentrations of P and Ca of wheat grain remained unaffected on liming whereas total uptake of P and Ca were increased due to application of lime which was mainly associated with increased wheat yields.

Kovacevic and Rastija (2010) examined the effect of liming on maize and reported that liming improved maize nutritional status and increased P, Ca, Mg and Mo concentration and decreased high Mn content to the adequate range.

Moreira and Fageria (2010) reported that N, Ca, and Mg concentrations in alfalfa increased with increasing lime rates which may be associated with higher $N_2$-fixation rate by $N_2$-fixing bacteria and higher Ca and Mg uptake with increasing lime rates.

Beukes *et al.* (2012) reported that liming significantly affected P, K, Ca, Mg and Mn concentrations of maize leaves but had no clear effect on leaf N, Cu, Fe and Zn. The increased uptake of the former nutrient elements indicates that liming improved the use efficiency of these elements by the maize crop.

Muindi *et al.* (2015) reported a significant increase of P concentrations in plant tissues of maize after lime application.

Meena and Varma (2016) reported that different lime levels (100, 200 and 300 kg $ha^{-1}$) improved NPK uptake in mungbean, where maximum was observed at 200 kg $ha^{-1}$ as compared to control.

Lynrah and Nongmaithem (2017) reported that application of lime at 1.5 t $ha^{-1}$ gave the highest response in terms of NPK uptake in soybean under acidic soil of Nagaland.

Bhindhu *et al.* (2018) in a study on influence of lime on plant nutrient content of rice reported that content of potassium, calcium and sulphur in plant increased at the lime level as per lime requirement.

Otieno *et al.* (2018) in a study on effects of farmyard manure, lime and inorganic fertilizers in soybean, reported that combined treatments of NPK+lime and manure+lime+NPK recorded higher uptake of N, P and K nutrients rather than individual treatments.

Han *et al.* (2019) reported that K uptake by maize and wheat crops under lime application significantly increased by 37.6% to 155.1% compared with the no-lime treatments.

Yadesa *et al.* (2019) reported significant increase in P uptake of maize with application of P and lime compared to the control experiments.

Zhihao *et al.* (2019) observed that increase of soil pH due to lime application increased the contents of soil available nitrogen and exchangeable $Ca^{2+}$ and exchangeable $Mg^{2+}$, which promoted the uptake of nitrogen, phosphorus and potassium nutrients of crops.

### 2.2.3 Effect on soil properties

Mikko (1972) reported that liming, in general, increased the B retention capacity of soil due to formation of insoluble metaborate.

Garica (1975) in a study reported that the pH of acid soils increases due to liming, and adsorption is higher with higher rate of lime application and calcium deficiencies are ameliorated.

Haynes (1982) in a study on effects of liming on phosphate availability in acid soils reported an increase in P availability due to increase in mineralization of P by lime.

Haynes and Naidu (1998) reported that increase in K availability in soil increases due to displacement of exchangeable K by Ca in the soil exchange complex.

Andersson and Nilsson (2001) in a study reported that liming increases microbial activity which enhances the mineralization of organic matter and thus releasing inorganic nutrients such as N and P.

It was reported by Ghosh and Mukhopadhyay (2001) that liming generally increased K fixation in soil, though liming soils of acidic reaction increased the cumulative release of potassium over unlimed system.

Caires et al. (2002) reported that application of lime in acid soil increases the soil pH as a result of precipitation of Al as $Al(OH)_3$.

Venkatesh *et al.* (2002) observed that there was an overall beneficial effect of liming on available P which appeared to be related to the suppression of exchangeable Al content to the extent of 88%. Liming resulted in a significant increase in pH, exchangeable Ca and Mg, whereas exchangeable K decreased which may be due to the entrapment of exchangeable K by different forms of Al precipitated upon liming the soil. Liming @ 2 t $ha^{-1}$ (25% LR) resulted in remarkable decrease in exchangeable Al content of soil from 0.92 to 0.11 cmol $(P^{+})$ $kg^{-1}$. Exchangeable acidity, which is a direct function of exchangeable $Al^{+}$ and $H^{+}$ registered a decline up to 72% on liming.

Hue (2004) in a study conducted on acid soils reported an increase in pH of soil due to liming possibly due to precipitation of Al as as $Al(OH)_3$.

Chaterjee *et al.* (2005) reported a decrease in soil acidity parameters (exchangeable and total acidity, exchangeable $H^+$, $Al^{3+}$ and $Fe^{3+}$ and total Fe and Al) due to liming which was maximum at 100% LR.

A study conducted by Rahman *et al.* (2005) in acidic alluvial soils at Dinajpur and Rangpur in Bangladesh reported that soil pH, available P, exchangeable Ca, and hot-water-extractable B were increased by liming. The available P, exchangeable Ca and hot-water-extractable B showed a percent increase of 235.185 and 186.792 %, 132.114 and 130.28 % and 62.5 and 69.38 %, respectively at Dinajpur and Rangpur.

Brown *et al.* (2008) reported that one-time broadcast application of calcitic lime @ 7000 kg $ha^{-1}$ significantly increased the pH by 0.7 units, while Al significantly lowered relative to the control.

Sarkar (2009) found that within the forms of K, water soluble K increased but exchangeable K decreased in all the soils after liming.

Singh *et al*. (2009) reported that with lime and fertilizer use, the pH of acid soil (5.5) increased by 0.9 units, while it decreased in unlimed plots.

Basak (2010) reported that liming in general increased the potassium availability in soils which is often low in acid soils due to the formation of soluble K salt by soil acids and their loss by leaching from the soil.

Dasog *et al.* (2010) found significant increase in soil pH with addition of lime, where application of lime at 100% lime requirement recorded a highest soil pH of 6.03 and the lowest exchangeable soil acidity. Also the highest available phosphorus in the soil was recorded at 100% of lime requirement.

Kumar *et al.* (2010) showed that liming has positive influence in exchangeable and reserved form of K.

Andric *et al.* (2012) observed that as a result of liming, soil pH increased from 4.75 to 5.28 and was close to neutral after application of 5 t $ha^{-1}$ and 20 t $ha^{-1}$ of lime, respectively. Liming also considerably affected soil nutrient availability because of increases in P (+44%), Ca (+58%), Mg (+74%), and B (+86%) and decreases in Mn (−33%) and Fe (−28%), compared to the control.

Beukes *et al.* (2012) observed that liming at various levels had highly significant effects on soil pH, extractable acidity (EA), acid saturation (AS), P, Ca and Mg. Soil pH (KCl), P, Ca and Mg increased, whereas EA and AS decreased significantly with an increase in lime application. Significant lime × fertiliser interaction was also observed in terms of soil P. The trends in the latter whereby at low soil pH there was no significant increase in P, followed by an increase as pH increased due to liming.

Costa (2012) reported that liming leads to an increase in soil organic matter (includes organic carbon).

Lege (2012) reported low pH value in soils of control treatment which was attributed to low exchangeable basic cations at the soil exchange sites due to exhaustive uptake of exchangeable bases by plants during the growing period.

Voor (2012) stated that soil acidity results in low exchangeable base cations due to aluminium toxicity.

Kisinyo *et al.* (2013) observed that lime significantly reduced exchangeable $Al^{3+}$ and increased soil pH and available P. Lime increased soil pH because of the likely displacement of $Al^{3+}$, $H^{+}$ and $Fe^{3+}$ ions by $Ca^{2+}$ ions it contains. This led to the observed reduction in P sorption at all the sites.

Osundwa *et al.* (2013) reported that addition of lime had significant increase on the soil pH above the control treatment with lime addition of 1.0, 1.5 and 2 t/ha. The soil available P was highest with lime addition of 2 t $ha^{-1}$.

Amer *et al.* (2014) observed a significant increase in the pH in lime treated soil and lowest total and exchangeable acidity were found to be with application of 20% lime of LR.

Das and Saha (2014) reported that liming of acid soil with half of its requirement and combined application of N and K fertilizers significantly reduced K fixation and increased water soluble K which can easily be taken up by the growing plants. Addition of lime decreased the exchangeable K in soil system the reason being the precipitation of exchangeable aluminium ($Al^{3+}$) and iron ($Fe^{3+}$) ions as hydroxy-aluminium and hydroxy-iron polymers which act as props between layer silicates, thereby inhibiting the collapse of the layers for the K ions. Also, the amount of exchangeable K was more in full limed as compared to half limed soil. This is due to liming with higher doses; higher amount of $Ca^{2+}$ occupy the exchange sites which encourages release of non-exchangeable K in the exchangeable phase.

Kamaruzzaman *et al.* (2014) reported that the application of different rate of lime increased the K availability of soils and better concentration of available K was obtained with lime rate at 1.5 t $ha^{-1}$.

Kisinyo *et al.* (2014) reported that lime could reduce the P sorption in acid soils resulting in increased available P for plants.

Badole *et al.* (2015) in a pot experiment reported that decrease in values of all the forms of acidity i.e., total acidity, hydrolytic acidity, exchange acidity, electrostatically bound aluminium ($EBAl^{3+}$), and electrostatically bound hydrogen ($EBH^{+}$) was greater in full lime ($L_1$) than in half lime ($L_{1/2}$)

treatment under Entisols of the terai zone, followed by Entisols of coastal saline zone, Inceptisols, and Alfisols.

Benjala *et al.* (2015) reported that liming effects caused exchangeable potassium (K) to increase with increasing rates of dolomitic limestone application. This is because raising the pH through liming soils particularly those with pH-dependent charge increases the soils' cation exchange capacity (CEC) and thus increases the soils' capacity to adsorb K.

Dey and Nath (2015) reported that liming along with integrated nutrient management practices showed improved status of post harvest soil analysis in organic C, N and P, but available K status declined.

Samant (2015) reported that application of lime at 100% LR was beneficial in improving the fertility status of acid soil. Maximum pH, available P, K, exchangeable Ca and Mg in post harvest soil was recorded at 100% LR with RDF.

Sethi (2015) narrated that lime application (inorganic) increased pH, base saturation, and cation exchange capacity and decreased Al, Fe, and Mn availability, acidity and P fixation.

In a field experiment carried out by Toppo and Kumar (2018), it was observed that liming showed no significant result in soil organic carbon. Also, the availability of phosphorus was more in limed plots as compared to that of control plot although it was treated with SSP. The reasons for this have been attributed to breaking of the complex of iron and aluminum phosphates by lime on acid soils and increasing the availability of phosphates in the form of calcium phosphates.

Han *et al.* (2019) reported that concentration of available K and exchangeable $Ca^{2+}$ in soil had a positive relationship with lime addition rates.

Shen *et al.* (2019) reported that lime might be a better choice over by-product amendments to improve chemical properties of the acidic soil. Results showed that lime significantly increased the pH and electrical conductivity of soil.

## 2.3. EFFECT OF PHOSPHORUS ON PLANTS AND SOIL PROPERTIES

### 2.3.1 Effect on growth and yield

Hamdi and Woodard (1995) reported an increase in leaf area index of corn with increase in P levels (0, 12, and 24 mg P $kg^{-1}$ soil).

Arya and Singh (2000) reported that P application of 90 kg $P_2O_5$ $ha^{-1}$ resulted in significantly more grain and straw yields compared with 60, 30 and 0 $P_2O_5$ $ha^{-1}$.

Sarma *et al.* (2000) in a field study on a composite maize variety 'Vijoy' found that on supplying three levels of P (20, 40 and 60 kg $P_2O_5$ $ha^{-1}$), maize responded significantly up to 60 kg $P_2O_5$ $ha^{-1}$ but the optimum P rate for maize was 20 kg $P_2O_5$ $ha^{-1}$.

Ayub *et al.* (2002) reported that leaf area of maize increased with increase in nitrogen and phosphorus levels.

Venkatesh *et al.* (2002) reported that on application of 0, 30, 60 and 90 kg $P_2O_5$ $ha^{-1}$, the grain and straw yield of maize increased significantly at phosphorus level up to 90 kg $P_2O_5$ $ha^{-1}$ over control when applied without FYM or lime. However, the P levels responded significantly only up to 60 kg $P_2O_5$ $ha^{-1}$ when applied along with lime/ FYM or lime + FYM. Similar trend as in grain and straw yields was also seen in case of test weight of maize. Phosphorus use efficiency by maize increased up to 60 kg $P_2O_5$ $ha^{-1}$, thereafter it significantly reduced indicating that PUE decreases at higher doses of P due to the fact that plants grown in extremely P deficient soil exhibit greater P sorption at lower doses of P.

Alias *et al.* (2003) studied the effect of varying levels of phosphorus (0, 50, 75, 100, 125 and 150 kg P $ha^{-1}$) on yield and yield components of maize on a sandy loam soil and reported that there was a significant increase in leaf area per plant, number of grains per cob and 1000- grains weight with increasing levels of P.

Assuero *et al.* (2004) in a study reaffirmed the important role of phosphorus in cell division and cell enlargement, wherein they reported a decreased cell production, and ultimately leaf elongation rates, in P-deficient maize plants.

Khan *et al.* (2005) studied the effect of different levels of phosphorus (0, 25, 50, 75 and 100 kg $P_2O_5$ $ha^{-1}$) on maize and reported that phosphorus significantly increased grain weight per cob, number of grains per cob, cob weight and 1000-grain weight and maximum values was observed at 75 kg $P_2O_5$ $ha^{-1}$.

Hussain *et al.* (2006) reported an increase in plant height of maize with increasing levels of phosphorus and attributed the promotion effect of P on plant height to better root development and nutrient absorption.

Hussain *et al.* (2007) studied that maximum number of grains $cob^{-1}$ and cob weight of maize was obtained with 90 kg P $ha^{-1}$ while minimum grains $cob^{-1}$ was obtained with 30 kg P $ha^{-1}$ and minimum cob weight was obtained with 30 and 60 kg P $ha^{-1}$. Increase in phosphorus level also increased 1000-grain weight and grain yield of maize where maximum was obtained with 90 kg P $ha^{-1}$.

Ali *et al.* (2008) reported that P application of 60, 90, 120 kg $ha^{-1}$ resulted in increase in number of cobs $plant^{-1}$, number of grains $cob^{-1}$, thousand grain weight and grain yield as compared to control. P dose of 60 kg $ha^{-1}$ resulted in maximum increase in number of grains $cob^{-1}$, thousand grain weight and grain yield.

Amanullah *et al.* (2009) reported an increase in plant height, leaf area index, grain and stover yield, harvest index, shelling percentage, thousand grain weight and grains $ear^{-1}$ of maize with increase in levels of phosphorus fertilizer.

Amanullah *et al.* (2010) reported that among P levels of 30, 60 and 90 kg P $ha^{-1}$, the highest level of 90 kg P $ha^{-1}$ increased plant height, number of leaves per plant, mean leaf area, dry weight of leaf, stem and ear as well as biomass yield and harvest index of maize.

Masood *et al.* (2011) found that P at the rate of 100 kg $ha^{-1}$ was the optimum rate for the yield components of maize like plant height, number of grains per cob and thousand grain weights. Further increase in P above 100 kg $ha^{-1}$ did not have a direct proportional effect on the yield components. However, number of cobs per plant and grain yield was found to be optimum at 100 kg $P_2O_5$ $ha^{-1}$ followed by 150 kg $P_2O_5$ $ha^{-1}$.

Khan *et al.* (2014) reported that the response of maize to three levels of phosphorus (60, 90 and 120 kg $ha^{-1}$) was found to be non-significant in case of plant height and leaf area while number of leaves $plant^{-1}$ and dry weight of plants were significant with highest values where P was applied @ 120 kg $ha^{-1}$ followed by 90 kg $ha^{-1}$.

Nsanzabaganwa *et al.* (2014) found that the yield attributes of maize such as number of grains per cob, cobs per plant, test weight were found to have no significant effect on P application except on test weight, which was significantly higher at 26.4 kg P $ha^{-1}$. The effect of P on grain and stover yield was found to be significant and the highest was reached at 26.4 kg P $ha^{-1}$ after which further increase declined the yield. There was an increase in grain yield, amounting to 12.6, 17.5, and 14.3% with 13.2, 26.4, and 39.6 kg P $ha^{-1}$ over control. In the case of stover yield, the corresponding increases were 28.6, 45.8, and 27.0%. Increase beyond 26.4 kg P $ha^{-1}$ caused a reduction in stover yield by 28.7%.

Amanullah and Khan (2015) reported that phosphorus applied at the two higher rates (75 and 100 kg P $ha^{-1}$) increased number of grains $ear^{-1}$ and grains $row^{-1}$, 1000 grains weight, grain yield, harvest index and shelling percentage of maize.

Umeri *et al.* (2016), observed an increase in maize plant height and number of leaves, with the application of 40kg N and 40 kg P $ha^{-1}$, respectively.

Chandrakala *et al.* (2017) reported higher phosphorus use efficiency (PUE) of maize when P was applied at the rate of 75 % of recommended dose along with recommended dose of N and K. This could be due to maximum utilization and uptake of added P and further application beyond this level was non beneficial and was also non economical to farmers as the PUE by the crops were only 20-40 per cent in general, the remaining amount was fixed in the soil.

Khan *et al.* (2017) reported that application of phosphorus significantly influenced the cob weight, grains $row^{-1}$ (35.30), grain rows $cob^{-1}$, grains $cob^{-1}$ and 100-grain weight of sweet corn. The treatment consisted of 5 levels of phosphorus (40, 50, 60, 70 and 80 kg $P_2O_5$ $ha^{-1}$) and maximum values for all was observed at 60 kg $P_2O_5$ $ha^{-1}$.

Kumar *et al.* (2017) reported that application of increasing levels of both phosphorus (90 kg $P_2O_5$ $ha^{-1}$) and sulphur (45 kg S $ha^{-1}$) resulted in a significant increase in seed and stover yield of soybean.

Opala (2017) reported that the highest dry matter yield of maize was obtained with 30 kg P ha$^{-1}$.

Pal *et al.* (2017) reported that phosphorus levels (40, 50 and 60 kg $P_2O_5$ ha$^{-1}$) significantly influenced the growth parameters, yield attribute and yield of maize *viz.*, plant height, number of cobs per plant, cob length, cob girth, number of grains per cob, 100 grain weight, grain yield and stover yield and highest values of these growth parameters, yield attribute and yield parameters were observed with application of 60 kg $P_2O_5$ ha$^{-1}$ while the lowest values were recorded under 40 kg $P_2O_5$ ha$^{-1}$.

Sadiq *et al.* (2017) reported that P applied at 120 kg ha$^{-1}$ increased rows ear$^{-1}$ by 40%, grains row$^{-1}$ by 18%, grains ear$^{-1}$ by 41%, thousand grains weight of maize by 8%, biological yield by 41%, stover yield by 34%, grain yield by 55% and harvest index by 10% over control.

Timlin *et al.* (2017) reported an increase in leaf appearance rate and area of maize due to P application

Sharma *et al.* (2018) reported that application of phosphorus at 75 kg ha$^{-1}$ was found to be best over its lower levels ((0, 25 and 50 kg ha$^{-1}$) on yield attributes (cob length, number of grains cob$^{-1}$ and 1000 grain weight) and yield (grain and stover) of hybrid maize which was closely followed by phosphorus at 50 kg ha$^{-1}$.

Irfan *et al.* (2019) studied the interactive effect of P and B on wheat wherein results revealed that yield and yield related attributes increased linearly with the addition of B at each P level. Nonetheless, the significant interactive effect of both nutrients was most pronounced in the treatment having 90 kg P ha$^{-1}$ and 1.5 kg B ha$^{-1}$.

### 2.3.2 Effect on nutrient composition and uptake

Chirnogeanu *et al.* (1997) found that concentration of absorbed phosphorus in maize leaves was 70-80% higher in plants which received 120 kg $P_2O_5$ $ha^{-1}$, as compared to unfertilized variants. However, there was an increase in potassium content in plants without phosphorus application. The highest values of potassium content corresponded to the lowest values of plant calcium content.

Dubey (2000) with reference to phosphorus use efficiency in crops stated that the decrease in phosphorus use efficiency at higher doses of P is because plants grown in P deficient soil exhibit greater P sorption at lower doses of P.

Shankarlingappa *et al.* (2000) reported that combined application of P and S up to 50 kg $P_2O_5$ and 20 kg S $ha^{-1}$ showed significant synergistic effect on uptake of N, P and S by cowpea which was attributed to higher concentration of nutrients as a result of increased availability of nutrients from soil and fertilizer.

Khan *et al.* (2002) reported a linear increase in total biomass, straw yield and grain yield of mungbean was observed with increasing rates of phosphorus fertilizer. Maximum increase in these parameters was found with phosphorus application at 100 kg $P_2O_5$ $ha^{-1}$. The P concentration was higher at 100 kg $P_2O_5$ $ha^{-1}$, while uptake was higher at 75 kg $P_2O_5$ $ha^{-1}$.

Venkatesh *et al.* (2002) reported that in maize significant increase in uptake by grain up to 60 kg $P_2O_5$ $ha^{-1}$ was observed when applied with or without FYM and lime but its value was maximum at 60 kg $P_2O_5$ $ha^{-1}$ when applied with FYM and lime.

Mehta *et al.* (2005) found that the application of P up to 40 kg $P_2O_5$ $ha^{-1}$ significantly improved nitrogen and phosphorus uptake by seed and stover over 20 kg $P_2O_5$ $ha^{-1}$.

Jaetzold *et al.* (2006) stated that positive influence of phosphorus application on nitrogen uptake in plants is due to the role of phosphorus in cell division of shoot and expanded growth of meristematic tissues or foliage.

Kumar *et al.* (2006) reported an increase on N, P, K uptake in maize due to application of increasing doses of phosphorus fertilizer. Agronomic efficiency in maize was reported to decrease with increasing level of phosphorus doses.

Nekesa (2007) reported a decrease in phosphorus use efficiency with increasing rate of phosphorus.

Ranjit *et al.* (2007) reported that application of different levels of phosphorus influenced nitrogen, phosphorus, potassium and calcium uptake in groundnut significantly where 112.5 kg $P_2O_5$ $ha^{-1}$ recorded maximum uptake over 37.5 and 75 kg $P_2O_5$ $ha^{-1}$.

Islam *et al.* (2008) studied the effect of phosphorus on nutrient uptake of Japonica rice variety (Nipponbare) and Indica rice variety (IR-28) and it was observed that phosphorus content in the plant and grain significantly increased with phosphorus levels up to 800 kg $P_2O_5$ $ha^{-l}$, while P uptake also significantly increased with phosphorus levels though in some cases, variation occurred which may be due to the variation in dry matter production of the two varieties. However, P application at different levels did not show any effect on N and K content and uptake in plant as well as grain.

Sharma *et al.* (2008) stated that increase in nutrient supply in green gram due to phosphorus application is due to its positive effect on better root system.

Hussein (2009) reported that increasing rate of phosphorus application was found to decrease phosphorus use efficiency and phosphorus agronomic efficiency.

Nedunchezhiyan *et al.* (2010) found significantly higher N, P and K uptake by maize grain on application of 32.7 kg P $ha^{-1}$ over 26.2 kg P $ha^{-1}$ for three successive years.

Awomi *et al.* (2012) reported that N, P, K uptake in mungbean increased with increasing levels of P, where maximum uptake was recorded at 60 kg $P_2O_5$ $ha^{-1}$ which was significantly superior to the lower levels of 20, 40 kg $P_2O_5$ $ha^{-1}$ and control.

Rashid and Iqbal (2012) showed that P concentration increased with its application. The maximum P concentration in maize was observed at highest P level of 57 kg P $ha^{-1}$.

Singh and Singh (2012) reported that application of 75 kg $P_2O_5$ $ha^{-1}$ gave higher total nitrogen, phosphorus, potassium and sulphur uptake in pigeonpea, which was at par with 50 kg $P_2O_5$ $ha^{-1}$ and significantly superior over 25 kg $P_2O_5$ $ha^{-1}$ and control.

Darwesh *et al.* (2013) reported an increase in nutrient uptake (N, P, K) due to phosphorus application and attributed the result to the influence of phosphorus on enhanced root growth, hair length and surface area which increased the nutrient content of plant.

Prajapati *et al.* (2013) reported that that soil applied phosphorus and sulphur increased the nitrogen content in seed and stover of mungbean.

Sentimenla *et al.* (2013) reported an increase in N, P, K and B content in both seed as well as stover of soybean with the application of increasing rates of both phosphorus and boron. The highest agronomic efficiency of phosphorus was recorded with the lowest dose of P application.

Sepat and Rai (2013) reported that response of maize to P application of 90 kg $P_2O_5$ $ha^{-1}$ through SSP recorded highest N and P uptake over 45 kg $P_2O_5$ $ha^{-1}$ and control.

Kisinyo *et al.* (2014) reported that agronomic phosphorus use efficiency efficiency and phosphorus fertilizer recovery efficiencies decreased with increase in P fertilizer rates.

Nsanzabaganwa *et al.* (2014) reported that application of N up to 240 kg $ha^{-1}$ and P up to 26.4 kg $ha^{-1}$ consistently maintained higher levels of N in maize plants over the control at almost all the growth stages. P application at 39.6 kg $ha^{-1}$ reduced N content than that observed at 26.4 kg P $ha^{-1}$ at all the growth stages. The concentration of N and P either declined or remained unchanged due to P application beyond 26.4 kg $ha^{-1}$. Phosphorus application also caused an increase in N uptake, but not at the same magnitude as N application. It led to an increase in N uptake in maize by 22.7, 40.2, and 24.4% due to application of 13.2, 26.4, and 39.6 kg P $ha^{-1}$, respectively over control. It also resulted in an increase in P uptake by 20.6, 34.0, and 22.7%, respectively with 13.2, 26.4, and 39.6 kg P $ha^{-1}$ over control.

Kumar *et al.* (2015) reported positive effect of phosphorus application on N, P, K content and uptake in urd bean.

Snehlata (2015) reported that application of 50 kg $P_2O_5$ $ha^{-1}$ significantly enhanced N, P and K accumulation by grain and stover of maize over 40 kg $P_2O_5$ $ha^{-1}$ and 30 kg $P_2O_5$ $ha^{-1}$.

Bak *et al.* (2016) in a field study on maize observed that the form of phosphorus applied as fertilizer showed no significant effect on P contents in the maize organs, as well as on the total accumulation of this nutrient in the plant.

Kumar *et al.* (2017) reported that application of increasing levels of phosphorus (0, 30, 60 and 90 kg $P_2O_5$ $ha^{-1}$) resulted in a significant increase in N, P, K, Ca, Mg and S content of soybean seed where maximum values were observed at 90 kg $P_2O_5$ $ha^{-1}$.

Muhlbachova *et al.* (2017) reported a positive effect of P on the plant growth and B uptake by plants. High positive correlations between B content in plants and B uptake was also reported.

Saeed *et al.* (2017) reported higher P contents in plants under elevated P applications where maximum was recorded at 200 kg P $ha^{-1}$ which declined with the declining P application rates of 150 and 100 kg P $ha^{-1}$.

Etabo *et al.* (2018) reported that there was no significant effect on plant tissue nitrogen and phosphorus due to phosphorus applications on soils, though increased level of P application consistently increased plant tissue nitrogen and phosphorus in the plant studied. It was observed that application of phosphorous @ 75 kg $ha^{-1}$ gave highest plant-tissue nitrogen and phosphorus content in rice plant over application of 0, 25 and 50 kg P $ha^{-1}$.

Uygur and Sen (2018) reported that phosphorous fertilization affected grain P, N and Mn concentration in wheat positively, while it affected the concentration of Ca, Mg, Na, Fe, Cu and Zn negatively. On the other hand, effect of phosphorus was non-significant on K concentration in wheat grains.

Wafula *et al.* (2018) reported that phosphorus application significantly influenced the calcium content of finger millet grains. They reported that application of phosphorus probably enhanced exchange reactions in the soil by releasing hydrogen ions in the microbial biomass that probably resulted in more availability of Ca and hence increased its uptake.

Irfan *et al.* (2019) reported that interactive effect of phosphorus and boron on their concentration in maize was such that application of B level of 2 kg $ha^{-1}$ resulted in relatively higher P concentration in maize grains and straw at P level of 90 kg $ha^{-1}$ contrarily to 45 and 135 kg P $ha^{-1}$. The B concentration in maize grains and straw increased with corresponding addition of B at each P level but at variable rate, with the maximum response at higher P level.

### 2.3.3 Effect on soil properties

Rekhi *et al.* (2000) reported that application of higher dose of phosphorus with organic manures raised the available phosphorus from 3 mg $kg^{-1}$ soil to 11.5 mg $kg^{-1}$ soil.

Okalebo *et al.* (2002) observed that in highly weathered soils of the tropical and subtropical acid soils, the applied P fertilizers readily react with Al and Fe sesquioxides to form sparingly soluble P forms which normally results in very low soil available P for plant absorption.

Venkatesh *et al.* (2002) reported that available P and exchangeable Ca and Mg in post-harvest soil increased due to application of P, FYM and lime. Phosphorus @ 90 kg $P_2O_5$ $ha^{-1}$ resulted in reduction of exchangeable Al content of soils which may be due to the formation of relatively stable hydroxy Al-phosphate complexes and their polymerisation.

Weisz *et al.* (2003) reported an increase in P content in soil due to P application.

Fageria *et al.* (2010) attributed the increase of P concentration in plant tissue after liming to 'P spring effect' of lime, where amount of available phosphorus in soil increases because of reduced adsorption-precipitation reaction between Al and P at the root surface and root free space.

Iqbal *et al.* (2010) reported that P can reduce exchangeable acidity by precipitating the Al in solution.

Sharma *et al.* (2011) found that application of P at 0, 30 and 60 kg $ha^{-1}$ showed no significant change in the soil pH over its initial value. The available N and K were significantly higher at zero level of applied P compared to when P was applied at 30 and 60 kg $ha^{-1}$. This may be attributed to the reason that removal of N and K was lower at zero level of applied P. However, available P increased significantly with successive levels of applied P registering an increase of 45.7 % and 94.2 % with 30 and 60 kg $ha^{-1}$ of applied P over zero level of P. A slight increase in exchangeable Ca and K was found with increase in the dose of applied P.

Kisinyo *et al.* (2014) reported that application of P fertilizer increased soil available P. However, higher soil available P was observed in combined application of lime and P fertilizer than when either of them was applied alone.

Kisinyo (2016) reported that application of TSP reduced the soil pH because of the release of phosphoric acid during its dissolution. Phosphate fertilizer had significant effect on soil available P due to release of phosphate ions into the soil solution during its dissolution. However, soil available P was more when lime and P fertilizer were applied in combination than when either of them was applied alone. This was probably because lime reduced P sorption making both the soil native and applied P fertilizer available for plants uptake as well as enhancing root growth.

Opala (2017) reported that only at high rates of P application (100 kg $ha^{-1}$) with high lime rates of 10 or 20 t $ha^{-1}$ the available P exceeded the critical value of 10 mg $kg^{-1}$ which has been found to be adequate for maize production.

Goswami *et al.* (2019) observed a significant effect of phosphorus application on soil organic carbon, available N and K and electrical conductivity of soil and a non-significant effect on soil pH. A slight increase in soil organic carbon, available N and K and a slight decrease in electrical conductivity of soil with higher levels of P (118 kg $P_2O_5$ $ha^{-1}$) were observed.

## 2.4. EFFECT OF BORON ON PLANTS AND SOIL PROPERTIES

### 2.4.1 Effect on growth and yield

Singh *et al.* (2002) observed that higher level of B (1.0 and 2.0 kg $ha^{-1}$) alone showed advantage in yield but it reduced the yield in presence of lime. Treatment of 0.5 kg B $ha^{-1}$ + 250 kg lime $ha^{-1}$ stood second in respect of grain (2555 kg $ha^{-1}$) and stover (8835 kg $ha^{-1}$) yields, resulting in 44.8 and 50.3% higher grain and stover yields over the control respectively. Application of boron @ 1.0 kg B $ha^{-1}$ even in absence of lime was found good enough for the maximum yield of maize grain (2830 kg $ha^{-1}$).

Rahim *et al.* (2004) reported an increase in number of grains per row and grains per cob in maize due to boron application.

Adiloglu and Adiloglu (2006) found that dry matter yield of maize decreased with B application which may be due to the fact that B uptake of plants are more in Zn deficient soils. Therefore, B toxicity is exposed and the plant growth is adversely affected by this situation.

Ceyhan *et al.* (2007) reported that B application increased the plant height of chickpea by 4 and 5% at 3 kg B $ha^{-1}$ and 6 kg B $ha^{-1}$, respectively over control.

Ahmed *et al.* (2008) reported that the growth parameters of cotton increased from 0-5 mg $kg^{-1}$ B levels, but thereafter reduced sharply in an irrigated arid climatic condition.

Chowdhury *et al.* (2008) assessed the impact of boron on grain yield of diverse wheat genotypes under foothill region of West Bengal. The wheat cultivars irrespective of genotypic variations showed significant positive responses to B application. Among the different methods of boron application, soil application of borax @ 10 kg ha$^{-1}$ was found to be best for increasing growth and yield parameters, like number of effective tillers, length of panicle, grains/spike and total kernel weight.

Akhter and Mahmud (2009) reported that the yield of maize grain increased significantly due to added boron up to 2.0 kg B ha$^{-1}$ and yield components like plant height, ear height and straw yield were influenced significantly due to application of boron.

Debnath and Ghosh (2011) conducted a pot culture experiment on rice in Terai Zone soils of West Bengal. B was applied at 0, 0.5, 1.0 and 1.5 mg kg$^{-1}$ soil. The critical concentration of B in soils and plant was 0.32 and 12.5 mg kg$^{-1}$, respectively. It was found that B significantly increased the average shoot yield from 5.76 to 10.75 g pot$^{-1}$ up to 1.5 mg B kg$^{-1}$ soil below the critical value and 9.99 to 10.29 g pot$^{-1}$ up to 1 mg B kg$^{-1}$ soil above the critical value and thereafter the decrement in yield occurred. It was found that application of 1.5 mg B kg$^{-1}$ can be applied safely for rice in the soils of Terai Zone of West Bengal where the available B is below 0.32 mg kg$^{-1}$.

Somroo *et al.* (2011) reported that boron application in maize increased the number of green leaves which might be due to the availability of boron at later growth stages of maize.

Tahir *et al.* (2012) observed that, application of boron at the rate of 0.30 kg ha$^{-1}$ significantly increased plant height, leaf area, stem diameter, cob weight, number of grains per cob and grain yield. However, futrther increase in boron dose decreased the yields.Muhammad *et al.* (2015) reported that, application of graded boron to maize increase all the agronomic growth parameters of maize. The increase was achieved with the application of 8 kg boron (granubor).

Gazala *et al.* (2016) observed that the application of boron at different rates in different crops have shown a positive influence on yield and other agronomical attributes in different crops, thereby proving the vital role boron plays in improving yield of different crops.

Saleem *et al.* (2016) reported that height of plant, stem width /girth, green and dry leaves per plant, ear head length and grain yield of maize were significantly affected with the application of 3 kg B $ha^{-1}$.

Arunkumar and Srinivasa (2018) in a field experiment on sandy loam soil conducted in maize crop observed that application of 5 kg borax $ha^{-1}$ recorded significantly higher grain yield (89.86 q $ha^{-1}$), stover yield (160.78 q $ha^{-1}$) and yield attributing parameters over control and 200 kg gypsum $ha^{-1}$.

Borase *et al.* (2018) reported that application of the micronutrients boron, iron and zinc along with RDF gave higher growth parameters in *kharif* maize *viz.*, plant height, number of functional leaves and leaf area.

Rahman *et al.* (2018) in a three year experiment revealed that for hybrid maize the highest grain yield was obtained with 2.5 kg B $ha^{-1}$, which was marginally significant with control but statistically identical to rest of the boron levels. Considering the boron fertilty of soil, response of maize to boron and economic return, the optimum dose of boron was found to be 0.5 kg $ha^{-1}$ for the cultivation of hybrid maize for medium level boron fertile soil.

Rehim *et al.* (2018) in a field experiment of maize crop observed that grain yield was increased to 65% with combined fertilization of K and B @125 and 16 kg $ha^{-1}$, respectively, with reference to control. Maximum plant height, cob length and 1000-g weight was observed @ 150 kg K $ha^{-1}$ and 16 kg B $ha^{-1}$.

Chanchal *et al.* (2020) in a study on rice-wheat cropping sequence, where wheat was grown after rice in the same pot without fresh application of B, observed that application of RDF + 1.5 kg B $ha^{-1}$ gave maximum grain and straw yield in rice, whereas in wheat, maximum grain and straw yield was observed in RDF + 3 kg B $ha^{-1}$. A significant residual effect of B application in rice was noticed even after the harvest of wheat crop particularly at highest doses of B application.

### 2.4.2 Effect on nutrient composition and uptake

Inal and Tarakcioglu (2001) reported an increase in N concentration of plants when B was applied.

Adiloglu and Adiloglu (2006) narrated that N, P and K concentration in maize increased with increasing rates of B and Zn application. But these increases were not found significant statistically.

Ayden and Sevin (2006) reported that, boron and zinc significantly increases the concentrations of phosphorous and potassium in maize.

Byju *et al.* (2007) reported that fertilizer B recovery of sweet potato was generally higher at the smallest B rate and decreased with further increase in B rate, but the differences were rather small.

Adem *et al.* (2011) suggested that addition of 7.7 kg $ha^{-1}$ of boron increased levels of N Ca, Mg, P, K and Mn in shoot and leaves tissues of maize, but decrease Fe, Zn and Cu content.

Aref (2011) reported that the use of 3 and 6 kg $ha^{-1}$ B increased grain N uptake from 129.07 at zero B level to 150.78 and 148.56 kg $ha^{-1}$, respectively. Highest P uptake by the grain was seen at boron application of 3 kg $ha^{-1}$ which significantly increased P uptake by the grain from 24.15 to 29.13 kg $ha^{-1}$, showing an increase of 20.62% as compared with the no B level. The use of 3 and 6 kg $ha^{-1}$ B, significantly increased K uptake by the grain from 34.86 to 39.5 and 39.06 kg $ha^{-1}$, respectively (13.31 and 12.05% increase relative to the no B level).

Günes *et al.* (2011) reported that boron fertilizer application in corn increased both leaves and shoot tissue N, Ca, Mg, P, K, and Mn but decreased tissue Fe, Zn, and Cu content, respectively. The 2 years average leaf and shoot tissue B content in the control treatments was 5.59 and 3.63 mg $kg^{-1}$ dry weight, respectively. This increased to 20.61 for leaf and 13.43 mg B $kg^{-1}$ for shoot, when B fertilizer was applied at 7.7 kg B $ha^{-1}$.

Khurana and Arora (2012) reported that increase in B levels from 0.75 to 1.25 kg B $ha^{-1}$ recorded a decrease in agronomic efficiency 286.7 to 78.4 and 293.3 to 244 kg seed $kg^{-1}$ B applied through borax in lentil and soybean, respectively.

Chuan *et al.* (2013) reported that agronomic efficiency for a nutrient increased with yield response increasing, but the amount of increase became smaller as the yield response became larger. A lower yield response indicates higher soil indigenous nutrient supply or higher soil fertility, resulting in lower agronomic efficiency. In contrast, a larger yield response means lower soil nutrient supply and relatively higher agronomic efficiency.

Mantovani *et al.* (2013) stated that the mobility of boron within the phloem is low, as a result of which boron fertilization as a function of doses and forms of application is low.

Sahin (2014) reported that boron concentration in maize increased significantly in contrast to where boron fertilization was not applied. This rate of increase was nearly 3 times more. Also with boron fertilization, total nitrogen concentration in maize increased by 10%.

Trautmann *et al.* (2014) stated that susceptibility of boron to leaching in soil may be attributed to its high mobility in soil, high solubility in water and low reactivity with the soil.

Arunkumar and Srinivasa (2018) reported that higher nutrient content and uptake in maize was observed at 5 kg borax $ha^{-1}$ over control and 200 kg gypsum $ha^{-1}$ and was at par with, 2.5 kg borax $ha^{-1}$, 200 kg gypsum + 2.5 kg borax $ha^{-1}$ and 200 kg gypsum + 5 kg borax $ha^{-1}$.

Rehim *et al.* (2018) in a field experiment of maize crop observed that concentrations of K in leaf and grains were increased 253% and 322% with combined fertilization (150 kg $ha^{-1}$ of K and 8 kg $ha^{-1}$ of B). Fertilization of K and B also increased B concentration in leaf and grains by 179% (150 kg $ha^{-1}$ of K and 16 kg $ha^{-1}$ of B) and 370% (125 kg $ha^{-1}$ of K and 16 kg $ha^{-1}$ of B).

Shrestha *et al.* (2020) observed that application of B and Zn, either sole or in combination, generally increased the respective nutrient concentration in the biomass of wheat. The application of B fertilizer increased tissue B contents from 5 to 22 mg B $kg^{-1}$ in wheat.

### 2.4.3 Effect on soil properties

Saha and Haldar (1998) found that the application of B and lime on a boron deficient Aeric Haplaquept increased the content of available B in soil the extent being 2.85 and 4.29 times over no-B at lower and higher level of B application. The combined effect of lime and B application also showed an increase in the content of extractable B in soils, the extent of increase being 3.3 and 3.5 times over that in the control at lower level of applied B coupled with lower and higher level of lime applied, respectively.

Barman *et al.* (2014) reported that there was no effect of B application on the status of available N, P, K, Ca, Mg, S, Zn, Cu, Fe, and Mn in soil.

Sarkar *et al.* (2015) in a laboratory incubation study on Inceptisols and Alfisols, found that only <50 percent of applied B was recovered from the soils in available form. Such recovery was lower in Alfisols than that in Inceptisols due to adsorption of a greater amount of added B with Fe and Al oxides in the former soil group. Required dose of lime showed an increase in availability of native soil B, particularly in Inceptisols (26%), and a net decrease in recovery of added B (32.5 %) as compared to no lime control (41.6%). The results thus suggested that liming to acidic soils increases extractable B.

Patil *et al.* (2017) observed that soil application of borax showed non-significant response on the soil properties; however there was significant increase in available B content in soil. Significantly highest soil available B was recorded where borax was applied at 10 kg $ha^{-1}$ followed by 7.5 and 5 kg borax $ha^{-1}$.

Kumar *et al.* (2020) observed that there was no significant effect of different sources and doses of boron on soil pH, EC, OC and available NPK. The different forms of boron increased over its initial status with the application of different sources and doses of boron but results did not vary significantly. While among different doses applied, application of 1.5 kg B $ha^{-1}$ was observed to be at par with the application of 2.0 kg B $ha^{-1}$ in increasing the amount of boron in different available forms.

## 2.5. Tolerance to soil acidity in plants

Mugwira (1980) reported that uptake of nutrients such as Ca, P, Mg, K, Fe, Zn and Cu was reduced in sensitive maize cultivars to soil acidity than in tolerant ones.

Foy (1984) stated that inter- and intra-specific plant differences for tolerance to soil acidity/Al toxicity have been reported. Differences in yield and nutrient uptake have been related to root development (elongation and absorption), translocation, and shoot demand per unit of nutrient absorbed.

Mendes *et al.* (1985) conducted a field experiment to compare the acid tolerance of 48 commercially grown maize cultivars and reported that on an average, 'tolerant' cultivars were 33% taller than 'intolerant' cultivars in the absence of lime, produced more than double the yield, and had a 60% lower leaf Al content. Significantly, several of the least acid tolerant cultivars were among the best performers in the absence of acidity.

Clark and Mgema (1993) noted that Al generally reduced P, Ca, Mg, Fe, Zn, Mn and Cu uptake in sensitive maize cultivars than in tolerant ones. partly because they have higher efficiency of utilization of absorbed essential nutrients, particularly P.

Malama *et al.* (2000) reported that tolerance to soil acidity is a complex character involving not only tolerance to low pH but also Al toxicity, and in some cases Mn and Fe toxicity and P, Ca and Mg deficiencies. The difference between varieties or species in terms of Al tolerance seems to be positively correlated with differences in P translocation rates in the presence of Al.

Dewi Hayati *et al*. (2014) in a study to check the performance of maize varieties on acid soil tolerance reported that reduction of grain yields in acid soil varied greatly within genotypes and acid soil conditions, ranging from 2.8 to 71%. Check varieties produced high yield on limed soil, but produced low yield on acid soil. It showed higher yield reduction compared to average yield reduction of hybrids.

Adie and Krisnawati (2016) studied the performance of 12 soybean genotypes on three acid soil locations with a pH of 5.87, 5.04, and 4.73, respectively. They reported that among the genotypes, G4AB consistently produced highest yield at pH 5.04 as well as at pH 4.73. Hence, the genotype

G4AB was not only adaptive at low pH but also relatively productive. Soybean genotype adaptive to acid soil was characterized by its ability to maintain the plant height, and followed by a high number of nodules per plant and pod per plant.

Moroni *et al.* (2018) reported that a significant range of differential responses to the acidic soil was shown among the cereals where oat was more tolerant than wheat and barley. Among wheat, there was a wider range of responses (32 to 100%) than barley (27 to 60%).

# CHAPTER III

# MATERIALS AND METHODS

# MATERIALS AND METHODS

Two experiments were conducted in the greenhouse of the Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, Nagaland during the *kharif* season of 2016 and 2017 to carry out the investigation entitled, "Study on Acidity Tolerance of Maize and its Response to Phosphorus and Boron". The details of materials used and techniques adopted during the course of investigation are briefly described in this chapter.

## 3.1. Experimental site

The experimental site lies at $25^0$ 45' 15.95" N latitude and $93^0$ 51' 44.71" E longitude at an elevation of 310 meter above mean sea level.

## 3.2. Climatic condition

The experimental site lies in humid sub-tropical zone with an average rainfall from 2000-2500 mm annually spread over 6 months *i.e.,* April to September, while the remaining period from October to March remains dry. The mean temperature ranges from $21^0$C to $32^0$C during summer and rarely goes below $8^0$C in winter due to high atmospheric humidity.

## 3.3. Characteristics of the experimental soil

The soil used for experimentation was collected from two different locations i.e., (i) from Research Farm, Department of Agricultural Chemistry and Soil Science, SASRD (pH 4.6) and (ii) from farmer's field of Medziphema village (pH 5.2). The composite soil sample collected from 0-15 cm depth and mixed well was subjected to analysis for some important physicochemical properties. The results of analysis are presented in Table 3.1.

**Table 3.1: Physicochemical properties of two different experimental soils**

| SOIL PARAMETERS | VALUES | | | | METHODS |
|---|---|---|---|---|---|
| | Soil I | | Soil II | | |
| | 2016 | 2017 | 2016 | 2017 | |
| Soil pH | 4.6 | 4.6 | 5.2 | 5.2 | Jackson (1973) |
| Lime requirement (t $ha^{-1}$) | 8.6 | 8.6 | 6.6 | 6.6 | Shoemaker *et al.* (1961) |
| EC ($dSm^{-1}$) | 0.22 | 0.23 | 0.20 | 0.21 | Jackson (1973) |
| Base Saturation (%) | 23.90 | 24.32 | 23.78 | 24.06 | 1 *N* $NH_4OAc$ at pH 7.0 (Chapman, 1965) |
| Organic C (%) | 1.52 | 1.55 | 1.53 | 1.56 | Rapid titration method by Walkley and Black (Jackson, 1973) |
| Available N (kg $ha^{-1}$) | 237.29 | 242.20 | 240.94 | 242.05 | Alkaline permanganate method (Subbiah and Asija, 1956) |
| Available P (kg $ha^{-1}$) | 8.45 | 8.50 | 9.50 | 9.13 | Bray $P_1$ method (1945) |
| Available K (kg $ha^{-1}$) | 144.48 | 146.45 | 150.22 | 149.20 | Ammonium acetate method (Jackson, 1973) |
| Exchangeable Ca {cmol ($p^+$) $kg^{-1}$} | 2.88 | 2.85 | 3.04 | 2.99 | 1 *N* ammonium acetate extracts of soil by titration against EDTA (Black, 1965) |
| Available B (mg $kg^{-1}$) | 0.45 | 0.40 | 0.50 | 0.54 | Curcumin method (Dible *et al.*, 1954) |
| Total potential acidity {cmol ($p^+$) $kg^{-1}$} | 15.09 | 15.03 | 14.8 | 14.57 | $BaCl_2$- triethanolamine extract buffered at pH 8.0 to 8.2 (Baruah and Barthakur, 1997) |
| Exchangeable $Al^{3+}$ {cmol ($p^+$) $kg^{-1}$} | 1.63 | 1.70 | 1.41 | 1.44 | NaF solution (4%) in 1 *N* KCl extract titrated against 0.1*N* HCl (Baruah and Barthakur, 1997) |
| Exchangeable $H^+$ {cmol ($p^+$) $kg^{-1}$} | 0.90 | 0.93 | 0.64 | 0.53 | Exchangeable $H^+$ = Exchangeable acidity – Exchangeable $Al^{3+}$ |
| Mechanical analysis | | | | | International pipette method (Piper, 1966) |
| Sand (%) | 50.4 | 48.9 | 45.4 | 42.6 | |
| Silt (%) | 27.0 | 25.1 | 23.7 | 25.7 | |
| Clay (%) | 22.6 | 26 | 30.9 | 31.7 | |
| Textural class | Sandy clay loam | Sandy clay loam | Sandy clay loam | Sandy clay loam | |

### 3.4. Details of experiments

In order to study the effects of treatments, two pot experiments were carried out in greenhouse of the Department of Agricultural Chemistry and Soil Science during Kharif season of 2016 and 2017. The details of experiments are given below:

#### 3.4.1 Experiment-I: To study the acidity tolerance and lime requirement of maize varieties

| Treatments | |
|---|---|
| i) Soil pH levels | 2 [pH 4.6 ($pH_1$) and pH 5.2 ($pH_2$)] |
| ii) Lime levels | 4 [Control ($L_0$), 30 ($L_{30}$), 60 ($L_{60}$) and 100 ($L_{100}$) % of LR] |
| iii) Varieties | 3 [RCM-75 ($V_1$), RCM-76 ($V_2$) and RCM-1-1 ($V_3$)] |
| iv) Crop | Maize |
| v) Number of treatment combinations | 24 |
| vi) Number of replications | 3 |
| vii) Experimental design | CRD |
| viii) Total number of pots | 72 |

**Experimental procedure:**

Earthen pots of 30 cm diameter size were filled with 15 kg of soil. Two type of soils (pH 4.6 and 5.2) was used to develop the pH levels. Lime levels were developed by calcite ($CaCO_3$). Recommended dose of nitrogen, phosphorus and potassium (100 kg N, 60 kg $P_2O_5$ and 50 kg $K_2O$ $ha^{-1}$) were applied through urea, single superphosphate and murate of potash, respectively. Half dose of nitrogen, full dose of phosphorus and full dose of potassium was applied one day before sowing. Remaining half dose of nitrogen was applied 15 days after emergence of crop. Lime was applied 10 days before sowing. The soil was well mixed after applying calculated quantities of fertilizer and lime. Three seeds of maize in each pot were sown as per variety treatments on 28$^{th}$ May, 2016 and 25$^{th}$ May, 2017. After 10 days of germination, thinning was done and one healthy plant was allowed to grow. Weeding was done to check the weed growth.

### 3.4.2 Experiment-2: To find out the P and B requirement of maize under acidic soil environment

| Treatments | |
|---|---|
| i) Lime levels | 2 [Control ($L_0$) and 25 ($L_{25}$) % of LR] |
| ii) Phosphorus levels | 4 [Control ($P_0$), 30 ($P_{30}$), 60 ($P_{60}$) and 90 ($P_{90}$) kg $P_2O_5$ $ha^{-1}$] |
| iii) Boron levels | 3 [Control ($B_0$), 1 ($B_1$) and 2 ($B_2$) kg B $ha^{-1}$] |
| iv) Crop | Maize |
| v) Number of treatment combinations | 24 |
| vi) Variety | RCM-75 |
| vii) Number of replications | 3 |
| viii) Experimental design | CRD |
| ix) Total number of pots | 72 |

**Experimental procedure:**

Earthen pots of 30 cm diameter size were filled with 10 kg soil (soil II pH 5.2). Lime, phosphorus and boron levels were developed through calcite ($CaCO_3$), single superphosphate and borax, respectively. Recommended dose of nitrogen and potassium (100 kg N and 50 kg $K_2O$ $ha^{-1}$) were applied through urea and murate of potash, respectively. Calculated amount of lime was applied 10 days before sowing. Half dose of nitrogen and full dose of phosphorus, potassium and boron were applied one day before sowing. Remaining half dose of nitrogen was given as top dressing 15 DAS. The soil was mixed properly after fertilizer and lime application. Three seeds of maize in each pot were sown at optimum soil moisture to ensure the germination. Seeds were sown on 28$^{th}$ May, 2016 and 25$^{th}$ May, 2017. Thinning was done 10 days after germination and one plant in each pot was allowed to grow. Time to time weeds was removed from the pots. Standard agronomic practices were adopted during entire crop growing period.

### 3.4.3 Harvesting and Threshing

The crop was harvested during last week of September (29$^{th}$ of September in 2016 and 25$^{th}$ of September in 2017). The harvested plants from each pot were cleaned and sun dried and weight was recorded for yield data.

## 3.5. Observations

### 3.5.1 Plant height

The plant height was measured in centimeter (cm) from the ground level to the top of the plants at 30, 60 DAS and at harvest. The average height of the plant for each treatment was calculated.

### 3.5.2 Number of leaves per plant

The number of leaves per plant was recorded from each pot at 30, 60 DAS and at harvest. The average number of leaves per plant for each treatment was calculated.

### 3.5.3 Leaf area index

The leaf area index was recorded at 30, 60 DAS and at harvest. The leaf area index was calculated as the ratio of leaf area to the ground area available to the maize plant. The leaf area was calculated by using the equation given by Montgomery (1911) as,

$$LA = L \times W \times A$$

Where, LA, L, W and A is leaf area, leaf length, leaf maximum width and a constant, respectively. The value of the constant A is 0.75.

### 3.5.4 Cob length (cm)

The length of the cob of maize from each pot was measured in cm.

### 3.5.5 Cob girth (cm)

The girth of the cob from each maize plant was measured in cm.

### 3.5.6 Number of rows per cob

The rows of the cob from each maize plant were counted.

### 3.5.7 Number of grains per row

The grains from the rows of the cob from each maize plant were counted.

### 3.5.8 Number of grains per cob

The grains of the cob from each pot were counted.

### 3.5.9 Cob weight (g)

The cob of maize from each pot was weighed in gram.

### 3.5.10 Test weight (g)

Test weight is the weight of 1000 grains. 100 viable grains were counted from the threshed grains and their weight was recorded which was multiplied by a factor of 10 for each treatment.

### 3.5.11 Grain yield

After proper sun drying of the grains, the grain yield of each pot was taken on treatment basis and the yield per pot of each treatment was obtained as g pot-$^{1}$.

### 3.5.12 Stover yield

The plant harvested from each pot was sun dried for about a week and their weight was taken and stover yield was obtained by deducting grain yield from total weight of the plant.

### 3.6. Plant analysis

The grain and stover samples were oven dried at a temperature of 60ºC to 70ºC to attain a constant weight. The dried seed and stover samples were then powdered and stored in polythene bags for chemical analysis. The powdered seed and stover samples were analyzed for N, P, K, Ca and B content.

### 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 distill water to known 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 Boron

For extraction of boron, dry ashing of the ground sample in a muffle furnace was done at $550^0$C for 1 h and subsequent extraction with 0.36 N $H_2SO_4$ (Gaines and Mitchell, 1979). For boron estimation curcumin method as described by Dible *et al.*, 1954 was carried out, where 1 mL of sample aliquot and 4 mL of curcumin solution was evaporated to dryness at $55 \pm 5^0$C. The rosocyanin colour such developed was dissolved in 95% ethanol to make the 25 mL mark in a volumetric flask. Readings were taken at 540 nm in the spectrophotometer within 2 h.

### 3.6.3 Digestion of plant samples for other nutrients

Half a gram powdered sample was pre-digested with concentrated $HNO_3$ overnight. Further predigested 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 6*N* HCl and transferred to the 100 mL volumetric flask through Whatman No. 42 filter paper and finally the volume of extract was made to 100 mL with double distilled water and preserved for further analysis.

### 3.6.3.1 Phosphorus

Phosphorous in the digested sample was determined by vanado-molybdate yellow colour method (Jackson, 1973) by using spectrophotometer at 470 nm.

### 3.6.3.2 Potassium

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

### 3.6.3.3 Calcium

Calcium was determined in the di-acid digest of plant sample by versenate (EDTA) method (Prasad, 1998).

## 3.7. Nutrient uptake

The uptake values of nitrogen, phosphorus, potassium, calcium and boron by maize were calculated by using the nutrient content (%) in plant and corresponding yield. The uptake values of nutrients were calculated using the following relationship.

Nutrient uptake (mg $pot^{-1}$) = Nutrient content (%) × yield (g $pot^{-1}$) ×10

## 3.8. Soil analysis

Soil samples were collected from each pot after harvest of the crop. The soil samples were air dried in shade, ground using mortar and pestle and sieved through 2 mm sieve and stored in polythene bags with proper labeling for the analysis of various soil parameters using standard methods as mentioned below.

### 3.8.1 Soil pH

The soil pH was determined in 1:2.5 water suspensions and analyzed using Glass electrode pH meter (Jackson, 1973).

### 3.8.2 Electrical conductivity (EC)

The electrical conductivity (EC) was determined using Conductivity Bridge (Jackson, 1973).

### 3.8.3 Percent base saturation

Base saturation is the percentage of total CEC occupied by $Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$. The base saturation was worked out by using the formula given below.

$$\text{Base saturation (\%)} = [(Ca^{2+} + Mg^{2+} + K^+ + Na^+/CEC] \times 100$$

### 3.8.4 Organic carbon

Organic carbon content in soil was determined by rapid titration method outlined by Walkley and Black (1934) and expressed in g $kg^{-1}$ as described by Jackson (1973).

### 3.8.5 Available nitrogen

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

### 3.8.6 Available phosphorus

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

### 3.8.7 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 photometre (Jackson, 1973).

### 3.8.8 Exchangeable calcium

The exchangeable calcium in soil was determined by versenate method, where a known volume of soil extract was titrated with standard 0.01*N* versenate (EDTA, ethylene diamine tetra acetic acid disodium salt) solution using murexide (ammonium purpurate) indicator in the presence of NaOH solution (Black, 1965).

### 3.8.9 Available boron

The available boron in soil was determined by curcumin method as described by Dible *et al.* (1954). Boron forms a reddish brown complex withcurcumin, a phenol dye. After evaporation to dryness, the B-curcumin complex was determined in ethanol at a wavelength of 540 nm in spectrophotometer.

### 3.8.10 Total potential acidity

The total potential acidity of soil includes all the acidity components like extractable acidity, non-exchangeable acidity, weak acidic carboxylic and phenolic hydroxyl groups of soil organic matter and partially neutralised hydroxyl Al polymers that could be present even in soils of pH >7. The total potential acidity was determined by using $BaCl_2$- triethanolamine extract buffered at pH 8.0 to 8.2 as described by Baruah and Barthakur (1997).

### 3.8.11 Exchangeable $Al^{3+}$

The exchangeable $Al^{3+}$ was determined by adding 5 ml of NaF solution (4%) in 1*N* KCl extract. This solution was then titrated against 0.1*N* HCl solution until the pink colour disappeared (Baruah and Barthakur, 1997).

### 3.8.12 Exchangeable $H^+$

The exchangeable $H^+$ was estimated by the difference between exchangeable acidity and exchangeable $Al^{3+}$.

Exchangeable $H^+$ = Exchangeable acidity – Exchangeable $Al^{3+}$

### 3.9. Agronomic efficiency

Agronomic efficiency is calculated in units of yield increase per unit of nutrient applied. It more closely reflects the direct production impact of an applied fertilizer and relates directly to economic return. It is expressed in kg $kg^{-1}$ or g $g^{-1}$.

It is calculated using the formula as follows:

$$\text{Agronomic efficiency} = \frac{Y - Y_0}{F}$$

Where, Y = Yield in nutrient applied plot

$Y_0$ = Yield in control plot

F = Amount of nutrient applied

### 3.10. Nutrient use efficiency (NUE)

The nutrient use efficiency (NUE) is a term used to indicate the relative balance between the amount of fertilizer taken up and used by the crop *versus* the amount of fertilizer lost.

It is calculated using the formula as follows:

$$\text{NUE (\%)} = \frac{U - U_0}{F} \text{ x } 100$$

Where, U = Nutrient uptake in nutrient applied plot

$U_0$ = Nutrient uptake in control plot

F = Amount of nutrient applied

### 3.11. Analysis of data

The collected data was processed, classified, tabulated and systematically and statistically analysed by applying the techniques of analysis of variance and the significant of different source of variations was tested by '*F*' test (Gomez and Gomez, 1984).

# CHAPTER IV

# RESULTS AND DISCUSSION

# RESULTS AND DISCUSSION

The results pertaining to “Study on Acidity Tolerance of Maize and its Response to Phosphorus and Boron” carried out during 2016 and 2017 are presented in this chapter. The performance of the crop under various treatments is illustrated by the use of tables and graphs incorporated at appropriate places. The data recorded were analyzed and significant variations have been discussed.

## 4.1. EFFECT OF SOIL PH, LIME AND VARIETIES ON THE PERFORMANCE OF MAIZE AND SOIL PROPERTIES (EXPT-I)

### 4.1.1 Effect of soil pH, lime and varieties on the performance of maize

#### 4.1.1.1 Effect on plant height

It is evident from Table 4.1.a and Fig. 1 that there was an appreciable increase in plant height with the advancement of days and also a significant difference among the treatments. Irrespective of treatments the pooled plant height at 30, 60 DAS and at harvest varied from 39.70 to 49.36 cm, 153.47 to 188.48 cm and 187.43 to 228.66 cm, respectively. In the year 2016 as well as 2017, at all stages of crop growth, it can be observed that maximum plant height was recorded in $pH_2$ soil (pH 5.2), while minimum plant height was recorded in $pH_1$ soil (pH 4.6). Thus, reduced plant height was observed in the lower soil pH (pH 4.6) which may be due to high solubility of aluminium to levels that are toxic which restricts the growth of root systems and in turn plant growth (Matsumoto, 2000).

It can be observed from Table 4.1.a and Fig. 1 that lime had a significant positive effect on plant height at all growth stages. It is apparent that in the year 2016 as well as 2017, the maximum plant height at 30, 60 DAS

Table 4.1.a: Plant height of maize at different growth stages as affected by soil pH, lime and varieties

| Treatment | Plant height (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | At 30 DAS | | | At 60 DAS | | | At harvest | | |
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 44.95 | 43.67 | 44.31 | 166.02 | 172.30 | 169.16 | 209.04 | 216.36 | 212.70 |
| $pH_2$ | 47.40 | 48.90 | 48.15 | 181.26 | 187.71 | 184.49 | 213.09 | 221.68 | 217.39 |
| SEm± | 0.49 | 0.41 | 0.32 | 0.75 | 0.82 | 0.55 | 0.80 | 0.82 | 0.57 |
| CD (P=0.05) | 1.40 | 1.16 | 0.90 | 2.14 | 2.32 | 1.56 | 2.29 | 2.34 | 1.61 |
| Lime levels | | | | | | | | | |
| $L_0$ | 39.00 | 40.40 | 39.70 | 150.27 | 156.66 | 153.47 | 183.44 | 191.41 | 187.43 |
| $L_{30}$ | 46.47 | 47.41 | 46.94 | 175.99 | 181.91 | 178.95 | 213.58 | 220.54 | 217.06 |
| $L_{60}$ | 48.88 | 48.96 | 48.92 | 183.22 | 189.57 | 186.39 | 222.68 | 231.37 | 227.03 |
| $L_{100}$ | 50.35 | 48.37 | 49.36 | 185.09 | 191.87 | 188.48 | 224.56 | 232.76 | 228.66 |
| SEm± | 0.70 | 0.58 | 0.45 | 1.06 | 1.16 | 0.78 | 1.14 | 1.16 | 0.81 |
| CD (P=0.05) | 1.98 | 1.65 | 1.27 | 3.02 | 3.28 | 2.20 | 3.23 | 3.30 | 2.28 |
| Varieties | | | | | | | | | |
| $V_1$ | 43.84 | 43.84 | 43.84 | 168.58 | 175.97 | 172.27 | 205.06 | 214.13 | 209.60 |
| $V_2$ | 48.93 | 49.02 | 48.97 | 177.22 | 185.01 | 181.12 | 215.86 | 223.78 | 219.82 |
| $V_3$ | 45.76 | 46.00 | 45.88 | 175.13 | 179.03 | 177.08 | 212.27 | 219.15 | 215.71 |
| SEm± | 0.60 | 0.50 | 0.39 | 0.92 | 1.00 | 0.68 | 0.98 | 1.01 | 0.70 |
| CD (P=0.05) | 1.71 | 1.43 | 1.10 | 2.62 | 2.84 | 1.91 | 2.80 | 2.86 | 1.98 |

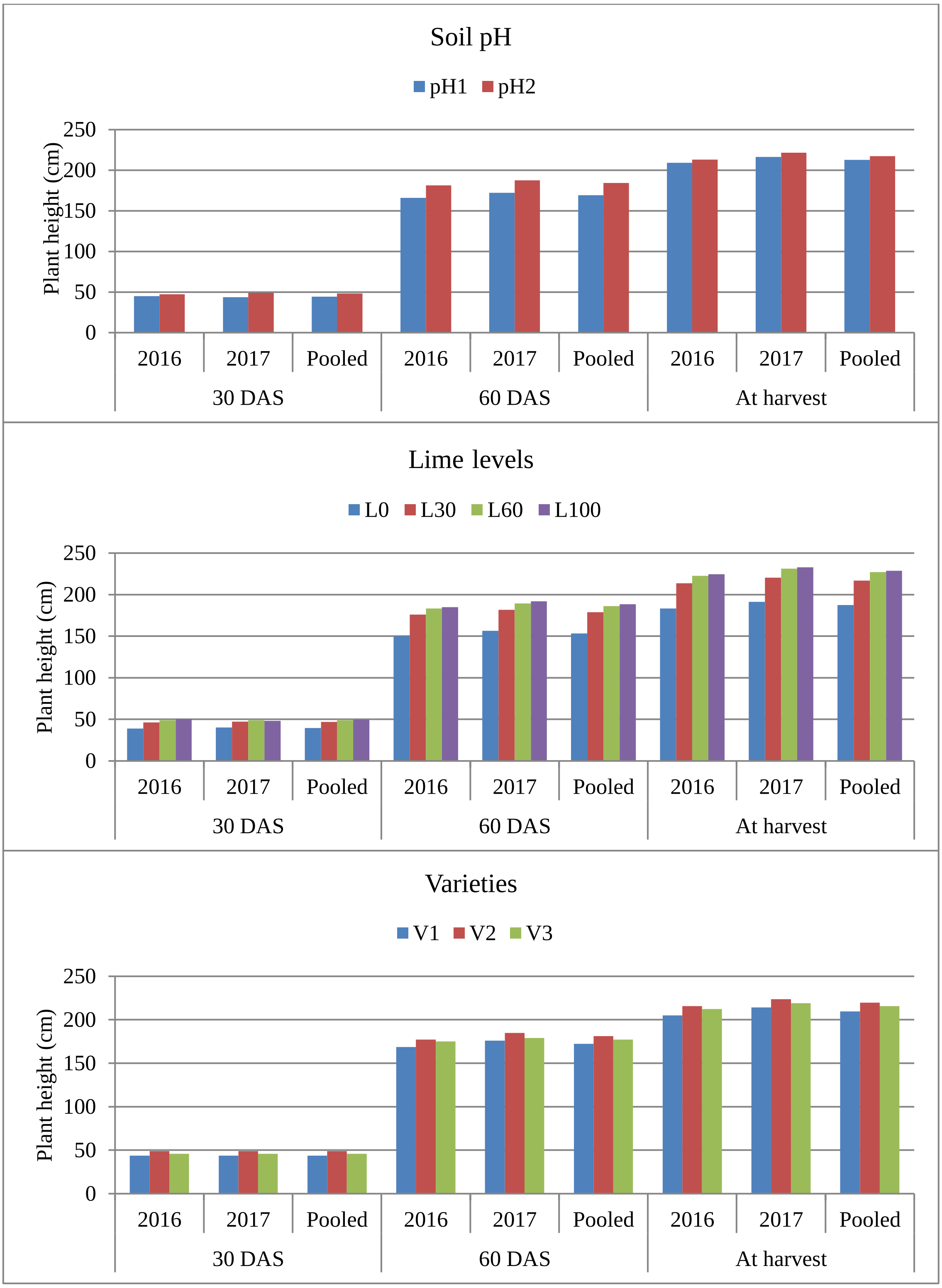


Fig 1: Effect of soil pH, lime and varieties on plant height of maize at 30, 60 DAS and at harvest

and at harvest was recorded in the treatment receiving full dose of lime i.e., at $L_{100}$. Treatment $L_{100}$, however, was found to be at par with $L_{60}$ in all growth stages. The minimum plant height at all growth stages *i.e.,* 30, 60 DAS and at harvest was recorded in control *i.e.,* $L_0$. At harvest, application of 100% lime enhanced the pooled plant height by 22% over control. The significant increase in maize growth at higher dose of lime may be attributed to decrease in aluminium toxicity which is found to inhibit root growth due to reduction in cell elongation and division (Foy, 1988). Liming decreases Al toxicity by precipitating soluble and exchangeable Al as positively charged monomeric $AlOH^{2+}$ and $Al(OH)_2^+$ species which may polymerize to form both large and small positively charged polynuclear complexes. The positively charged polynuclear complexes become sorbed to clay mineral and organic matter surfaces around the root zone (Stol *et al*., 1976), which improves the ability of plants to explore the soil volume for nutrients and water.

From the data depicted in Table 4.1.a and Fig. 1, the results revealed that in both years at all growth stages, maximum plant height was recorded in the variety $V_2$ (RCM-76), while minimum plant height was recorded in the variety $V_1$ (RCM-75). Variation in plant height of varieties was significant at all growth stages during both the years. At harvest, pooled plant height of RCM-76 was 4.8 and 1.9% higher than RCM-75 and RCM-1-1, respectively. On the basis of pooled plant height at harvest, superiority of varieties was recorded in the order of RCM-76 > RCM-1-1 > RCM-75. The reason for differences in plant height among the varieties may be due to the variation in the genetic makeup of these varieties.

**Interaction effect of pH and lime on plant height**

It can be observed from Table 4.1.b that in the year 2016 as well as 2017, the effect of pH and lime had a significant effect on plant height at 30 DAS which showed an increasing trend with increase in lime levels, irrespective of soil pH levels. Higher soil pH level along with higher lime

Table 4.1.b: Interaction effect between pH and lime on plant height at 30 DAS

| Soil pH levels | Plant height at 30 DAS (cm) | | | |
|---|---|---|---|---|
| | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2016 | | | |
| $pH_1$ | 37.70 | 45.59 | 46.01 | 50.49 |
| $pH_2$ | 40.30 | 47.34 | 51.74 | 50.21 |
| SEm± | 0.98 | | | |
| CD (P=0.05) | 2.80 | | | |
| | 2017 | | | |
| $pH_1$ | 36.70 | 43.83 | 46.86 | 47.29 |
| $pH_2$ | 44.10 | 50.99 | 51.06 | 49.46 |
| SEm± | 0.82 | | | |
| CD (P=0.05) | 2.33 | | | |
| | Pooled | | | |
| $pH_1$ | 37.20 | 44.71 | 46.43 | 48.89 |
| $pH_2$ | 42.20 | 49.17 | 51.40 | 49.83 |
| SEm± | 0.64 | | | |
| CD (P=0.05) | 1.80 | | | |

levels yielded in higher plant height, which may be attributed to the fact that at higher soil pH coupled with lime application, the soil reached the desirable neutral pH and also decreased the solubility of aluminium ion, which thus favoured the growth of maize. It could be observed that at pH 4.6 ($pH_1$), maximum plant height was recorded at 100% lime of LR ($L_{100}$), whereas at pH 5.2 ($pH_2$), maximum plant height was recorded at 60% lime of LR ($L_{60}$). This observation is in line with the findings of Muindi *et al.* (2015) who reported a similar trend in the plant height of maize due to liming grown in two types of soil - extremely acidic and strongly acidic soil. However, further examination of the pooled data elucidated that in $pH_2$ soil, plant height at $L_{60}$ was at par with $L_{100}$. Conversely, minimum plant height in both pH was observed in $L_0$. This may be due to the fact that at lower pH, there is higher concentration of aluminium ions in exchangeable forms, thus hampering crop growth.

**4.1.1.2 Effect on number of leaves**

From Table 4.2, it can be clearly seen that the effect of pH on number of leaves was non-significant in the year 2016 as well as 2017. However, it can be observed that there was a noticeable increase in the number of leaves with the advancement of days.

It is apparent from Table 4.2 that lime had a significant effect on the number of leaves. The number of leaves at 30 and 60 DAS was found to be highest at 100% lime of LR ($L_{100}$) during 2016 as well as 2017, and treatment $L_{100}$ was at par with treatment $L_{60}$. On the other hand, the number of leaves at harvest was highest at 60% lime of LR ($L_{60}$) in both the year 2016 and 2017. Pooled data further elucidated that treatment $L_{60}$ was at par with treatment $L_{100}$. The lowest number of leaves in all the growth stages was observed in control ($L_0$) during 2016 and 2017. Thus, the significant positive effect of liming on number of leaves may be due to liming, the soil pH increased towards neutral condition which increased the plant nutrient availability in the soil and resulted

Table 4.2: Number of leaves per plant of maize at different growth stages as affected by soil pH, lime and varieties

| Treatment | Number of leaves plant$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | At 30 DAS | | | At 60 DAS | | | At harvest | | |
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 6.92 | 7.11 | 7.01 | 9.94 | 10.17 | 10.06 | 13.00 | 13.33 | 13.17 |
| $pH_2$ | 7.00 | 7.25 | 7.13 | 10.11 | 10.39 | 10.25 | 13.22 | 13.53 | 13.38 |
| SEm± | 0.08 | 0.09 | 0.06 | 0.08 | 0.09 | 0.06 | 0.09 | 0.07 | 0.06 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Lime levels | | | | | | | | | |
| $L_0$ | 6.50 | 6.78 | 6.64 | 9.50 | 9.89 | 9.69 | 12.67 | 13.11 | 12.89 |
| $L_{30}$ | 6.56 | 7.11 | 6.83 | 9.83 | 10.11 | 9.97 | 13.17 | 13.39 | 13.28 |
| $L_{60}$ | 7.33 | 7.33 | 7.33 | 10.33 | 10.50 | 10.42 | 13.33 | 13.78 | 13.56 |
| $L_{100}$ | 7.44 | 7.50 | 7.47 | 10.44 | 10.61 | 10.53 | 13.28 | 13.44 | 13.36 |
| SEm± | 0.11 | 0.13 | 0.08 | 0.11 | 0.12 | 0.08 | 0.13 | 0.10 | 0.08 |
| CD (P=0.05) | 0.31 | 0.36 | 0.23 | 0.31 | 0.35 | 0.23 | 0.36 | 0.28 | 0.23 |
| Varieties | | | | | | | | | |
| $V_1$ | 6.67 | 6.92 | 6.79 | 9.63 | 9.92 | 9.77 | 12.83 | 13.25 | 13.04 |
| $V_2$ | 7.25 | 7.42 | 7.33 | 10.42 | 10.63 | 10.52 | 13.42 | 13.58 | 13.50 |
| $V_3$ | 6.96 | 7.21 | 7.08 | 10.04 | 10.29 | 10.17 | 13.08 | 13.46 | 13.27 |
| SEm± | 0.09 | 0.11 | 0.07 | 0.09 | 0.11 | 0.07 | 0.11 | 0.09 | 0.07 |
| CD (P=0.05) | 0.26 | 0.31 | 0.20 | 0.26 | 0.31 | 0.20 | 0.31 | 0.25 | 0.20 |

in absorption of more nutrients by plants and ultimately enhanced the plant growth.

From the data (Table 4.2) it can be inferred that significant differences existed among the varieties with regard to leaves per plant and the highest number of leaves was recorded in the variety RCM-76 ($V_2$), while the minimum number of leaves was recorded in treatment RCM-75 ($V_1$) during 2016 and 2017. It may also be inferred here that the reason for differences in number of leaves among the varieties may be due to the variation in their genetic makeup.

#### 4.1.1.3 Effect on leaf area index

The results on the leaf area index in different treatments have been presented in Table 4.3. The effect of pH on leaf area index was non-significant at all crop stages during both the years of experimentation.

It is apparent from Table 4.3 that lime did not have any significant effect on the leaf area index at 30 DAS. However, at 60 DAS and at harvest, it could be observed that lime had a significant positive effect on leaf area index. The maximum leaf area index at 60 DAS as well as at harvest was recorded at 60% lime of LR ($L_{60}$), while minimum leaf area index in both crop stages was recorded in control ($L_0$) during 2016 and 2017. At 60 DAS, treatment $L_{60}$ was at par with $L_{100}$ and at harvest, treatment $L_{60}$ was at par with $L_{30}$ and $L_{100}$. Higher value of leaf area index was recorded at 60 DAS growth stage and thereafter it declined at harvest due to drying of leaves. In general, the application of lime was observed to boost the growth of the crop due to increase in the soil pH. Similar results have also been reported by Kumar *et al.* (2014); Muindi *et al.* (2015) and Singh *et al.* (2016) in various crops, who all reported a significant increase in leaf area index with lime application.

From table 4.3, it is clear that varieties did not have any significant effect on the leaf area index of maize at any growth stage.

Table 4.3: Leaf area index of maize at different growth stages as affected by soil pH, lime and varieties

| Treatment | Leaf area index | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | At 30 DAS | | | At 60 DAS | | | At harvest | | |
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 0.61 | 0.64 | 0.63 | 1.30 | 1.37 | 1.33 | 1.17 | 1.21 | 1.19 |
| $pH_2$ | 0.63 | 0.69 | 0.66 | 1.32 | 1.36 | 1.34 | 1.18 | 1.21 | 1.19 |
| SEm± | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | 0.04 | NS | NS | NS | NS | NS | NS |
| Lime levels | | | | | | | | | |
| $L_0$ | 0.59 | 0.63 | 0.61 | 1.28 | 1.33 | 1.31 | 1.14 | 1.18 | 1.16 |
| $L_{30}$ | 0.60 | 0.66 | 0.63 | 1.29 | 1.35 | 1.32 | 1.17 | 1.21 | 1.19 |
| $L_{60}$ | 0.65 | 0.68 | 0.67 | 1.34 | 1.40 | 1.37 | 1.21 | 1.23 | 1.22 |
| $L_{100}$ | 0.64 | 0.70 | 0.67 | 1.32 | 1.38 | 1.35 | 1.18 | 1.20 | 1.19 |
| SEm± | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | 0.04 | 0.05 | 0.03 | 0.04 | 0.03 | 0.03 |
| Varieties | | | | | | | | | |
| $V_1$ | 0.60 | 0.63 | 0.61 | 1.31 | 1.36 | 1.33 | 1.18 | 1.22 | 1.20 |
| $V_2$ | 0.64 | 0.69 | 0.66 | 1.33 | 1.39 | 1.36 | 1.18 | 1.21 | 1.19 |
| $V_3$ | 0.62 | 0.68 | 0.65 | 1.29 | 1.35 | 1.32 | 1.17 | 1.20 | 1.18 |
| SEm± | 0.02 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

**4.1.1.4 Effect on cob length, cob girth and cob weight of maize**

It is apparent from Table 4.4 that pH was observed to have a significant effect on cob length, cob girth and cob weight of maize. The maximum cob length, cob girth and cob weight was recorded in pH 5.2 ($pH_2$) soil while the minimum was recorded in pH 4.6 ($pH_1$) soil during 2016 and 2017. Maize grows best if the soil is maintained at an optimal pH and crop performance is affected indirectly by low soil pH from aluminium and manganese toxicity resulting from overly acidic conditions of the soil (Mallarino, 2011 and Kai *et al.,* 2012).

The cob length, cob girth and cob weight of maize was observed to be significantly influenced by different lime levels. In the year 2016 as well as 2017, the maximum cob length (18.22 and 18.48 cm) was recorded at 60% lime of LR ($L_{60}$), whereas maximum cob girth (14.91 cm and 14.88 cm) and cob weight (92.39 g and 94.67 g) was recorded at 100% lime of LR ($L_{100}$). In case of cob length and cob weight, treatment $L_{100}$ was at par with $L_{60}$ and in case of cob girth, treatment $L_{100}$ was at par with $L_{30}$ and $L_{60}$ in both the years. On the other hand, minimum cob length, cob girth and cob weight was observed in control ($L_0$) during 2016 as well as 2017. Thus, application of lime produced significantly higher yield attributes which could be ascribed to higher photosynthesis and better translocation to the fruiting sink due to liming. Similar lines of findings where application of lime increased these yield attributes have been noted by Brajendra *et al.* (2006); Kumar *et al.* (2012) and Kumar (2015).

From the data presented in Table 4.4, it could be inferred that the maximum cob length, cob girth and cob weight of maize was recorded in variety RCM-76 ($V_2$) in both the years. Minimum cob length and cob weight was recorded in RCM-1-1 ($V_3$) and minimum cob girth was recorded in RCM-75 ($V_1$) during 2016 and 2017. A critical examination of data shows that pooled cob weight of $V_2$ variety (RCM-76) was 1.02 and 7.2% higher than $V_1$

Table 4.4: Cob length, cob girth and cob weight of maize as affected by soil pH, lime and varieties

| Treatment | Cob length (cm) | | | Cob girth (cm) | | | Cob weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 17.69 | 18.04 | 17.86 | 14.56 | 14.53 | 14.54 | 81.86 | 83.03 | 82.44 |
| $pH_2$ | 18.14 | 18.45 | 18.29 | 14.93 | 14.85 | 14.89 | 89.33 | 91.01 | 90.17 |
| SEm± | 0.05 | 0.05 | 0.04 | 0.08 | 0.06 | 0.05 | 0.61 | 0.72 | 0.47 |
| CD (P=0.05) | 0.15 | 0.14 | 0.10 | 0.21 | 0.16 | 0.13 | 1.73 | 2.04 | 1.32 |
| Lime levels | | | | | | | | | |
| $L_0$ | 17.35 | 17.78 | 17.57 | 14.33 | 14.29 | 14.31 | 71.61 | 72.75 | 72.18 |
| $L_{30}$ | 17.90 | 18.27 | 18.08 | 14.86 | 14.78 | 14.82 | 86.48 | 88.40 | 87.44 |
| $L_{60}$ | 18.22 | 18.48 | 18.35 | 14.89 | 14.80 | 14.85 | 91.90 | 92.25 | 92.07 |
| $L_{100}$ | 18.17 | 18.45 | 18.31 | 14.91 | 14.88 | 14.90 | 92.39 | 94.67 | 93.53 |
| SEm± | 0.08 | 0.07 | 0.05 | 0.11 | 0.08 | 0.07 | 0.86 | 1.01 | 0.66 |
| CD (P=0.05) | 0.22 | 0.20 | 0.14 | 0.30 | 0.22 | 0.19 | 2.45 | 2.88 | 1.86 |
| Varieties | | | | | | | | | |
| $V_1$ | 17.91 | 18.26 | 18.09 | 14.57 | 14.54 | 14.55 | 86.71 | 88.70 | 87.70 |
| $V_2$ | 18.10 | 18.35 | 18.23 | 14.90 | 14.86 | 14.88 | 88.22 | 88.98 | 88.60 |
| $V_3$ | 17.72 | 18.12 | 17.92 | 14.77 | 14.68 | 14.72 | 81.86 | 83.38 | 82.62 |
| SEm± | 0.07 | 0.06 | 0.04 | 0.09 | 0.07 | 0.06 | 0.75 | 0.88 | 0.58 |
| CD (P=0.05) | 0.19 | 0.17 | 0.13 | 0.26 | 0.19 | 0.16 | 2.12 | 2.49 | 1.61 |

and $V_3$ varieties, respectively. Varietal characteristics might be the reason for the difference.

#### 4.1.1.5 Effect on number of grains per row, number of rows and grains per cob

From Table 4.5.a it is apparent that effect of pH on number of rows per cob was non-significant during both the years. However, an increase in number of rows per cob was observed in the higher pH of 5.2 ($pH_2$). The pH had a fairly significant influence on the number of grains per row and a greater significant influence on number of grains per cob. The maximum number of grains per row (23.29) and number of grains per cob (347.57) was recorded in pH 5.2 ($pH_2$) soil. The minimum number of grains per row (20.89) and number of grains per cob (305.32) was recorded in pH 4.6 ($pH_1$) soil. Soil reaction accounts for an essential portion of the environmental influence on growth and development of maize (Mallarino, 2011). The pH 4.6 being strongly acidic in reaction results in aluminium toxicity which may have ultimately affected the yield components.

It is apparent from Table 4.5.a that the maximum number of grains per row (22.75) was recorded with application of 60% lime of LR ($L_{60}$), while number of rows per cob (15.14) and number of grains per cob (355.89) was recorded with application of 100% lime of LR ($L_{100}$). The minimum number of grains per row, number of rows per cob and number of grains per cob was recorded in control ($L_0$) in both the years. Application of 60% lime of LR enhanced pooled number of grains per row to the extent of 8.0% over control, while application of 100% lime of LR enhanced number of rows per cob and grains per cob to the extent of 9.0 and 27.0%, respectively over control. A critical examination of data indicates that in case of pooled values of grains per row, 60% lime of LR was at par with 100% lime of LR and in case of pooled values of rows per cob 100% lime of LR was at par with 60% lime of LR. The positive significant effect of lime on these yield attributes can be ascribed to the higher supply of nutrients particularly NPK due to liming and their subsequent increase in uptake. These results are in accordance with those of Chatterjee *et al.* (2005) and Kumar (2015) who reported increase in yield attributes in various crops with application of lime.

The data (Table 4.5.a) indicated that varieties showed significant influence on number of grains per row, number of rows per cob and number of grains per cob. Among the varieties, the RCM-76 variety produced significantly higher grains per row, rows per cob and grains per cob in comparison to RCM-75 and RCM-1-1. The RCM-76 variety increased pooled grains per row by 2.0% and 5.3%, rows per cob by 1.5 and 4.2% and grains per cob by 4.1 and 10.3% over RCM-75 and RCM-1-1, respectively.

**Interaction effect of pH and lime on number of rows per cob**

**F**rom Table 4.5.b, it can be observed that number of rows per cob enhanced with increase in lime levels in both the pH levels. It was observed that in pH 4.6 soil, maximum number of rows was recorded at 100% lime ($pH_1L_{100}$) and in pH 5.2 soil, maximum number of rows was recorded with 60% lime of LR ($pH_2L_{60}$) during both the years. It can thus be observed that in both the pH, lime had a positive effect on number of rows per cob with the maximum at $L_{100}$ in case of $pH_1$ and at $L_{60}$ in case of $pH_2$ which however was at par with $L_{30}$ and $L_{60}$. This indicates that liming even up to 30% lime of LR in case of $pH_2$ was sufficient to obtain the beneficial effect.

**Interaction effect of pH and varieties on number of grains per row**

From the data presented in Table 4.5.c, it is apparent that effect of pH and varieties on number of grains per row was significant during 2016. It can be observed from the data that highest number of grains per row was in pH 5.2 with variety RCM-76 ($pH_2V_2$) and lowest number of grains per row was in pH 4.6 with variety RCM-1-1 ($pH_1V_3$). Further, it can also be observed that in both the pH, variety RCM-76 ($V_2$) gave the highest response, while RCM-1-1 gave

Table 4.5.a: Number of grains per row, number of rows per cob and number of grains per cob as affected by soil pH, lime and varieties

| Treatment | No of grains per row | | | No of rows per cob | | | No of grains per cob | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 20.86 | 20.92 | 20.89 | 14.56 | 14.89 | 14.72 | 301.44 | 309.19 | 305.32 |
| $pH_2$ | 23.25 | 23.33 | 23.29 | 14.69 | 14.83 | 14.76 | 341.92 | 353.22 | 347.57 |
| SEm± | 0.10 | 0.12 | 0.08 | 0.08 | 0.09 | 0.06 | 4.42 | 4.19 | 3.05 |
| CD (P=0.05) | 0.27 | 0.35 | 0.22 | NS | NS | NS | 12.57 | 11.92 | 8.55 |
| Lime levels | | | | | | | | | |
| $L_0$ | 21.00 | 21.11 | 21.06 | 13.83 | 13.94 | 13.89 | 276.39 | 284.00 | 280.19 |
| $L_{30}$ | 22.17 | 21.94 | 22.06 | 14.83 | 14.89 | 14.86 | 321.22 | 334.28 | 327.75 |
| $L_{60}$ | 22.67 | 22.83 | 22.75 | 14.89 | 15.28 | 15.08 | 338.33 | 345.56 | 341.94 |
| $L_{100}$ | 22.39 | 22.61 | 22.50 | 14.94 | 15.33 | 15.14 | 350.78 | 361.00 | 355.89 |
| SEm± | 0.14 | 0.18 | 0.11 | 0.12 | 0.13 | 0.09 | 6.25 | 5.93 | 4.31 |
| CD (P=0.05) | 0.39 | 0.50 | 0.31 | 0.34 | 0.36 | 0.24 | 17.78 | 16.86 | 12.10 |
| Varieties | | | | | | | | | |
| $V_1$ | 22.25 | 22.08 | 22.17 | 14.71 | 14.88 | 14.79 | 323.50 | 332.50 | 328.00 |
| $V_2$ | 22.46 | 22.79 | 22.63 | 14.88 | 15.17 | 15.02 | 337.04 | 346.33 | 341.69 |
| $V_3$ | 21.46 | 21.50 | 21.48 | 14.29 | 14.54 | 14.42 | 304.50 | 314.79 | 309.65 |
| SEm± | 0.12 | 0.15 | 0.10 | 0.10 | 0.11 | 0.08 | 5.42 | 5.14 | 3.73 |
| CD (P=0.05) | 0.34 | 0.43 | 0.27 | 0.29 | 0.31 | 0.21 | 15.40 | 14.60 | 10.48 |

Table 4.5.b: Interaction effect between pH and lime on number of rows per cob

| Soil pH levels | Number of rows per cob | | | |
|---|---|---|---|---|
| | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2016 | | | |
| $pH_1$ | 13.67 | 14.78 | 14.56 | 15.22 |
| $pH_2$ | 14.00 | 14.89 | 15.22 | 14.67 |
| SEm± | 0.17 | | | |
| CD (P=0.05) | 0.47 | | | |
| | 2017 | | | |
| $pH_1$ | 13.67 | 14.78 | 15.44 | 15.67 |
| $pH_2$ | 14.22 | 15.00 | 15.11 | 15.00 |
| SEm± | 0.18 | | | |
| CD (P=0.05) | 0.51 | | | |
| | Pooled | | | |
| $pH_1$ | 13.67 | 14.78 | 15.00 | 15.44 |
| $pH_2$ | 14.11 | 14.94 | 15.17 | 14.83 |
| SEm± | 0.12 | | | |
| CD (P=0.05) | 0.34 | | | |

Table 4.5.c: Interaction effect between pH and varieties on number of grains per row

| Soil pH levels | Number of grains per row | | |
|---|---|---|---|
| | Varieties | | |
| | $V_1$ | $V_2$ | $V_3$ |
| | 2016 | | |
| $pH_1$ | 21.25 | 21.42 | 19.92 |
| $pH_2$ | 23.25 | 23.50 | 23.00 |
| SEm± | 0.17 | | |
| CD (P=0.05) | 0.47 | | |
| | Pooled | | |
| $pH_1$ | 21.08 | 21.58 | 20.00 |
| $pH_2$ | 23.25 | 23.67 | 22.96 |
| SEm± | 0.14 | | |
| CD (P=0.05) | 0.38 | | |

the lowest response in terms of number of grains per row. Also, all the three varieties performed better in pH 5.2 than in pH 4.6.

**4.1.1.6 Effect on test weight, grain yield and stover yield of maize**

From Table 4.6 and Fig. 2 it is apparent that the effect of pH on test weight, grain yield as well as stover yield of maize was found to be significant in both the years 2016 and 2017. Irrespective of treatments and years, the test weight varied from 23.32 g to 24.88 g, grain yield of maize varied from 56.79 g $pot^{-1}$ to 73.10 g $pot^{-1}$ and stover yield from 108.85 g $pot^{-1}$ to 134.64 g $pot^{-1}$. Between the two soil pH, the highest test weight, grain yield and stover yield was observed in pH 5.2 ($pH_2$). From pooled data, it can be observed that grain and stover yield increased by 13.3% and 9.6%, respectively in pH 5.2 ($pH_2$) soil as compared to pH 4.6 ($pH_1$) soil. The reason for lower yields at soil pH 4.6 may be due to it being strongly acidic in reaction as compared to soil pH 5.2.

It can be observed from the Table 4.6 and Fig. 2 that test weight, grain yield as well as stover yield exhibited an increasing trend with increase in lime application. Lime application significantly increased the yield which is usually associated with significant reduction in exchangeable Al. Maximum test weight, grain yield and stover yield was observed at 100% lime of LR ($L_{100}$) during 2016 and 2017. A critical examination of data revealed that each increasing level of lime up to $L_{60}$ (60% lime of LR) enhanced the grain and stover yield significantly in comparison to preceding lower level of lime. However, beyond $L_{60}$ level, effect of lime application was at par. Hence, $L_{60}$ (60% lime of LR) proved to be the optimum dose of lime for getting better yield of maize. The $L_{60}$ level of lime enhanced the grain yield by 28.5% and stover yield by 21.3% over control. The lowest values for all the three parameters were recorded in treatment $L_0$ in both the years. In case of test weight, treatments $L_{30}$, $L_{60}$ and $L_{100}$ were found to be

Table 4.6: Test weight, grain yield and stover yield of maize as affected by soil pH, lime and varieties

| Treatment | Test weight (g) | | | Grain yield (g $pot^{-1}$) | | | Stover yield (g $pot^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 24.02 | 24.14 | 24.08 | 64.09 | 63.76 | 63.92 | 119.03 | 121.56 | 120.29 |
| $pH_2$ | 24.61 | 24.78 | 24.69 | 71.76 | 73.13 | 72.45 | 130.39 | 133.40 | 131.89 |
| SEm± | 0.09 | 0.15 | 0.09 | 0.38 | 0.38 | 0.27 | 1.14 | 1.12 | 0.80 |
| CD (P=0.05) | 0.27 | 0.43 | 0.25 | 1.09 | 1.08 | 0.76 | 3.24 | 3.17 | 2.24 |
| Lime levels | | | | | | | | | |
| $L_0$ | 23.23 | 23.42 | 23.32 | 56.51 | 57.07 | 56.79 | 107.31 | 110.39 | 108.85 |
| $L_{30}$ | 24.43 | 24.69 | 24.56 | 70.10 | 69.58 | 69.84 | 127.51 | 130.14 | 128.83 |
| $L_{60}$ | 24.76 | 24.80 | 24.78 | 72.73 | 73.30 | 73.01 | 130.93 | 133.19 | 132.06 |
| $L_{100}$ | 24.85 | 24.91 | 24.88 | 72.37 | 73.82 | 73.10 | 133.09 | 136.19 | 134.64 |
| SEm± | 0.13 | 0.21 | 0.13 | 0.54 | 0.54 | 0.38 | 1.61 | 1.58 | 1.13 |
| CD (P=0.05) | 0.38 | 0.61 | 0.35 | 1.55 | 1.53 | 1.07 | 4.59 | 4.49 | 3.17 |
| Varieties | | | | | | | | | |
| $V_1$ | 24.39 | 24.41 | 24.40 | 68.46 | 69.10 | 68.78 | 125.51 | 128.31 | 126.91 |
| $V_2$ | 24.43 | 24.63 | 24.53 | 70.72 | 70.93 | 70.82 | 127.53 | 130.89 | 129.21 |
| $V_3$ | 24.14 | 24.33 | 24.23 | 64.61 | 65.29 | 64.95 | 121.10 | 123.24 | 122.17 |
| SEm± | 0.12 | 0.19 | 0.11 | 0.47 | 0.46 | 0.33 | 1.40 | 1.37 | 0.98 |
| CD (P=0.05) | NS | NS | NS | 1.34 | 1.32 | 0.93 | 3.97 | 3.89 | 2.74 |

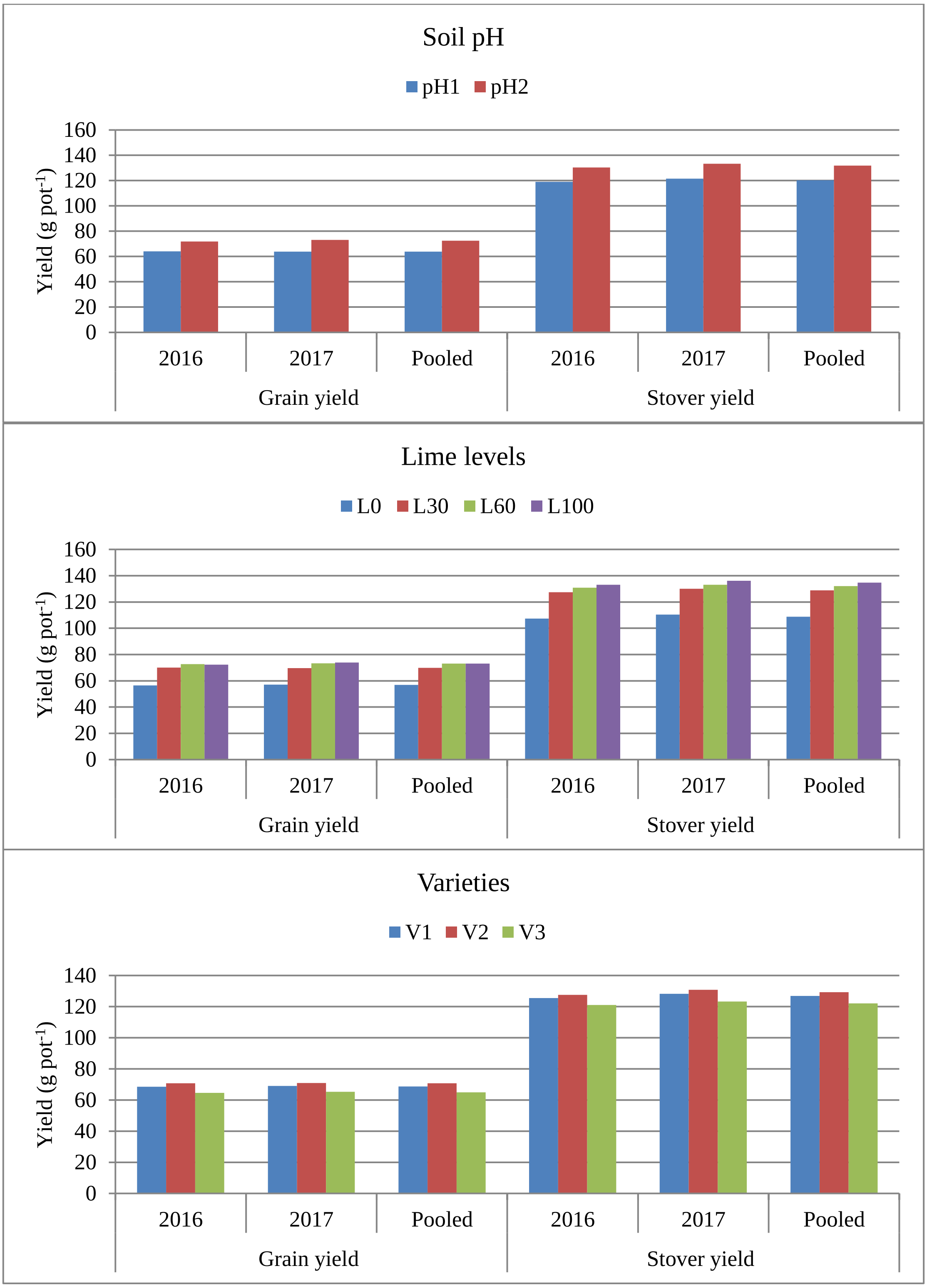


Fig 2: Effect of soil pH, lime and varieties on grain yield and stover yield of maize

at par with each other. The lowest yield consistently recorded in control treatment ($L_0$) which may be due to soil acidity in the control pot, which consequently resulted in aluminium toxicity and deficiency of the exchangeable bases or cations which are unavailable in acid soils (Voor, 2012). Liming is an important practice to achieve optimal yields of crops in acid soils. Application of lime at a suitable rate in acid soils brings about several chemical and biological changes in the soils, which is beneficial for improving the yield of crops (Fageria and Baligar, 2008). These results are in congruence with those of Chatterjee *et al.* (2005); Dixit (2006) and Kumar *et al.* (2012).

The effect of variety on test weight was found to be non- significant, while significant response was observed on grain and stover yield. As seen in Table 4.6 and Fig. 2, variety RCM-76 ($V_2$) gave the highest grain yield as well as stover yield and RCM-1-1 ($V_3$) gave the lowest grain yield as well as stover yield. It was observed that variety $V_2$ (RCM-76) gave 3.0% and 9.0% higher grain yield over $V_1$ and $V_3$, respectively. It was also observed that $V_1$ variety (RCM-75) produced 5.9% higher yield over $V_3$ variety (RCM-1-1). On the basis of pooled grain yield, order of superiority of varieties may be arranged as RCM-76 > RCM-75 > RCM-1-1.

#### 4.1.1.7 Nitrogen content in grain and stover

As can be seen from Table 4.7, effect of pH on nitrogen content in grain as well as stover was in both the years non-significant.

It can be observed from Table 4.7 that effect of lime on nitrogen content in both grain and stover was significant during the two years of experimentation. The highest nitrogen content in both grain and stover during 2016 and 2017 was recorded in the treatment $L_{100}$ and lowest was recorded in $L_0$. Pooled data reflected an increase in nitrogen content by 27.4% and 23.0%, respectively in grain and stover in $L_{100}$ over $L_0$. The substantial improvement in

Table 4.7: Nitrogen content in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | N content in grain (%) | | | N content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 1.17 | 1.20 | 1.19 | 0.66 | 0.69 | 0.67 |
| $pH_2$ | 1.20 | 1.22 | 1.21 | 0.67 | 0.70 | 0.69 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| Lime levels | | | | | | |
| $L_0$ | 1.02 | 1.02 | 1.02 | 0.60 | 0.63 | 0.61 |
| $L_{30}$ | 1.21 | 1.24 | 1.23 | 0.64 | 0.67 | 0.65 |
| $L_{60}$ | 1.24 | 1.26 | 1.25 | 0.69 | 0.72 | 0.71 |
| $L_{100}$ | 1.28 | 1.32 | 1.30 | 0.74 | 0.76 | 0.75 |
| SEm± | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 |
| Varieties | | | | | | |
| $V_1$ | 1.19 | 1.21 | 1.20 | 0.67 | 0.69 | 0.68 |
| $V_2$ | 1.21 | 1.23 | 1.22 | 0.68 | 0.71 | 0.69 |
| $V_3$ | 1.16 | 1.19 | 1.17 | 0.65 | 0.68 | 0.67 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

N concentration in plant with liming may be due to their increased solubility in the soil. Enhanced concentration of N as a result of addition of lime in acid soils have been reported by various workers such as Oya and Khondaker (1996); Bhat *et al.* (2007) and Ossom and Rhykerd (2008) in various crops.

From Table 4.7, it is evident that effect of varieties on nitrogen content in grain and stover was non-significant during 2016 as well as 2017.

#### 4.1.1.8 Phosphorus content in grain and stover

It could be inferred from Table 4.8.a that between $pH_1$ (pH 4.6) and $pH_2$ (pH 5.2), the highest phosphorus content in both grain and stover was realised in $pH_2$, *i.e.,* in pH 5.2 during 2016 and 2017. From pooled data, it was observed that phosphorus content in grain increased by 14.7% and in stover by 23.07% in $pH_2$ over $pH_1$. Similar findings have been reported by Marquez and Baucas (1990) where higher soil pH (soil pH 5.74) was found to enhance NPK absorption in crops. Low pH soil decreased the phosphorus content in grain and stover of maize. It might be because at low pH, phosphorus is fixed in the soil with aluminium (Adnan *et al.,* 2003) which must have resulted in a decrease in the availability of phosphorus and ultimately reduced phosphorus absorption by plant.

It is evident from Table 4.8.a that the effect of lime on phosphorus content in grain and stover was significant during both the years of experimentation. The maximum phosphorus content in grain was recorded in treatment $L_{100}$ during 2016 as well as 2017, while in stover it was recorded in $L_{100}$ during 2016 and in $L_{60}$ during 2017. From pooled data, P content in both grain and stover was found to increase by 33.3% each in treatment $L_{100}$ in case of grain and in $L_{60}$ in case of stover over $L_0$.The minimum phosphorus content in grain and stover was recorded in $L_0$. It can be observed that for both grain and stover, treatments $L_{60}$ and $L_{100}$ were at par with each other. The significant increase of P concentrations in plant tissues after lime application can be

Table 4.8.a: Phosphorus content in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | P content in grain (%) | | | P content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 0.32 | 0.36 | 0.34 | 0.14 | 0.13 | 0.13 |
| $pH_2$ | 0.37 | 0.41 | 0.39 | 0.17 | 0.15 | 0.16 |
| SEm± | 0.004 | 0.005 | 0.003 | 0.006 | 0.006 | 0.004 |
| CD (P=0.05) | 0.01 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 |
| Lime levels | | | | | | |
| $L_0$ | 0.29 | 0.31 | 0.30 | 0.13 | 0.12 | 0.12 |
| $L_{30}$ | 0.35 | 0.39 | 0.37 | 0.15 | 0.14 | 0.14 |
| $L_{60}$ | 0.37 | 0.41 | 0.39 | 0.16 | 0.16 | 0.16 |
| $L_{100}$ | 0.38 | 0.43 | 0.40 | 0.18 | 0.15 | 0.16 |
| SEm± | 0.006 | 0.008 | 0.005 | 0.008 | 0.008 | 0.006 |
| CD (P=0.05) | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.02 |
| Varieties | | | | | | |
| $V_1$ | 0.35 | 0.38 | 0.36 | 0.14 | 0.13 | 0.14 |
| $V_2$ | 0.36 | 0.41 | 0.39 | 0.16 | 0.15 | 0.16 |
| $V_3$ | 0.33 | 0.36 | 0.35 | 0.15 | 0.14 | 0.15 |
| SEm± | 0.005 | 0.007 | 0.004 | 0.007 | 0.007 | 0.005 |
| CD (P=0.05) | 0.02 | 0.02 | 0.01 | NS | NS | NS |

Table 4.8.b: Interaction effect between pH and lime on phosphorus content in grain

| Soil pH levels | P content in grain (%) | | | |
|---|---|---|---|---|
| | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2016 | | | |
| $pH_1$ | 0.26 | 0.32 | 0.35 | 0.37 |
| $pH_2$ | 0.32 | 0.38 | 0.39 | 0.38 |
| SEm± | 0.01 | | | |
| CD (P=0.05) | 0.03 | | | |
| | 2017 | | | |
| $pH_1$ | 0.27 | 0.35 | 0.38 | 0.42 |
| $pH_2$ | 0.34 | 0.42 | 0.44 | 0.44 |
| SEm± | 0.01 | | | |
| CD (P=0.05) | 0.03 | | | |
| | Pooled | | | |
| $pH_1$ | 0.26 | 0.34 | 0.37 | 0.40 |
| $pH_2$ | 0.33 | 0.40 | 0.42 | 0.41 |
| SEm± | 0.01 | | | |
| CD (P=0.05) | 0.02 | | | |

as a result of reduced adsorption-precipitation reaction between Al and P at the root surface and in the root free space also known as 'P spring effect' of lime (Fageria *et al.*, 2010). These results are in agreement with those of Jibrin *et al.* (2002); Kovacevic and Rastija (2010) and Muindi *et al.* (2015).

The results revealed that there was no significant difference among the varieties with respect to phosphorus content in stover. However, phosphorus content in grain was observed to show significant difference among the varieties where highest phosphorus content (0.39%) was recorded in the variety RCM-76 ($V_2$) followed by RCM-75 ($V_1$) (0.36%) and RCM-1-1 ($V_3$) (0.35%). However, RCM-75 ($V_1$) and RCM-1-1 ($V_3$) were found to be at par with each other.

**Interaction effect of pH and lime on phosphorus content in grain**

It is evident from Table 4.8.b that maximum phosphorus content in grain was observed in treatment combination $pH_2L_{60}$ and minimum was observed in $pH_1L_0$. In both the pH, it was observed that P content increased with increase in lime levels, where at $pH_1$, maximum phosphorus content was observed in lime level of $L_{100}$, while at $pH_2$, it was observed in lime level of $L_{60}$ during both the years. Examination of pooled data further revealed that at $pH_2$ soil, lime levels $L_{30}$, $L_{60}$ and $L_{100}$ were all at par with each other. This indicates that at pH 5.2, liming up to 30% lime of LR would be ideal for enhancement of phosphorus content in grain. Lime increased the P content in both the soil pH owing to the 'P spring effect' of lime (Fageria *et al.* 2010).

### 4.1.1.9 Potassium content in grain and stover

It is apparent from Table 4.9 that pH had a significant effect on potassium content where maximum potassium content in both grain and stover was recorded in pH 5.2 ($pH_2$) and minimum in pH 4.6 ($pH_1$) during 2016 as well as 2017. From pooled data it can be stated that potassium content in grain and stover increased by 14.9% and 3.5%, respectively in $pH_2$ over $pH_1$.

Table 4.9: Potassium content in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | K content in grain (%) | | | K content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 0.46 | 0.48 | 0.47 | 1.14 | 1.14 | 1.14 |
| $pH_2$ | 0.53 | 0.55 | 0.54 | 1.17 | 1.18 | 1.18 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.02 |
| Lime levels | | | | | | |
| $L_0$ | 0.45 | 0.47 | 0.46 | 1.07 | 1.06 | 1.06 |
| $L_{30}$ | 0.49 | 0.51 | 0.50 | 1.15 | 1.16 | 1.15 |
| $L_{60}$ | 0.51 | 0.52 | 0.52 | 1.20 | 1.19 | 1.19 |
| $L_{100}$ | 0.55 | 0.57 | 0.56 | 1.21 | 1.22 | 1.21 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.04 | 0.04 | 0.03 | 0.03 | 0.03 | 0.02 |
| Varieties | | | | | | |
| $V_1$ | 0.47 | 0.49 | 0.48 | 1.15 | 1.16 | 1.15 |
| $V_2$ | 0.53 | 0.55 | 0.54 | 1.17 | 1.17 | 1.17 |
| $V_3$ | 0.50 | 0.51 | 0.51 | 1.15 | 1.15 | 1.15 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | NS | NS | NS |

This is in close conformity with the findings of Otieno *et al.* (2018) who reported positive relationships between pH and N, P, K uptake.

The potassium content in grain and stover was found to increase with increase in lime levels. It is apparent from Table 4.9 that maximum potassium content in both grain (0.56%) and stover (1.21%) was recorded in treatment $L_{100}$ while minimum was recorded in $L_0$ during both the years of experimentation. Thus, from pooled data it can be stated that $L_{100}$ level of lime enhanced potassium content in grain and stover which increased by 21.7% and 14.2%, respectively over $L_0$. Lime application increased the soil pH of acid soils due to which solubility of potassium bearing minerals might have increased which resulted in plants to absorb more potassium from the soil. This is in line with the findings of Ranjit *et al.* (2007) who reported that lime application at 100% lime of LR recorded higher total potassium uptake than other lime levels. Otieno *et al.* (2018) also reported an increase in potassium content in soybean on application of lime.

It can be observed from Table 4.9 that effect of varieties on potassium content was found to be significant only in grain which varied from 0.48 to 0.51%. Maximum potassium content in grain was reported in RCM-76 ($V_2$) variety which was significantly higher in comparison to other tested varieties which was followed by RCM-1-1 ($V_3$) and RCM-75 ($V_1$).

#### 4.1.1.10 Calcium content in grain and stover

The results on calcium content in grain and stover in different treatments have been presented in Table 4.10. It is apparent from the data that maximum calcium content in both grain and stover was recorded in pH 5.2 ($pH_2$) during 2016 and 2017, whereas the minimum calcium content in grain and stover was recorded in pH 4.6 ($pH_1$) during both the years. From pooled data, a percent increase of 18.6% in grain and 15.2% in stover can be observed in $pH_2$ over $pH_1$. Treatment $pH_1$ being very strongly acidic in reaction may

Table 4.10: Calcium content in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | Ca content in grain (%) | | | Ca content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH Levels | | | | | | |
| $pH_1$ | 0.42 | 0.43 | 0.43 | 0.45 | 0.48 | 0.46 |
| $pH_2$ | 0.50 | 0.52 | 0.51 | 0.53 | 0.53 | 0.53 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.01 |
| Lime Levels | | | | | | |
| $L_0$ | 0.28 | 0.28 | 0.28 | 0.29 | 0.32 | 0.31 |
| $L_{30}$ | 0.50 | 0.53 | 0.51 | 0.53 | 0.54 | 0.54 |
| $L_{60}$ | 0.53 | 0.54 | 0.53 | 0.56 | 0.57 | 0.56 |
| $L_{100}$ | 0.54 | 0.56 | 0.55 | 0.58 | 0.59 | 0.58 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 |
| Varieties | | | | | | |
| $V_1$ | 0.46 | 0.48 | 0.47 | 0.49 | 0.50 | 0.49 |
| $V_2$ | 0.47 | 0.48 | 0.47 | 0.49 | 0.51 | 0.50 |
| $V_3$ | 0.46 | 0.47 | 0.46 | 0.49 | 0.51 | 0.50 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

have contained toxic levels of Al which may have affected the uptake of calcium through suppression of root growth. Furthermore, in low pH soils calcium solubility decreases which in turn leads to low calcium absorption by plant. Increase in concentration of $H^+$ ions soil in general causes a decrease in the rate of adsorption of cations, which may be due to competition between the similarly charged ions for binding and carrier sites (Alam *et al.*, 1999).

A perusal of the data in Table 4.10 reflects that lime had a significant positive effect on calcium content in grain and stover. The maximum calcium content in both grain and stover was found to be highest in treatment $L_{100}$ during 2016 as well as 2017, whereas the minimum calcium content in grain and stover was recorded in treatment $L_0$ during 2016 as well as 2017. However, treatment $L_{100}$ was at par with $L_{60}$ in case of calcium content in both grain and stover during both the years. Irrespective of treatments and years, pooled calcium content in grain and stover ranged from 0.28 to 0.55% and 0.31 to 0.58%, respectively. From pooled data, percent increase of 96.4% and 87.1% in grain and stover, respectively in $L_{100}$ over $L_0$ can be observed. Lime application enhanced the solubility of calcium concentration in soil and resulted in plants to absorb more calcium. These results are in compliance with the findings of Kovacevic and Rastija (2010); Barman *et al.* (2014) and Bhindu *et al.* (2018) who reported a significant increase in Ca concentration in plants with the application of lime.

The calcium content in grain and stover had non-significant difference among the varieties (Table 4.10). Comparatively higher amount of calcium was recorded in stover than grain in case of all varieties.

#### 4.1.1.11 Boron content in grain and stover

From Table 4.11, it is evident that boron content in grain with respect to pH was found to be non-significant. However, it was found to be significant

Table 4.11: Boron content in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | B content in grain (mg $kg^{-1}$) | | | B content in stover (mg $kg^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 9.49 | 9.51 | 9.50 | 3.23 | 3.27 | 3.25 |
| $pH_2$ | 9.51 | 9.54 | 9.53 | 3.27 | 3.31 | 3.29 |
| SEm± | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | 0.02 | 0.02 | 0.01 |
| Lime levels | | | | | | |
| $L_0$ | 9.38 | 9.40 | 9.39 | 3.14 | 3.17 | 3.15 |
| $L_{30}$ | 9.60 | 9.62 | 9.61 | 3.33 | 3.36 | 3.34 |
| $L_{60}$ | 9.57 | 9.61 | 9.59 | 3.31 | 3.35 | 3.33 |
| $L_{100}$ | 9.45 | 9.48 | 9.46 | 3.23 | 3.27 | 3.25 |
| SEm± | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.05 | 0.06 | 0.04 | 0.03 | 0.03 | 0.02 |
| Varieties | | | | | | |
| $V_1$ | 9.51 | 9.54 | 9.52 | 3.25 | 3.28 | 3.26 |
| $V_2$ | 9.50 | 9.53 | 9.52 | 3.26 | 3.29 | 3.28 |
| $V_3$ | 9.49 | 9.51 | 9.50 | 3.25 | 3.29 | 3.27 |
| SEm± | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

for boron content in stover, where highest value was recorded in pH 5.2 ($pH_2$) during 2016 as well as 2017. Thus, lowest B content in stover was recorded in pH 4.6 ($pH_1$) in both the years. Strongly acid soils (pH less than 5.0) are likely to be low in available boron because of boron sorption to surfaces of iron and aluminium oxides which thus reduces its concentration in plants.

It is apparent from Table 4.11 that maximum boron content in grain and stover was recorded in $L_{30}$ during 2016 as well as 2017. Pooled data reflected an increase in grain and boron content in grain and stover by 2.3% and 6.0%, respectively on application of 30% lime of LR ($L_{30}$). The minimum boron content in both grain and stover was recorded in $L_0$ during both the years. It was also observed that application of lime at 30% and 60% lime of LR were statistically at par in influencing the B concentration in plant. At 100% lime of LR significant reduction in plant B concentration could be observed in both grain and stover which may be because B absorption by plants decreases when both pH and Ca concentrations are increased in the soil (Alam *et al.,* 1999). The reduction in B concentration at higher lime level has also been reported by Barman *et al.* (2014).

The results on effect of varieties on boron content in grain and stover was non-significant (Table 4.11).

#### 4.1.1.12 Nitrogen uptake in grain and stover

As can be seen from Table 4.12 and Fig. 3, nitrogen uptake in both grain and stover showed significant difference between the two treatments. It is apparent from the table, maximum nitrogen uptake in both grain and stover was recorded in pH 5.2 ($pH_2$) and minimum was recorded in pH 4.6 ($pH_1$) in both the years. From pooled data it can be observed that $pH_2$ enhanced nitrogen uptake in grain by 14.8% and in stover by 12.5% over $pH_1$. Results on decrease in N uptake in plants with decrease in soil pH has been reported by Fageria and Zimmermann (1998); Otieno *et al.* (2018) and Pan *et al.* (2020).

Table 4.12: Nitrogen uptake in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | N uptake in grain (mg $pot^{-1}$) | | | N uptake in stover (mg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 759.34 | 775.39 | 767.37 | 786.83 | 836.92 | 811.88 |
| $pH_2$ | 865.76 | 896.05 | 880.91 | 884.66 | 942.69 | 913.68 |
| SEm± | 8.91 | 7.63 | 5.87 | 12.05 | 14.51 | 9.43 |
| CD (P=0.05) | 25.33 | 21.70 | 16.47 | 34.27 | 41.26 | 26.48 |
| Lime levels | | | | | | |
| $L_0$ | 575.83 | 581.49 | 578.66 | 641.40 | 693.09 | 667.24 |
| $L_{30}$ | 848.67 | 863.14 | 855.91 | 812.47 | 869.39 | 840.93 |
| $L_{60}$ | 900.79 | 921.25 | 911.02 | 909.09 | 965.93 | 937.51 |
| $L_{100}$ | 924.91 | 977.01 | 950.96 | 980.04 | 1030.82 | 1005.43 |
| SEm± | 12.60 | 10.79 | 8.30 | 17.04 | 20.52 | 13.34 |
| CD (P=0.05) | 35.82 | 30.69 | 23.29 | 48.46 | 58.35 | 37.44 |
| Varieties | | | | | | |
| $V_1$ | 821.72 | 845.94 | 833.83 | 843.38 | 896.92 | 870.15 |
| $V_2$ | 860.26 | 878.19 | 869.22 | 869.09 | 929.15 | 899.12 |
| $V_3$ | 755.67 | 783.04 | 769.36 | 794.78 | 843.35 | 819.07 |
| SEm± | 10.91 | 9.35 | 7.18 | 14.76 | 17.77 | 11.55 |
| CD (P=0.05) | 31.02 | 26.58 | 20.17 | 41.97 | 50.53 | 32.43 |

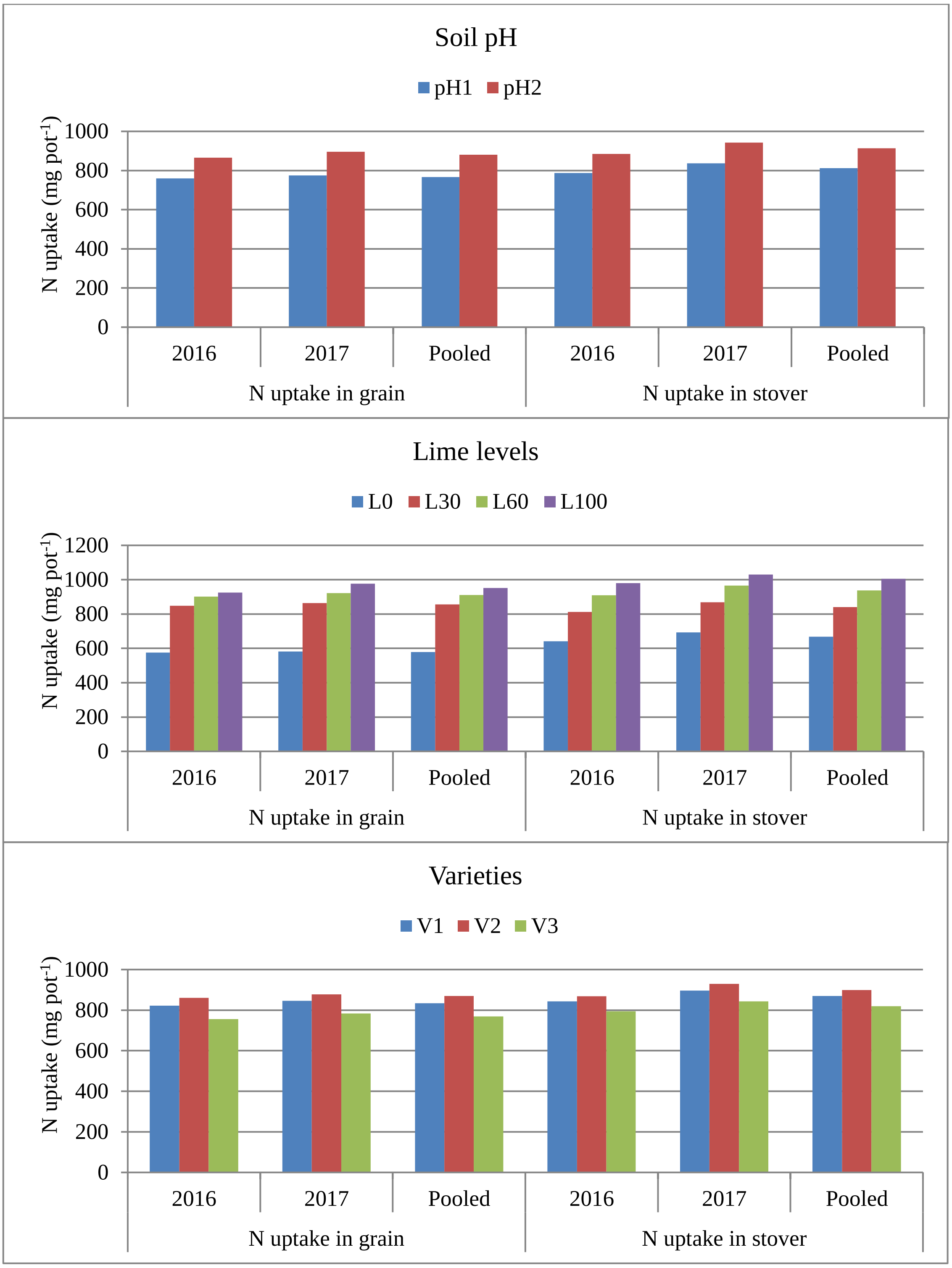


Fig 3: Effect of soil pH, lime and varieties on nitrogen uptake in grain and stover of maize

From Table 4.12 and Fig. 3, it can be observed that lime had a significant positive effect on nitrogen uptake in both grain and stover. From pooled data, it can be observed that during 2016 as well as 2017, maximum nitrogen uptake in both grain and stover was recorded at 100% lime of LR ($L_{100}$), and the minimum in control ($L_0$). From pooled data, it can be observed that liming at 100% lime of LR enhanced nitrogen uptake to the extent of 64.3% and 50.6% in grain and stover, respectively over control. Lime application increased the grain and stover yield as well as nitrogen content which ultimately enhanced the nitrogen uptake by crop. Increase in nitrogen uptake in plants due to liming has been reported by Chaterjee *et al.* (2005); Ranjit *et al.* (2007) and Lynrah and Nongmaithem (2017).

The results on effect of varieties on nitrogen uptake revealed that there was a significant difference among the treatments (Table 4.12 and Fig. 3). In both the years, maximum nitrogen uptake in both grain and stover was observed in variety RCM-76 ($V_2$), while minimum was recorded in RCM-1-1 ($V_3$). A critical examination of data shows that significantly higher nitrogen uptake was recorded in $V_2$ in comparison to $V_1$ and $V_3$ varieties. The nitrogen uptake in grain of $V_2$ variety was 4.2% and 13.0% higher than $V_1$ and $V_3$, respectively. Variation in nitrogen uptake might be due to variation in grain and stover yield of tested varieties.

#### 4.1.1.13 Phosphorus uptake in grain and stover

The results from Table 4.13.a and Fig. 4 revealed that there was a significant effect of pH levels on phosphorus uptake. During 2016 and 2017, the maximum phosphorus uptake in both grain and stover was recorded in pH 5.2 ($pH_2$). Thus, minimum P uptake in both grain and stover was recorded in pH 4.6 ($pH_1$). From pooled data, it can be observed that phosphorus uptake increased by 29.1% in grain and by 31.8% in stover in $pH_2$ compared to $pH_1$.

Table 4.13.a: Phosphorus uptake in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | P uptake in grain (mg pot$^{-1}$) | | | P uptake in stover (mg pot$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 210.22 | 232.15 | 221.18 | 162.63 | 160.48 | 161.55 |
| $pH_2$ | 267.61 | 303.50 | 285.55 | 221.45 | 204.67 | 213.06 |
| SEm± | 3.50 | 3.82 | 2.59 | 7.35 | 7.32 | 5.19 |
| CD (P=0.05) | 9.96 | 10.87 | 7.28 | 20.90 | 20.82 | 14.56 |
| Lime levels | | | | | | |
| $L_0$ | 166.02 | 177.06 | 171.54 | 134.82 | 135.21 | 135.02 |
| $L_{30}$ | 245.69 | 269.58 | 257.63 | 187.77 | 175.85 | 181.81 |
| $L_{60}$ | 271.37 | 305.04 | 288.21 | 204.49 | 216.20 | 210.35 |
| $L_{100}$ | 272.58 | 319.62 | 296.10 | 241.06 | 203.04 | 222.05 |
| SEm± | 4.95 | 5.41 | 3.67 | 10.40 | 10.35 | 7.34 |
| CD (P=0.05) | 14.09 | 15.38 | 10.29 | 29.56 | 29.44 | 20.59 |
| Varieties | | | | | | |
| $V_1$ | 240.87 | 266.55 | 253.71 | 180.89 | 169.91 | 175.40 |
| $V_2$ | 257.73 | 296.02 | 276.87 | 208.80 | 199.16 | 203.98 |
| $V_3$ | 218.14 | 240.90 | 229.52 | 186.41 | 178.66 | 182.53 |
| SEm± | 4.29 | 4.68 | 3.18 | 9.00 | 8.97 | 6.35 |
| CD (P=0.05) | 12.20 | 13.32 | 8.91 | NS | NS | NS |

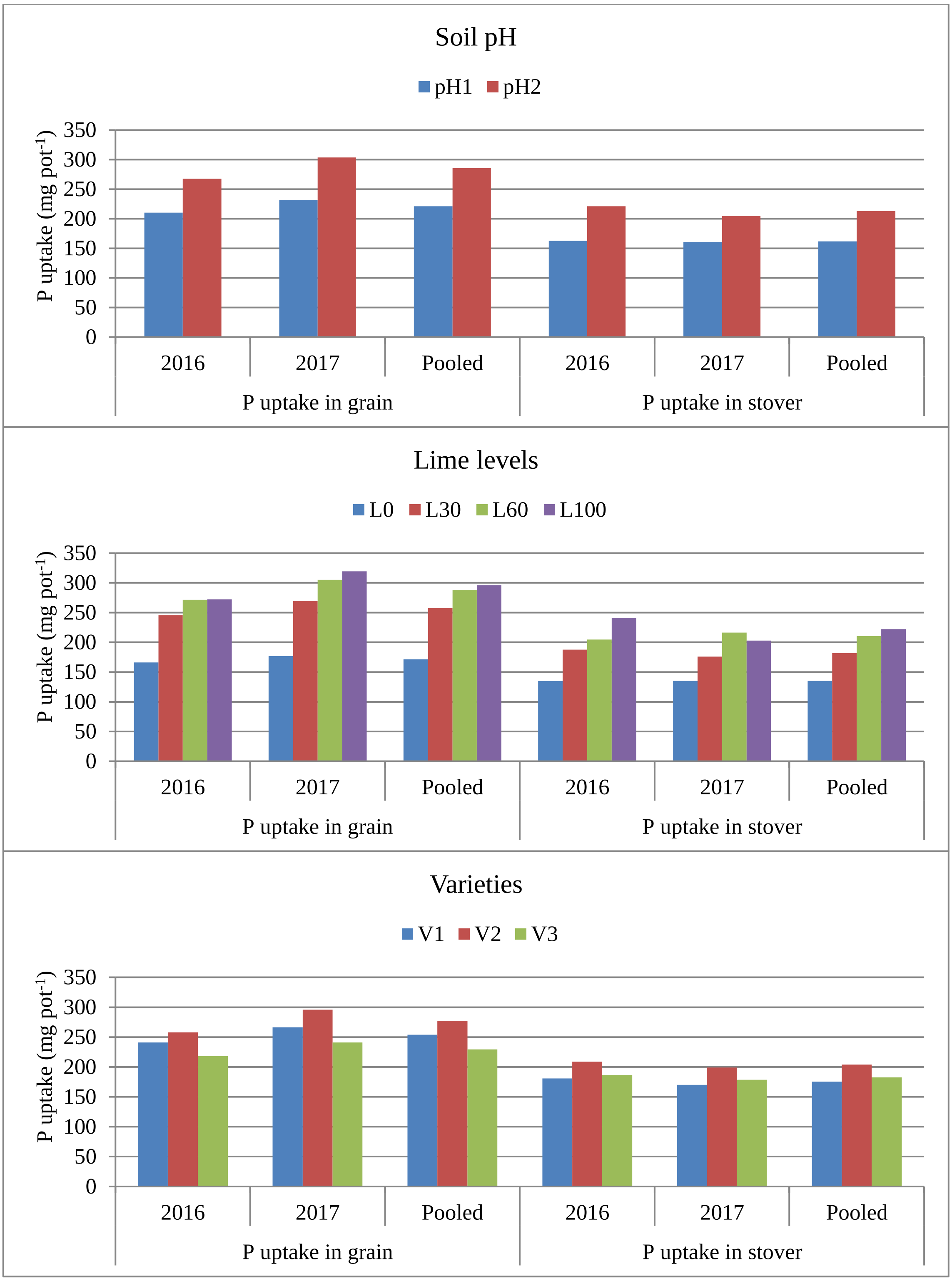


Fig 4: Effect of soil pH, lime and varieties on phosphorus uptake in grain and stover of maize

Table 4.13.b: Interaction effect between pH and lime on phosphorus uptake in grain

| Soil pH levels | P uptake in grain (mg $pot^{-1}$) | | | |
|---|---|---|---|---|
| | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2017 | | | |
| $pH_1$ | 144.50 | 230.61 | 258.29 | 295.18 |
| $pH_2$ | 209.61 | 308.55 | 351.79 | 344.06 |
| SEm± | 7.65 | | | |
| CD (P=0.05) | 21.75 | | | |

Similar findings have also been reported by Fageria and Zimmermann (1998) where higher pH increased the uptake of phosphorus in corn, wheat and common bean. At high pH, grain and stover yield and phosphorus content increased and ultimately phosphorus uptake was increased because uptake is product of yield and nutrient content.

The data (Table 4.13.a and Fig. 4) showed that during 2016 as well as 2017 maximum phosphorus uptake in grain was recorded at 100% lime of LR ($L_{100}$) which was however found to be at par with treatment $L_{60.}$ On the other hand, maximum phosphorus uptake in stover during 2016 was recorded in treatment $L_{100}$, while during 2017 it was recorded in treatment $L_{60}$ which was found to be at par with treatment $L_{100}$. Minimum phosphorus uptake in both grain and stover was recorded in control ($L_0$). From pooled data it can be observed that there was 72.6% and 64.5% increase in grain and stover, respectively in $L_{100}$ as compared to $L_0$. Liming may have increased plant P uptake by relatively decreasing Al than by increasing the availability of phosphorus in soil. Thus, this may have improved the root growth of the plant allowing for a greater volume of soil to be explored (Friesen *et al.*, 1980). Lime application enhanced yield and phosphorus content in grain and stover which resulted in increased phosphorus uptake. These results are in agreement with those of Kovacevic and Rastija (2010); Muindi *et al.* (2015) and Zhihao *et al.* (2019).

In case of effect of varieties on phosphorus uptake, it can be observed from Table 4.13.a and Fig. 4 that in both the years, maximum phosphorus uptake in grain was recorded in variety RCM-76 ($V_2$) followed by RCM-75 ($V_1$) and minimum was observed in RCM-1-1 ($V_3$). However, variety did not have any significant effect on phosphorus uptake in stover in both the years. It was also revealed that phosphorus uptake in grain of RCM-76 ($V_2$) variety was 9.1% and 20.6% higher as compared to $V_1$ and $V_2$ varieties, respectively.

**Interaction effect of pH and lime on phosphorus uptake in grain**

It is evident from Table 4.13.b that during 2017, maximum phosphorus uptake in grain at pH 4.6 ($pH_1$) was observed at 100% lime of LR ($pH_1L_{100}$), whereas at pH 5.2 ($pH_2$), maximum phosphorus uptake in grain was observed at 60% lime of LR ($pH_2L_{60}$). It could also be observed that $pH_2L_{60}$ was at par with $pH_2L_{100}$. The minimum phosphorus uptake in grain in both the soil pH was observed at $L_0$. Thus, it could be observed that irrespective of pH levels, lime enhanced phosphorus uptake in grain. Thus, soil pH and lime was observed to exhibit positive interaction which reduced aluminium toxicity in the soils and improved P uptake in acid soils. However $pH_2$ soil gave greater response in terms of P uptake in grain as compared to $pH_1$ soil.

**4.1.1.14 Potassium uptake in grain and stover**

The results on the potassium uptake in different treatments have been presented in Table 4.14 and Fig. 5. Effect of pH on potassium uptake in both grain and stover was found to be highly significant, where during 2016 and 2017, maximum potassium uptake in both grain and stover was recorded in pH 5.2 ($pH_2$) whereas minimum potassium uptake in both grain and stover was recorded in pH 4.6 ($pH_1$). An examination of pooled data reflects a 29.9% and 13.3% increase in potassium uptake by grain and stover, respectively in $pH_2$ over $pH_1$. Low uptake of K in pH 4.6 could have been due to the detrimental effect of low soil pH. Such low pH hinders normal root growth, development, and absorption of water and nutrients (Lin *et al.*, 2012). Positive relationship between soil pH and NPK uptake has also been reported by Fageria and Zimmermann (1998) and Otieno *et al.* (2018).

The data (Table 4.14 and fig. 5) showed that in 2016 as well as 2017, in both grain and stover, maximum uptake was recorded at 100% lime of LR ($L_{100}$) and minimum in control ($L_0$). From pooled data, it can be observed that there was an increase in potassium uptake in grain by 54.7% and in stover by

Table 4.14: Potassium uptake in grain and stover of maize as affected by soil pH, lime and varieties

| Treatments | K uptake in grain (mg $pot^{-1}$) | | | K uptake in stover (mg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 299.88 | 308.86 | 304.37 | 1357.53 | 1389.03 | 1373.28 |
| $pH_2$ | 384.95 | 406.13 | 395.54 | 1536.90 | 1576.86 | 1556.88 |
| SEm± | 7.23 | 7.35 | 5.16 | 16.73 | 16.57 | 11.77 |
| CD (P=0.05) | 20.56 | 20.91 | 14.48 | 47.58 | 47.11 | 33.05 |
| Lime levels | | | | | | |
| $L_0$ | 258.11 | 270.66 | 264.39 | 1145.05 | 1172.92 | 1158.99 |
| $L_{30}$ | 342.57 | 352.45 | 347.51 | 1471.07 | 1506.27 | 1488.67 |
| $L_{60}$ | 371.70 | 385.80 | 378.75 | 1566.81 | 1589.62 | 1578.21 |
| $L_{100}$ | 397.26 | 421.06 | 409.16 | 1605.91 | 1662.95 | 1634.43 |
| SEm± | 10.22 | 10.40 | 7.29 | 23.66 | 23.43 | 16.65 |
| CD (P=0.05) | 29.07 | 29.58 | 20.47 | 67.28 | 66.63 | 46.74 |
| Varieties | | | | | | |
| $V_1$ | 324.82 | 342.54 | 333.68 | 1451.47 | 1490.14 | 1470.81 |
| $V_2$ | 378.38 | 391.19 | 384.79 | 1493.02 | 1539.50 | 1516.26 |
| $V_3$ | 324.04 | 338.75 | 331.39 | 1397.14 | 1419.19 | 1408.17 |
| SEm± | 8.85 | 9.01 | 6.32 | 20.49 | 20.29 | 14.42 |
| CD (P=0.05) | 25.18 | 25.61 | 17.73 | 58.27 | 57.70 | 40.48 |

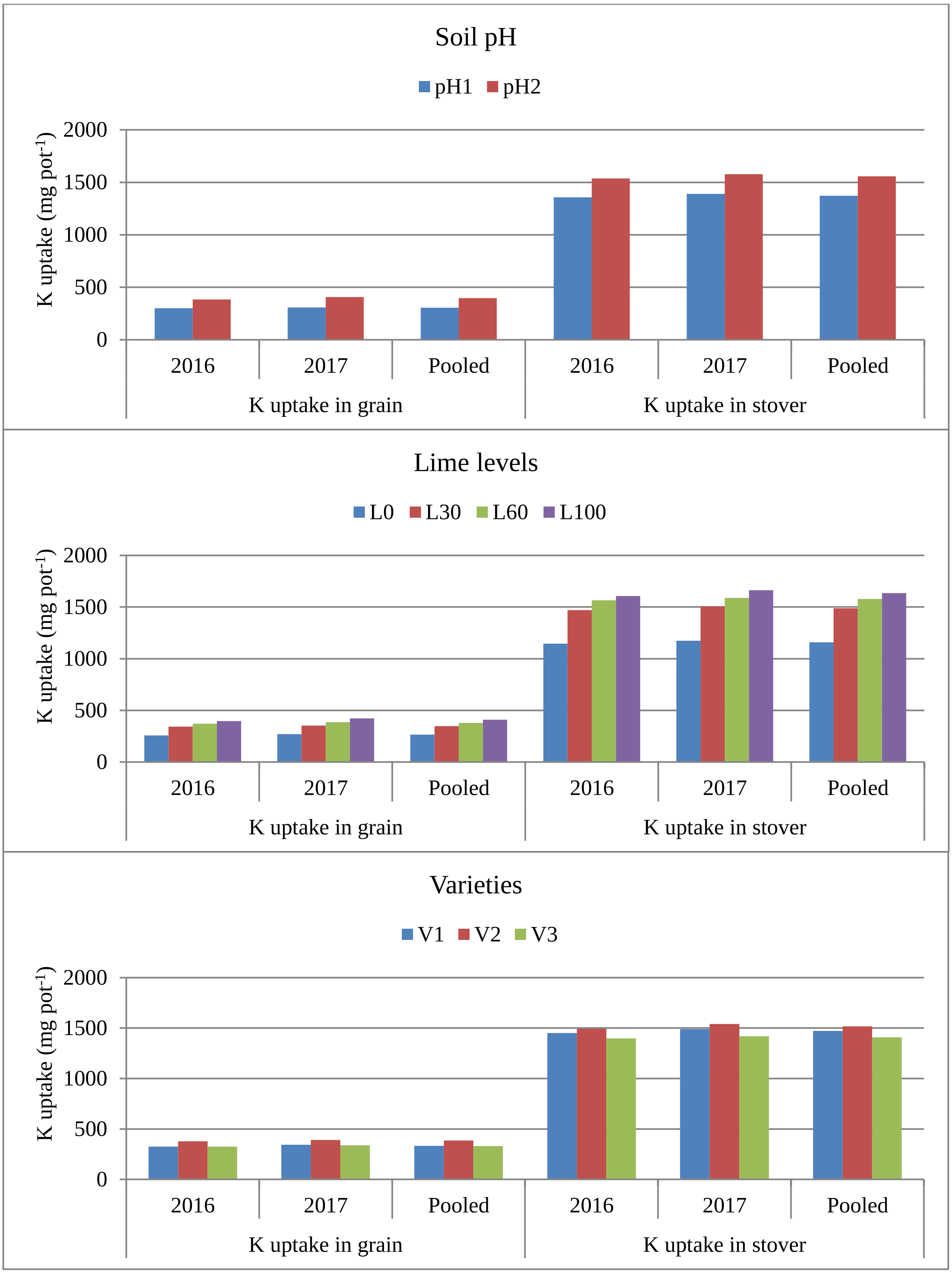


Fig 5: Effect of soil pH, lime and varieties on potassium uptake in grain and stover of maize

41.0% in $L_{100}$ over control. Lime application enhanced the grain and stover yield and potassium content due to which potassium uptake in grain and stover also increased. Increase in potassium uptake due to liming on various crop plants have been reported by Meena and Varma (2016); Lynrah and Nongmaithem (2017) and Han *et al.* (2019).

The data (Table 4.14 and fig. 5) showed that varieties had a significant effect on both potassium uptake in grain and stover. Maximum uptake in both grain and stover in both the years was recorded in the variety RCM-76 ($V_2$) followed by RCM-75 ($V_1$) while minimum was observed in RCM-1-1 ($V_3$). A critical examination of data indicate that pooled potassium uptake in grain of $V_2$ was 15.3% and 16.1% higher over $V_1$ and $V_3$, respectively.

**4.1.1.15 Calcium uptake in grain and stover**

Data pertaining to calcium uptake is summarized in Table 4.15 and depicted in Fig. 6. The results on effect of pH revealed significant influence on calcium uptake in grain and stover. During 2016 and 2017, maximum calcium uptake was recorded in pH 5.2 ($pH_2$) in grain as well as stover while minimum calcium uptake was recorded in pH 4.6 ($pH_1$). Irrespective of treatments and years the calcium uptake in grain and stover varied from 161.73 to 404.16 mg $pot^{-1}$ in grain and from 338.23 to 784.55 mg $pot^{-1}$ in stover. From pooled data it can be observed that calcium uptake in grain and stover increased by 34.7% and 25.3%, respectively in $pH_2$ over $pH_1$. Lower Ca uptake in pH 4.6 ($pH_1$) may be due to the antagonistic effect between $H^+$ and $Ca^{2+}$ ions at the substitution site of the cell wall and/or of the plasma membrane, thus inhibiting $Ca^{2+}$ uptake in plants (Alam *et al.*, 1999).

The data (Table 4.15) showed that the maximum calcium uptake in both grain and stover was recorded at 100% lime of LR ($L_{100}$) in both the years. However, in case of Ca uptake in grain, treatment $L_{100}$ was at par with $L_{60}$. The

Table 4.15: Calcium uptake in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | Ca uptake in grain (mg pot$^{-1}$) | | | Ca uptake in stover (mg pot$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 278.53 | 283.24 | 280.89 | 547.98 | 589.57 | 568.77 |
| $pH_2$ | 367.21 | 389.56 | 378.39 | 702.30 | 722.92 | 712.61 |
| SEm± | 5.62 | 5.94 | 4.09 | 10.61 | 10.46 | 7.45 |
| CD (P=0.05) | 15.99 | 16.88 | 11.48 | 30.18 | 29.74 | 20.91 |
| Lime levels | | | | | | |
| $L_0$ | 160.86 | 162.60 | 161.73 | 318.31 | 358.15 | 338.23 |
| $L_{30}$ | 352.48 | 367.63 | 360.05 | 681.40 | 707.89 | 694.65 |
| $L_{60}$ | 386.79 | 398.43 | 392.61 | 729.72 | 760.97 | 745.34 |
| $L_{100}$ | 391.35 | 416.97 | 404.16 | 771.13 | 797.96 | 784.55 |
| SEm± | 7.95 | 8.40 | 5.78 | 15.01 | 14.79 | 10.54 |
| CD (P=0.05) | 22.61 | 23.88 | 16.23 | 42.68 | 42.06 | 29.58 |
| Varieties | | | | | | |
| $V_1$ | 325.41 | 340.90 | 333.16 | 625.60 | 655.64 | 640.62 |
| $V_2$ | 339.00 | 352.15 | 345.57 | 638.67 | 676.54 | 657.60 |
| $V_3$ | 304.20 | 316.16 | 310.18 | 611.16 | 636.54 | 623.85 |
| SEm± | 6.89 | 7.27 | 5.01 | 13.00 | 12.81 | 9.12 |
| CD (P=0.05) | 19.58 | 20.68 | 14.06 | NS | NS | NS |

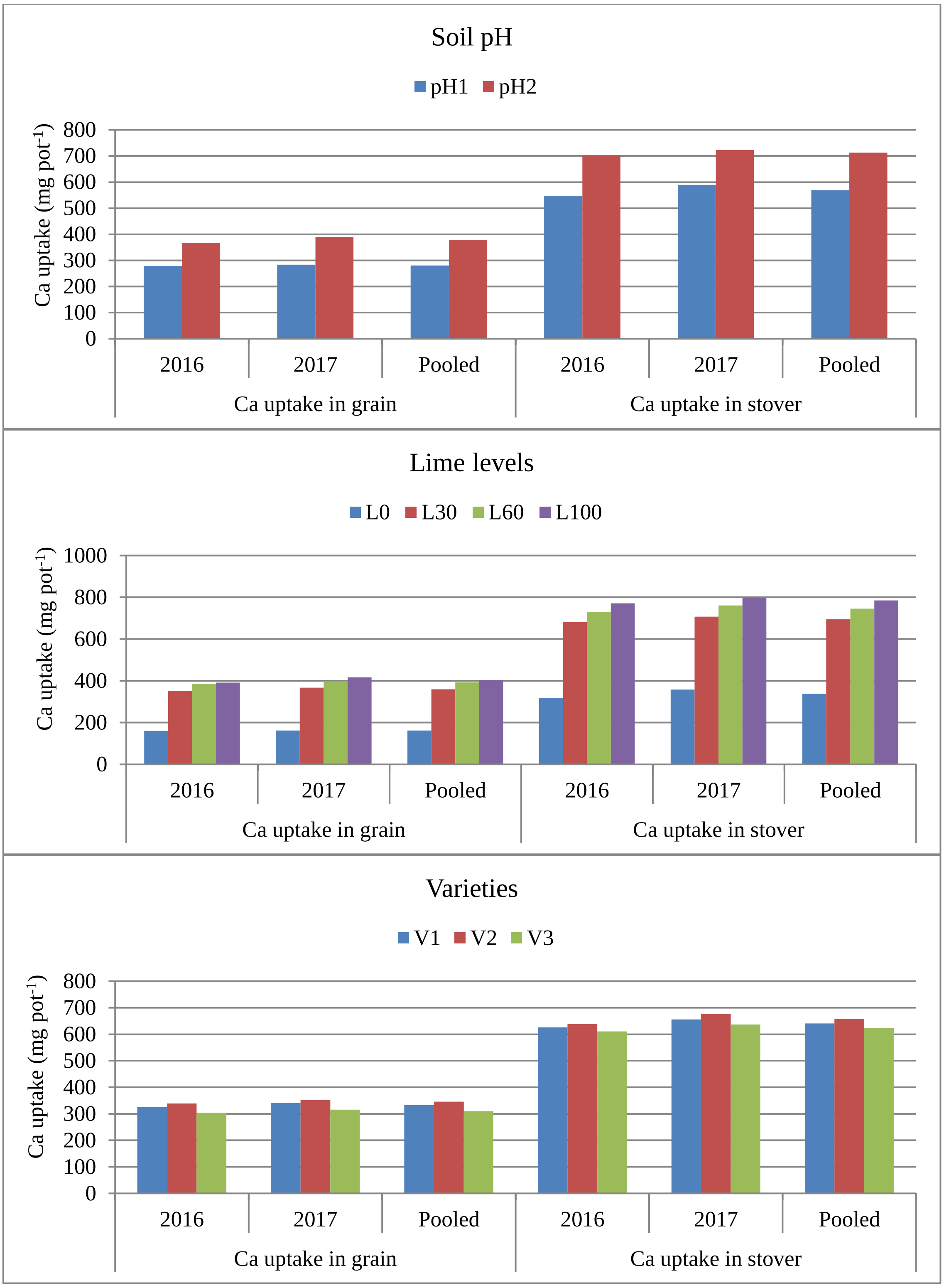


Fig 6: Effect of soil pH, lime and varieties on calcium uptake in grain and stover of maize

minimum calcium uptake in grain as well as stover was observed to be associated with control treatment ($L_0$) in both the years. Thus, an increase in 149.9% in grain and 131.9% in stover, respectively at 100% lime of LR over control can be observed from the pooled data. Each increasing level of lime resulted in significant increase in calcium uptake by grain and stover in comparison to preceding lower level of lime. Increase in Ca uptake due to liming is recorded in the findings of Singh *et al.* (2009); Moreira and Fageria (2010) and Bhindu *et al.* (2018).

The data (Table 4.15) showed that on the basis of pooled data effect of varieties on calcium uptake in grain was found to be significant where maximum Ca uptake was observed in variety RCM-76 ($V_2$) followed by RCM-75 ($V_1$) and the minimum in RCM-1-1 ($V_3$). Effect of varieties on Ca uptake in stover was observed to be non-significant during both the years.

**4.1.1.16 Boron uptake in grain and stover**

The data presented in Table 4.16 and depicted in Fig. 7 revealed that the effect of pH on boron uptake in grain and stover was significant. The maximum boron uptake in both the years in both grain and stover was observed in pH 5.2 ($pH_2$) and the minimum was observed in pH 4.6 ($pH_{4.6}$). Thus, from pooled data, boron uptake in grain increased by 13.7% and in stover by 10.8% in pH 5.2 over pH 4.6. This may be due to the fact that at a lower soil pH, boron is held more tightly by sesquioxides compared to relatively higher soil pH (Goldberg, 1997) and thus may have led to less availability for plant uptake.

The data (Table 4.16 and Fig. 7) showed that in both the years, maximum B uptake in grain as well as stover was recorded at 60% lime of LR ($L_{60}$) while minimum B uptake was observed to be associated with control ($L_0$). A critical examination of the data shows that effect of $L_{60}$ was at par with $L_{100}$ in boron uptake in grain, while $L_{60}$ was at par with $L_{100}$ and $L_{30}$ in boron uptake in stover. The $L_{60}$ level of lime increased pooled boron uptake in grain and

Table 4.16: Boron uptake in grain and stover of maize as affected by soil pH, lime and varieties

| Treatment | B uptake in grain (µg $pot^{-1}$) | | | B uptake in stover (µg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 608.46 | 606.53 | 607.50 | 385.07 | 398.41 | 391.74 |
| $pH_2$ | 683.17 | 698.49 | 690.83 | 426.78 | 441.90 | 434.34 |
| SEm± | 3.82 | 3.79 | 2.69 | 3.69 | 4.06 | 2.74 |
| CD (P=0.05) | 10.85 | 10.77 | 7.55 | 10.49 | 11.54 | 7.70 |
| Lime levels | | | | | | |
| $L_0$ | 530.30 | 536.28 | 533.29 | 336.57 | 350.16 | 343.36 |
| $L_{30}$ | 673.37 | 669.64 | 671.51 | 424.30 | 437.61 | 430.96 |
| $L_{60}$ | 695.84 | 704.29 | 700.06 | 433.01 | 446.64 | 439.83 |
| $L_{100}$ | 683.75 | 699.82 | 691.79 | 429.81 | 446.20 | 438.00 |
| SEm± | 5.40 | 5.36 | 3.80 | 5.21 | 5.74 | 3.88 |
| CD (P=0.05) | 15.34 | 15.23 | 10.67 | 14.83 | 16.32 | 10.89 |
| Varieties | | | | | | |
| $V_1$ | 651.39 | 659.56 | 655.48 | 408.09 | 422.02 | 415.06 |
| $V_2$ | 672.44 | 676.39 | 674.42 | 415.88 | 431.97 | 423.92 |
| $V_3$ | 613.61 | 621.58 | 617.59 | 393.80 | 406.46 | 400.13 |
| SEm± | 4.67 | 4.64 | 3.29 | 4.52 | 4.97 | 3.36 |
| CD (P=0.05) | 13.29 | 13.19 | 9.24 | 12.84 | 14.14 | 9.43 |

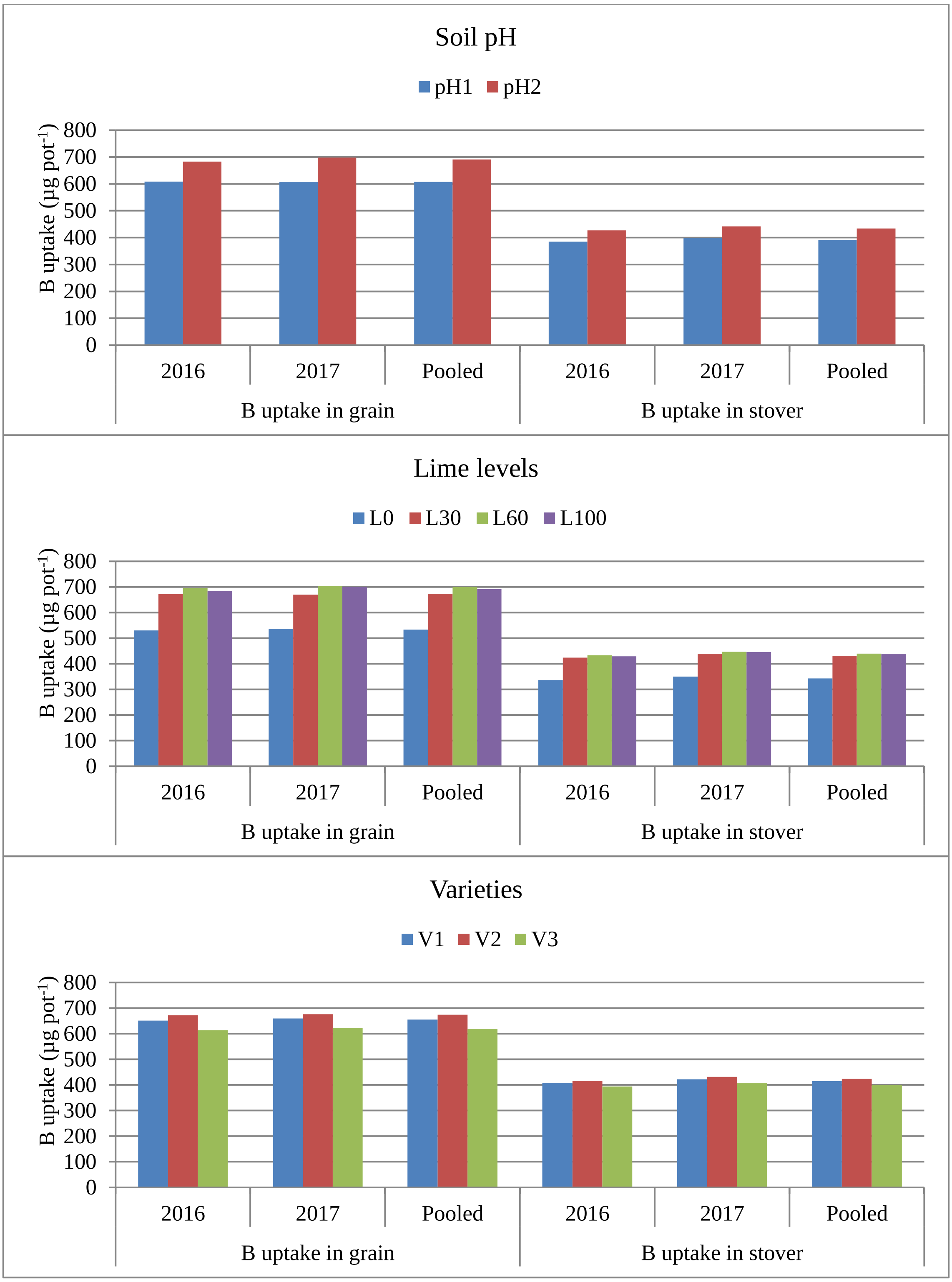


Fig 7: Effect of soil pH, lime and varieties on boron uptake in grain and stover of maize

stover to the extent of 31.2% and 28.1% over control, respectively. Similar results where liming increased boron uptake in plants is found in conformity with the findings of Su *et al.* (1994) and Singh *et al.* (2009).

The data presented in table 4.16 and illustrated in fig. 7 showed that the maximum B uptake in grain and stover was recorded in RCM-76 ($V_2$) and minimum in RCM-1-1 ($V_3$). In case of B uptake in stover, RCM-75 ($V_1$) and RCM-76 ($V_2$) was found to be at par with each other. It was also revealed that pooled boron uptake in grains of $V_2$ variety was 2.8 and 9.2% higher than $V_1$ and $V_3$ varieties, respectively.

### 4.1.2 Effect of soil pH, lime levels and varieties on soil properties

#### 4.1.2.1 Effect on soil pH and electrical conductivity

It is apparent from the data (Table 4.17.a) that during 2016 and 2017 maximum pH in soil after harvest was recorded in $pH_2$ with pooled data of 5.92 while minimum pH was recorded in $pH_1$ with pooled data of 5.61. Effect of pH on electrical conductivity was found to be non-significant in both the years. However, it could be observed that electrical conductivity was higher in pH 4.6 ($pH_1$) compared to pH 5.2 ($pH_2$). Lower soil pH indicates larger number of hydrogen ions in the soil and higher amount of hydrogen ions in the soil exhibits higher rate of electrical conductivity (Bruckner, 2012). Hydrogen ions in the soil environment can appear in varying amounts which can affect the level of electrical conductivity.

It is apparent from table 4.17.a that lime did not have significant effect on electrical conductivity. However, in case of soil pH, incorporation of increasing doses of lime increased pH across the treatments. From the data, it can be observed that during 2016 as well as 2017, maximum pH was recorded in $L_{100}$ level of lime with a pooled value of 6.42 while minimum pH was observed in $L_0$ with a pooled value of 4.91. Thus, highest soil pH was recorded at 100% lime of LR which is in congruence with

Table 4.17.a: Soil pH and electrical conductivity of post-harvest soil as affected by soil pH, lime and varieties

| Treatment | Soil pH | | | Electrical conductivity ($dSm^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 5.61 | 5.61 | 5.61 | 0.19 | 0.22 | 0.21 |
| $pH_2$ | 5.92 | 5.91 | 5.92 | 0.18 | 0.21 | 0.19 |
| SEm± | 0.006 | 0.006 | 0.004 | 0.008 | 0.008 | 0.006 |
| CD (P=0.05) | 0.02 | 0.02 | 0.01 | NS | NS | NS |
| Lime levels | | | | | | |
| $L_0$ | 4.90 | 4.91 | 4.91 | 0.21 | 0.23 | 0.22 |
| $L_{30}$ | 5.68 | 5.73 | 5.71 | 0.19 | 0.20 | 0.19 |
| $L_{60}$ | 6.06 | 6.00 | 6.03 | 0.17 | 0.22 | 0.19 |
| $L_{100}$ | 6.43 | 6.40 | 6.42 | 0.18 | 0.21 | 0.20 |
| SEm± | 0.009 | 0.009 | 0.006 | 0.011 | 0.011 | 0.008 |
| CD (P=0.05) | 0.02 | 0.03 | 0.02 | NS | NS | NS |
| Varieties | | | | | | |
| $V_1$ | 5.77 | 5.76 | 5.77 | 0.20 | 0.22 | 0.21 |
| $V_2$ | 5.76 | 5.77 | 5.76 | 0.18 | 0.22 | 0.20 |
| $V_3$ | 5.77 | 5.76 | 5.76 | 0.19 | 0.21 | 0.20 |
| SEm± | 0.007 | 0.008 | 0.005 | 0.010 | 0.010 | 0.007 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

Table 4.17.b: Interaction effect between pH and lime on soil pH of post-harvest soil

| Soil pH levels | Soil pH | | | |
|---|---|---|---|---|
| | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2016 | | | |
| $pH_1$ | 4.60 | 5.47 | 5.96 | 6.42 |
| $pH_2$ | 5.20 | 5.88 | 6.16 | 6.44 |
| SEm± | 0.01 | | | |
| CD (P=0.05) | 0.03 | | | |
| | 2017 | | | |
| $pH_1$ | 4.60 | 5.52 | 5.94 | 6.39 |
| $pH_2$ | 5.21 | 5.94 | 6.07 | 6.42 |
| SEm± | 0.01 | | | |
| CD (P=0.05) | 0.04 | | | |
| | Pooled | | | |
| $pH_1$ | 4.60 | 5.50 | 5.95 | 6.41 |
| $pH_2$ | 5.21 | 5.91 | 6.11 | 6.43 |
| SEm± | 0.01 | | | |
| CD (P=0.05) | 0.02 | | | |

the findings of Dasog *et al.* (2010). Liming at 100% lime of LR ($L_{100}$) increased soil pH by 30.7% over the control treatment ($L_0$) as reflected in pooled data. Liming increased soil pH because of the probable displacement of $Al^{3+}$, $H^+$ and $Fe^{3+}$ ions by $Ca^{2+}$ ions present in lime (Kisinyo *et al.*, 2013). The lowest soil pH value obtained in the control ($L_0$) can be attributed to the lowest values of exchangeable basic cations at the exchange sites of soil due to exhaustive uptake of the exchangeable bases by maize during the growing period which is in conformity with the findings of Lege (2012).

The results revealed that there was no significant difference among the varieties with respect to soil pH and electrical conductivity.

**Interaction effect of pH and lime on soil pH**

From the data (Table 4.17.b) the maximum pH in soil at harvest during 2016 and 2017 was recorded in $pH_2L_{100}$ with a pooled value of 6.24 while the minimum pH was recorded in $pH_1L_0$ with a pooled value of 4.44. Soil pH showed a linear increase with increase in lime levels irrespective of pH levels during both the years 2016 and 2017. Lime increases soil pH because of the $Ca^{2+}$ ions present in lime which displaces $Al^{3+}$, $H^+$ and $Fe^{3+}$ ions in the soil exchange complex (Kisinyo *et al.*, 2013).

### 4.1.2.2 Effect on percent base saturation and organic carbon

From Table 4.18.a it is evident that effect of pH was non-significant on base saturation and organic carbon content in soil at harvest. But, a slightly higher value of base saturation and organic carbon was recorded in $pH_2$ soils.

It can be observed from Table 4.18.a that there was no significant effect of lime on soil organic carbon during both the years of experimentation. The base saturation of soil was affected significantly with lime application during both the years of experimentation. The pooled base saturation increased from 24.33% in control to 33.47% in 100% lime of LR. Each increasing level of

Table 4.18.a: Base saturation and organic carbon of post-harvest soil as affected by soil pH, lime and varieties

| Treatment | Base saturation (%) | | | Organic carbon (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 29.57 | 29.16 | 29.36 | 1.55 | 1.55 | 1.55 |
| $pH_2$ | 30.25 | 29.60 | 29.92 | 1.56 | 1.57 | 1.56 |
| SEm± | 0.40 | 0.34 | 0.26 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| Lime levels | | | | | | |
| $L_0$ | 24.17 | 24.48 | 24.33 | 1.55 | 1.56 | 1.55 |
| $L_{30}$ | 28.82 | 27.97 | 28.39 | 1.55 | 1.56 | 1.56 |
| $L_{60}$ | 32.88 | 31.90 | 32.39 | 1.56 | 1.55 | 1.56 |
| $L_{100}$ | 33.76 | 33.17 | 33.47 | 1.57 | 1.57 | 1.57 |
| SEm± | 0.56 | 0.48 | 0.37 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 1.61 | 1.38 | 1.04 | NS | NS | NS |
| Varieties | | | | | | |
| $V_1$ | 30.05 | 29.33 | 29.69 | 1.55 | 1.56 | 1.56 |
| $V_2$ | 29.72 | 29.34 | 29.53 | 1.56 | 1.57 | 1.56 |
| $V_3$ | 29.95 | 29.47 | 29.71 | 1.56 | 1.55 | 1.56 |
| SEm± | 0.49 | 0.42 | 0.32 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

Table 4.18.b: Interaction effect between pH and lime on percent base saturation of post-harvest soil

| Soil pH levels | Base saturation (%) | | | |
|---|---|---|---|---|
| | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2017 | | | |
| $pH_1$ | 24.69 | 28.88 | 30.19 | 32.87 |
| $pH_2$ | 24.27 | 27.05 | 33.62 | 33.48 |
| SEm± | 0.69 | | | |
| CD (P=0.05) | 1.95 | | | |
| | Pooled | | | |
| $pH_1$ | 24.35 | 28.82 | 30.71 | 33.57 |
| $pH_2$ | 24.30 | 27.96 | 34.07 | 33.36 |
| SEm± | 0.53 | | | |
| CD (P=0.05) | 1.48 | | | |

lime enhanced pooled base saturation significantly over preceding lower level of lime. Application of $L_{100}$ level of lime increased base saturation by 37.5% as compared to control. The increase in percent base saturation due to liming can be attributed to the replacement of acidic cations by basic cations. These results are in agreement with those of Sethi (2015).

As apparent from Table 4.18.a there was no significant effect of varieties on percent base saturation and organic carbon in both the years.

**Interaction effect of pH and lime on percent base saturation**

The effect of pH and lime on percent base saturation in soil at harvest was found to be significant during the second year of experimentation. From Table 4.18.b it can be seen that during 2017, the maximum percent base saturation in soil at harvest was recorded in $pH_2L_{60}$ with pooled data as 34.07%. It can also be observed that increase in lime levels led to an increase in the percent base saturation under both the soil pH. This is because liming increases the soil pH, and acidic cations such as Al and H are replaced by basic cations such as Ca, Mg and K which then increases the percent base saturation.

### 4.1.2.3 Effect on available nitrogen, phosphorus and potassium

From Table 4.19 it can be observed that pH did not have any effect on available nitrogen and potassium whereas effect of pH on phosphorus was significant during both the years. The maximum available phosphorus in soil at harvest during 2016 as well as 2017 was recorded in $pH_2$ with a pooled value of 12.13 kg $ha^{-1}$, whereas the minimum available phosphorus was recorded in $pH_1$ with pooled value of 8.97 kg $ha^{-1}$. The $pH_2$ level enhanced available phosphorus by 10.6% over $pH_1$. Thus, available P significantly increased with increasing pH, suggesting that the relative abundance of available P decreased with increasing acidity. Soil acidification can result in decreased available P value (Awani, 2012). Concentration of P in soil depends mainly on soil pH and

Table 4.19: Available nitrogen, phosphorus and potassium of post-harvest soil as affected by soil pH, lime and varieties

| Treatment | Available nitrogen (kg ha$^{-1}$) | | | Available phosphorus (kg ha$^{-1}$) | | | Available potassium (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 262.14 | 263.66 | 262.90 | 10.65 | 9.82 | 10.23 | 150.95 | 151.49 | 151.22 |
| $pH_2$ | 265.01 | 265.35 | 265.18 | 11.69 | 10.94 | 11.32 | 151.98 | 152.06 | 152.02 |
| SEm± | 1.54 | 1.56 | 1.10 | 0.18 | 0.27 | 0.16 | 0.54 | 0.54 | 0.38 |
| CD (P=0.05) | NS | NS | NS | 0.51 | 0.76 | 0.45 | NS | NS | NS |
| Lime levels | | | | | | | | | |
| $L_0$ | 240.18 | 241.80 | 240.99 | 9.13 | 8.82 | 8.97 | 149.52 | 148.89 | 149.21 |
| $L_{30}$ | 259.02 | 258.10 | 258.56 | 10.74 | 10.35 | 10.54 | 151.83 | 151.37 | 151.60 |
| $L_{60}$ | 277.77 | 279.99 | 278.88 | 12.27 | 11.03 | 11.65 | 151.68 | 152.83 | 152.25 |
| $L_{100}$ | 277.33 | 278.13 | 277.73 | 12.53 | 11.33 | 11.93 | 152.82 | 154.01 | 153.41 |
| SEm± | 2.18 | 2.21 | 1.55 | 0.25 | 0.38 | 0.23 | 0.76 | 0.76 | 0.54 |
| CD (P=0.05) | 6.20 | 6.29 | 4.36 | 0.72 | 1.08 | 0.64 | 2.17 | 2.16 | 1.51 |
| Varieties | | | | | | | | | |
| $V_1$ | 262.96 | 263.30 | 263.13 | 11.18 | 10.21 | 10.70 | 151.84 | 151.88 | 151.86 |
| $V_2$ | 263.16 | 264.75 | 263.95 | 11.09 | 10.42 | 10.76 | 151.30 | 151.66 | 151.48 |
| $V_3$ | 264.59 | 265.47 | 265.03 | 11.24 | 10.51 | 10.87 | 151.25 | 151.78 | 151.51 |
| SEm± | 1.89 | 1.92 | 1.34 | 0.22 | 0.33 | 0.20 | 0.66 | 0.66 | 0.47 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

therefore, a decrease in the soil pH level reduces the concentration of P in soil due to the precipitation of P as Al or Fe phosphate which are amorphous polynuclear complexes with high surface area causing fixation to occur (Alam *et al.*, 1999).

It is apparent from table 4.19 that maximum and minimum nitrogen content in soil at harvest was recorded in $L_{60}$ and $L_0$, respectively during 2016 and 2017. However, $L_{60}$ was found to be at par with $L_{100}$. Phosphorus and potassium content in soil at harvest was recorded maximum in $L_{100}$ during 2016 and 2017 which was at par with $L_{30}$ and $L_{60}$ in case of phosphorus content, while $L_{100}$ was at par with $L_{60}$ in case of potassium content in soil. The minimum phosphorus and potassium content was recorded in treatment $L_0$ during 2016 and 2017. A critical examination of data showed that $L_{60}$ level of lime enhanced available nitrogen by 15.7% over control while $L_{100}$ level of lime enhanced availability of phosphorus and potassium by 33% and 2.8% over control. Higher availability of N with liming may be due to increase in soil pH where the rate of organic matter mineralization and microbial activity increases. Higher availability of P in soil under liming might be attributed to increased solubility of native and applied P due to increase in soil pH as reported by Rahman *et al.* (2005). Liming increased K availability, likely through the displacement of exchangeable K by Ca. The increase in potassium availability in soil due to liming coincides with the findings of Basak (2010) and Han *et al.* (2019).

It is apparent from Table 4.19 that effect of varieties on available nitrogen, phosphorus and potassium was non-significant during both the experimentation years.

#### 4.1.2.4 Effect on exchangeable calcium and available boron

Effect of pH was non-significant on exchangeable calcium whereas it was significant with respect to available boron as can be observed in Table 4.20. During 2016 as well as 2017 maximum available boron content in soil at

Table 4.20: Exchangeable calcium and available boron of post-harvest soil as affected by soil pH, lime and varieties

| Treatment | Exchangeable $Ca^{2+}$ [cmol $(p^+)$ $kg^{-1}$] | | | Available B (mg $kg^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | |
| $pH_1$ | 4.92 | 4.91 | 4.92 | 0.47 | 0.45 | 0.46 |
| $pH_2$ | 4.94 | 4.95 | 4.95 | 0.55 | 0.53 | 0.54 |
| SEm± | 0.06 | 0.06 | 0.04 | 0.005 | 0.005 | 0.004 |
| CD (P=0.05) | NS | NS | NS | 0.01 | 0.02 | 0.01 |
| Lime levels | | | | | | |
| $L_0$ | 2.98 | 2.95 | 2.96 | 0.49 | 0.47 | 0.48 |
| $L_{30}$ | 4.24 | 4.23 | 4.24 | 0.53 | 0.51 | 0.52 |
| $L_{60}$ | 6.01 | 6.02 | 6.02 | 0.51 | 0.49 | 0.50 |
| $L_{100}$ | 6.50 | 6.51 | 6.51 | 0.50 | 0.49 | 0.49 |
| SEm± | 0.08 | 0.08 | 0.06 | 0.007 | 0.008 | 0.005 |
| CD (P=0.05) | 0.24 | 0.24 | 0.17 | 0.02 | 0.02 | 0.01 |
| Varieties | | | | | | |
| $V_1$ | 4.93 | 4.92 | 4.92 | 0.51 | 0.50 | 0.51 |
| $V_2$ | 4.93 | 4.93 | 4.93 | 0.50 | 0.48 | 0.49 |
| $V_3$ | 4.94 | 4.94 | 4.94 | 0.51 | 0.49 | 0.50 |
| SEm± | 0.07 | 0.07 | 0.05 | 0.006 | 0.007 | 0.004 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

harvest was recorded in pH 5.2 ($pH_2$), whereas, the minimum was recorded in pH 4.6 ($pH_1$). Thus, higher pH level recorded higher available boron. Availability of boron was improved by 17.4% in $pH_2$ soil over $pH_1$. The positive relationship of B desorption with soil pH may be ascribed to the fact that both free Fe and Al oxide contents in soil decreased with an increase in soil pH. It can also be inferred that the B adsorbed on sesquioxides at lower pH was held more tightly as compared to that adsorbed on soil constituents other than sesquioxides at relatively higher pH (Goldberg, 1997).

From Table 4.20 it can be observed that increasing doses of lime increased exchangeable calcium significantly during both the years of experimentation. During 2016 as well as 2017 the highest exchangeable calcium was observed in treatment $L_{100}$ and lowest in control treatment ($L_0$). The data further revealed that each increasing level of lime resulted in a significant enhancement in pooled exchangeable calcium in comparison to preceding lower levels of lime. The $L_{100}$ level of lime enhanced exchangeable calcium to the extent of 119.9% over control. On the other hand, highest available boron was observed in treatment $L_{30}$ and lowest in control ($L_0$). Available boron @ 30% lime of LR ($L_{30}$) was observed to increase by 8.3% over control ($L_0$). Increasing doses of lime was observed to reduce the soil available boron. Liming generally increases the retention capacity of boron in soil due to formation of insoluble metaborate (Mikko, 1972) which may have been the reason for its reduction in higher lime levels. The result on soil available boron is in line with the findings of Barman *et al.* (2014). The status of available Ca on soils was positively correlated with the rate of lime application. This result is in close conformity with the findings of Garica (1975) who reported that the pH of acid soils becomes raised due to liming, and higher rate of lime application leads to higher adsorption of Ca and thus ameliorates calcium deficiency.

There was no significant effect of varieties on soil exchangeable calcium and available boron content at harvest.

**4.1.2.5 Effect on exchangeable hydrogen, aluminium and total potential acidity**

From Table 4.21.a it can be observed that the effect of pH on exchangeable hydrogen, exchangeable aluminium and total potential acidity was found to be significant where highest values during 2016 and 2017 was observed in pH 4.6 ($pH_1$) soil and lowest values were observed in pH 5.2 ($pH_2$) soil. Thus, from pooled data it can be stated that exchangeable hydrogen, exchangeable aluminium and total potential acidity decreased by 32.6%, 9.2% and 6.3%, respectively in $pH_2$ as compared to $pH_1$. At low pH (<5) aluminium becomes soluble and is adsorbed by silicate clays or is tightly bound by organic matter. The $Al^{3+}$ ions are then hydrolysed in the soil solution releasing $H^+$ ions which contribute to soil acidity. However, an increase in the pH of soil leads to the precipitation of exchangeable and soluble Al to insoluble Al hydroxides which reduces the concentration of Al in the soil solution (Kifuko *et al.*, 2007).

From Table 4.21.a it is evident that the exchangeable hydrogen, aluminium and total potential acidity in soil at harvest was highest during 2016 as well as 2017 in control ($L_0$). Decreasing trend in exchangeable hydrogen, aluminium and total potential acidity was observed with increasing doses of lime where the lowest values were observed in $L_{100}$. From pooled data it can be observed that exchangeable hydrogen, exchangeable aluminium and total potential acidity registered a decline of 65.8%, 43.6% and 28.8%, respectively in $L_{100}$ when compared to $L_0$. Similar findings have also been reported by Badole *et al* (2015) where liming decreased all forms of soil acidity and the effect was greater in full dose of lime application than in half dose of lime application. The decrease in exchangeable $Al^+$ and $H^+$ as a result of liming

Table 4.21.a: Exchangeable $H^{+}$, $Al^{3+}$ and total potential acidity of post-harvest soil as affected by soil pH, lime and varieties

| Treatment | Exchangeable $H^{+}$ [cmol ($p^{+}$) $kg^{-1}$] | | | Exchangeable $Al^{3+}$ [cmol ($p^{+}$) $kg^{-1}$] | | | Total potential acidity [cmol ($p^{+}$) $kg^{-1}$] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Soil pH levels | | | | | | | | | |
| $pH_1$ | 0.48 | 0.50 | 0.49 | 1.18 | 1.21 | 1.19 | 13.03 | 13.00 | 13.02 |
| $pH_2$ | 0.36 | 0.30 | 0.33 | 1.08 | 1.09 | 1.08 | 12.35 | 12.05 | 12.20 |
| SEm± | 0.03 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.17 | 0.17 | 0.12 |
| CD (P=0.05) | 0.07 | 0.09 | 0.06 | 0.05 | 0.04 | 0.03 | 0.47 | 0.47 | 0.33 |
| Lime levels | | | | | | | | | |
| $L_0$ | 0.79 | 0.72 | 0.76 | 1.52 | 1.59 | 1.56 | 15.01 | 14.83 | 14.92 |
| $L_{30}$ | 0.31 | 0.30 | 0.31 | 1.13 | 1.13 | 1.13 | 13.16 | 12.98 | 13.07 |
| $L_{60}$ | 0.30 | 0.32 | 0.31 | 0.98 | 0.99 | 0.98 | 11.90 | 11.76 | 11.83 |
| $L_{100}$ | 0.26 | 0.25 | 0.26 | 0.88 | 0.89 | 0.88 | 10.70 | 10.54 | 10.62 |
| SEm± | 0.04 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.23 | 0.23 | 0.17 |
| CD (P=0.05) | 0.10 | 0.13 | 0.08 | 0.07 | 0.05 | 0.04 | 0.67 | 0.67 | 0.46 |
| Varieties | | | | | | | | | |
| $V_1$ | 0.44 | 0.41 | 0.42 | 1.11 | 1.14 | 1.13 | 12.68 | 12.52 | 12.60 |
| $V_2$ | 0.40 | 0.40 | 0.40 | 1.15 | 1.15 | 1.15 | 12.71 | 12.54 | 12.62 |
| $V_3$ | 0.41 | 0.39 | 0.40 | 1.13 | 1.15 | 1.14 | 12.69 | 12.53 | 12.61 |
| SEm± | 0.03 | 0.04 | 0.02 | 0.02 | 0.02 | 0.01 | 0.20 | 0.20 | 0.14 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

Table 4.21.b: Interaction effect between pH and lime on exchangeable hydrogen and aluminium of post-harvest soil

| Soil pH levels | Exchangeable $H^+$ [cmol ($p^+$) $kg^{-1}$] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Lime levels | | | | Lime levels | | | | Lime levels | | | |
| | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ | $L_0$ | $L_{30}$ | $L_{60}$ | $L_{100}$ |
| | 2016 | | | | 2017 | | | | Pooled | | | |
| $pH_1$ | 0.96 | 0.34 | 0.31 | 0.30 | 0.93 | 0.38 | 0.35 | 0.32 | 0.95 | 0.36 | 0.33 | 0.31 |
| $pH_2$ | 0.62 | 0.29 | 0.29 | 0.22 | 0.51 | 0.23 | 0.28 | 0.18 | 0.57 | 0.26 | 0.29 | 0.20 |
| SEm± | 0.05 | | | | 0.06 | | | | 0.04 | | | |
| CD (P=0.05) | 0.15 | | | | 0.18 | | | | 0.11 | | | |
| | Exchangeable $Al^{3+}$ [cmol ($p^+$) $kg^{-1}$] | | | | | | | | | | | |
| | 2016 | | | | 2017 | | | | Pooled | | | |
| $pH_1$ | 1.64 | 1.12 | 1.04 | 0.92 | 1.72 | 1.13 | 1.06 | 0.93 | 1.68 | 1.12 | 1.05 | 0.92 |
| $pH_2$ | 1.40 | 1.13 | 0.93 | 0.85 | 1.46 | 1.13 | 0.91 | 0.85 | 1.43 | 1.13 | 0.92 | 0.85 |
| SEm± | 0.03 | | | | 0.03 | | | | 0.02 | | | |
| CD (P=0.05) | 0.09 | | | | 0.07 | | | | 0.06 | | | |

might be due to the precipitation of exchangeable $Al^+$ and neutralization of exchangeable $H^+$ in the soil.

It can be observed from Table 4.21.a that varieties did not have any significant influence on exchangeable hydrogen, aluminium and total potential acidity in the post harvest soil.

**Interaction effect of pH and lime on exchangeable hydrogen and aluminium**

It can be observed from Table 4.21.b that exchangeable hydrogen and aluminium in soil at harvest in both the years were found to be highest in the treatment combination $pH_1L_0$. On the other hand, lowest exchangeable hydrogen and aluminium was observed in $pH_2L_{100}$ treatment combination. On further examination of the data it can be observed that irrespective of soil pH, exchangeable hydrogen and aluminium decreased as lime levels increased under each level of soil pH. This is because of the increase in soil pH due to liming and lime is known to precipitate the Al ions to hydroxyl compounds such as $Al(OH)_3$ (Caires *et al.*, 2002 and Hue, 2004). This has the effect of reducing exchangeable acidity which comprises $Al^{3+}$ and $H^+$.

## 4.2. EFFECT OF LIME, PHOSPHORUS AND BORON ON PERFORMANCE OF MAIZE AND SOIL PROPERTIES (EXPT-II)

### 4.2.1 Effect of lime, phosphorus and boron on performance of maize

#### 4.2.1.1 Effect on plant height

The results on the plant height in different treatments have been presented in Table 4.22.a and Fig. 8. There was an appreciable increase in the height of the plant with the advancement of days and also significant difference among various treatments. It is apparent from the data the maximum plant height was recorded in the treatment $L_{25}$ (25% lime of LR) at 30, 60 DAS and at harvest, while the minimum plant height was recorded in control ($L_0$) during 2016 and 2017. This positive response in growth to lime can be ascribed to reduction of Al-toxicity and/ increase in availability of P (Kisinyo *et al.,* 2014). The significant increase in maize growth after lime application has been reported by Brajendra *et al.* (2006); Muindi *et al.* (2015) and Opala (2017).

Plant height of maize was significantly affected by different phosphorus levels (Table 4.22.a and Fig. 8). Data regarding phosphorus levels at all crop stages during 2016 and 2017 revealed that taller plants were produced when phosphorus was applied at 90 kg $ha^{-1}$ which was statistically at par with phosphorus applied at 60 kg $ha^{-1}$. The minimum plant height at 30, 60 DAS and at harvest was recorded in the treatment $P_0$ (control) during 2016 and 2017. A critical examination of data revealed that application of 90 kg $P_2O_5$ $ha^{-1}$ increased pooled plant height at 30, 60 DAS and at harvest by 12.04%, 21.2% and 21.7%, respectively over control. The probable reason for the increase in plant height due to phosphorus might be that it improved the root development and nutrient absorption which had a great effect on overall growth performance which resulted in taller plants. Similar findings have been reported by Hussain *et al.* (2006); Masood *et al.* (2011); Rashid and Iqbal (2012).

From the data depicted in Table 4.22.a and illustrated in Fig. 8, the results revealed that there was a significant difference among the treatments and the maximum plant height was recorded in the treatment $B_2$ *i.e.,* at 2 kg B $ha^{-1}$ while the minimum plant height was recorded in the treatment $B_0$ *i.e.,* at 0 kg B $ha^{-1}$ during 2016 and 2017. The data further revealed that each increment in boron application resulted in significant enhancement in plant height in comparison to preceding lower levels of boron at all three growth stages during both the years of experimentation. It was also observed that $B_2$ level of boron increased plant height to the extent of 12.0%, 7.5% and 4.9%, respectively at 30, 60 DAS and at harvest over control. Increase in plant height due to boron application may be due to its vital role in cell wall synthesis, division, elongation and nucleic acid metabolism. Similar results have also been reported by Ceyhan *et al.* (2007) and Ahmed *et al.* (2008).

Table 4.22.a: Plant height of maize at different growth stages as affected by lime, phosphorus and boron

| Treatment | Plant height (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | At 30 DAS | | | At 60 DAS | | | At harvest | | |
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 41.96 | 40.18 | 41.07 | 159.13 | 161.79 | 160.46 | 195.00 | 195.82 | 195.41 |
| $L_{25}$ | 45.48 | 43.14 | 44.31 | 180.56 | 182.25 | 181.41 | 220.73 | 221.34 | 221.04 |
| SEm± | 0.59 | 0.63 | 0.43 | 0.71 | 0.71 | 0.50 | 0.52 | 0.66 | 0.42 |
| CD (P=0.05) | 1.68 | 1.79 | 1.21 | 2.03 | 2.02 | 1.41 | 1.49 | 1.86 | 1.18 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 42.01 | 38.37 | 40.19 | 147.66 | 151.16 | 149.41 | 182.07 | 181.84 | 181.95 |
| $P_{30}$ | 43.07 | 40.32 | 41.69 | 171.87 | 173.27 | 172.57 | 209.25 | 208.66 | 208.95 |
| $P_{60}$ | 44.48 | 43.24 | 43.86 | 179.71 | 181.53 | 180.62 | 218.98 | 221.99 | 220.48 |
| $P_{90}$ | 45.33 | 44.73 | 45.03 | 180.16 | 182.12 | 181.14 | 221.18 | 221.84 | 221.51 |
| SEm± | 0.84 | 0.89 | 0.61 | 1.01 | 1.00 | 0.71 | 0.74 | 0.93 | 0.59 |
| CD (P=0.05) | 2.38 | 2.53 | 1.71 | 2.86 | 2.85 | 1.99 | 2.11 | 2.64 | 1.67 |
| Boron levels | | | | | | | | | |
| $B_0$ | 41.60 | 39.01 | 40.31 | 163.09 | 165.93 | 164.51 | 202.07 | 203.74 | 202.91 |
| $B_1$ | 43.71 | 41.49 | 42.60 | 170.08 | 172.89 | 171.49 | 208.02 | 209.59 | 208.81 |
| $B_2$ | 45.85 | 44.49 | 45.17 | 176.37 | 177.24 | 176.80 | 213.51 | 212.41 | 212.96 |
| SEm± | 0.72 | 0.77 | 0.53 | 0.87 | 0.87 | 0.62 | 0.64 | 0.80 | 0.51 |
| CD (P=0.05) | 2.06 | 2.19 | 1.48 | 2.48 | 2.47 | 1.73 | 1.82 | 2.28 | 1.44 |

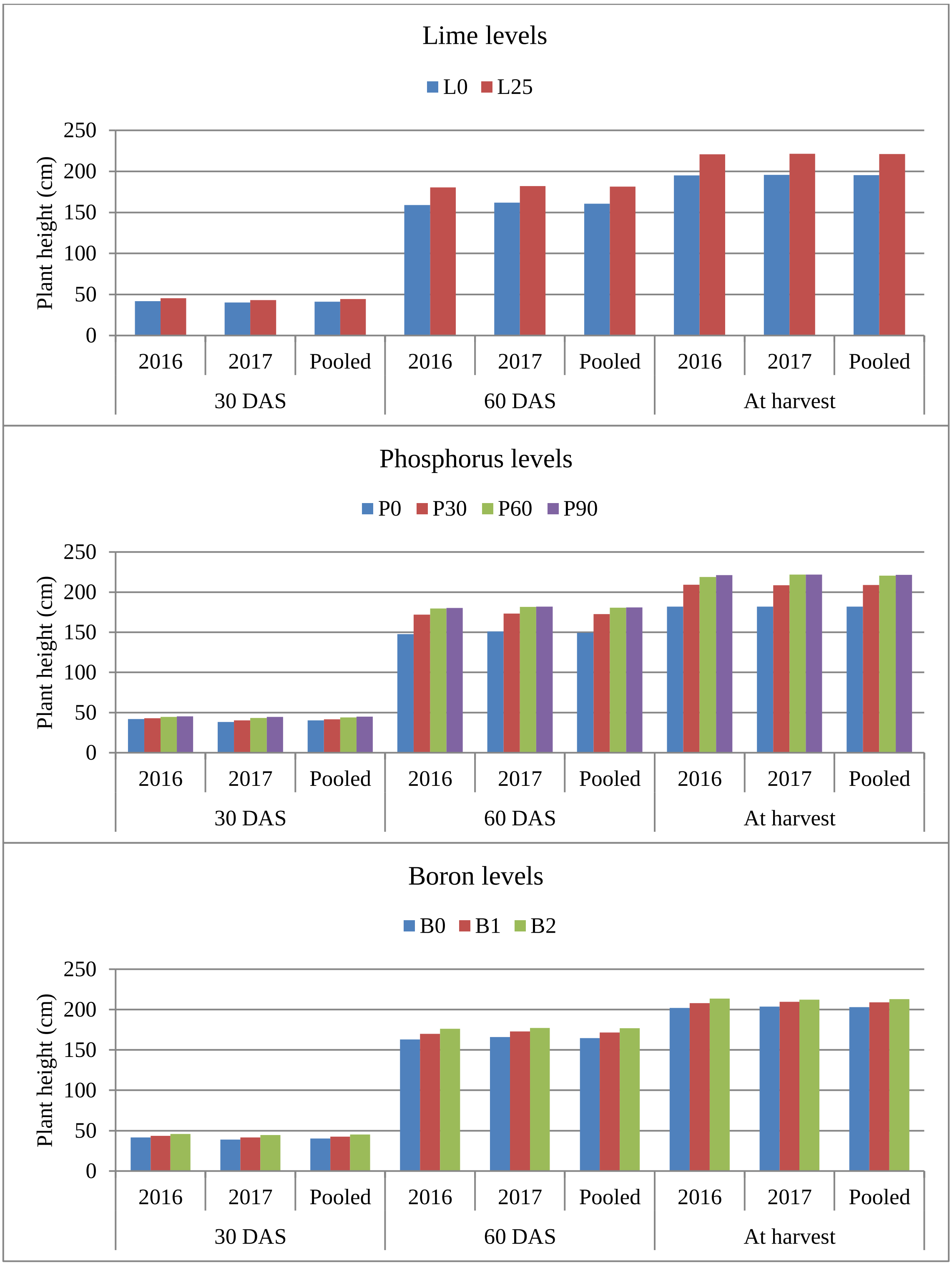


Fig 8: Effect of lime, phosphorus and boron on plant height of maize at 30, 60 DAS and at harvest

**Interaction effect of lime and phosphorus on plant height**

The interaction effect of lime and phosphorus was found to be significant at 60 DAS during 2016 and pooled (Table 4.22.b). Without lime application, plant height increased with increasing P rates, but with lime application plant height increased from 0 to 60 kg $P_2O_5$ $ha^{-1}$ and declined at 90 kg $P_2O_5$ $ha^{-1}$. The observed increase in plant height with increasing P rate in treatments with no lime application shows that P might be a limiting factor to maize growth in this soil. The observed positive effect of lime on maize growth was likely due to its effect in ameliorating aluminium toxicity. Maximum plant height was recorded in treatment combination $L_{25}P_{60}$. Significant interaction between lime and phosphorus on plant height of maize has also been reported by Opala (2017).

**Interaction effect of lime, phosphorus and boron on plant height at harvest**

The data indicated that the plant height at harvest was found to be significantly affected by the combined application of lime, phosphorus and boron during 2017 (Table 4.22.c). A critical examination of the data revealed that plant height was observed to increase with increase in phosphorus and boron levels irrespective of lime application. However, higher plant heights were observed with lime application and among the treatment combinations, maximum plant height was recorded in $L_{25}P_{60}B_2$ (240.60 cm) during 2017, while in pooled data maximum plant height was recorded in $L_{25}P_{90}B_2$ (239.87 cm). Treatment combinations $L_{25}P_{60}B_2$ and $L_{25}P_{90}B_2$ were found to be at par with each other during 2017 as well as in the pooled data. Minimum plant height in 2017 and pooled data was recorded in $L_0P_0B_0$. The results revealed that $L_{25}P_{60}B_2$ enhanced plant growth significantly compared to the other treatment combinations, except $L_{25}P_{60}B_1$ and $L_{25}P_{90}B_2$ during 2017. Application of lime along with increased nutrient input may have led to an

Table 4.22.b: Interaction effect between lime and phosphorus on plant height at 60 DAS

| Lime levels | Plant height at 60 DAS (cm) | | | |
|---|---|---|---|---|
| | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{100}$ |
| | 2016 | | | |
| $L_0$ | 138.16 | 161.37 | 166.32 | 170.68 |
| $L_{25}$ | 157.16 | 182.38 | 193.09 | 189.63 |
| SEm± | 1.42 | | | |
| CD (P=0.05) | 4.05 | | | |

Table 4.22.c: Interaction effect of lime, phosphorus and boron on plant height at harvest

| Phosphorus levels | Plant height at harvest (cm) | | | | | |
|---|---|---|---|---|---|---|
| | Lime levels | | | | | |
| | $L_0$ | | | $L_{25}$ | | |
| | Boron levels | | | Boron levels | | |
| | $B_0$ | $B_1$ | $B_2$ | $B_0$ | $B_1$ | $B_2$ |
| | 2017 | | | | | |
| $P_0$ | 159.77 | 170.83 | 172.83 | 192.37 | 197.57 | 197.67 |
| $P_{30}$ | 189.77 | 195.40 | 203.13 | 217.57 | 222.73 | 223.33 |
| $P_{60}$ | 209.60 | 209.87 | 209.23 | 228.33 | 234.30 | 240.60 |
| $P_{90}$ | 205.87 | 210.10 | 213.40 | 226.67 | 235.93 | 239.07 |
| SEm± | 2.27 | | | | | |
| CD (P=0.05) | 6.45 | | | | | |
| | Pooled | | | | | |
| $P_0$ | 160.47 | 170.45 | 175.38 | 190.83 | 196.13 | 198.45 |
| $P_{30}$ | 192.23 | 195.22 | 199.87 | 216.82 | 223.85 | 225.73 |
| $P_{60}$ | 205.85 | 207.98 | 209.63 | 227.02 | 232.58 | 239.83 |
| $P_{90}$ | 203.72 | 209.20 | 214.92 | 226.32 | 235.03 | 239.87 |
| SEm± | 1.45 | | | | | |
| CD (P=0.05) | 4.08 | | | | | |

increase in availability of nutrients which may have aided in favourable conditions for crop growth resulting in increased plant height.

#### 4.2.1.2 Effect on number of leaves

The data on the number of leaves in different treatments have been presented in table 4.23. It is apparent from the data, that during 2016 and 2017, maximum number of leaves was recorded in the treatment $L_{25}$ at 30, 60 DAS and at harvest while minimum number of leaves was recorded in the treatment $L_0$. In general the application of lime was observed to boost the growth of the crop due to increase in the soil pH towards neutrality (Opala, 2017). The increase in number of leaves in maize due to application of lime at higher rate has been observed by Muindi *et al.* (2015).

It is apparent from Table 4.23 that during 2016 and 2017, maximum number of leaves was recorded in treatment $P_{90}$ at all crop stages, while minimum number of leaves was recorded in the treatment $P_0$. The reason for higher number of leaves at all the growth stages of crop with higher levels of phosphorus can be ascribed to the important role of phosphorus in cell division and cell enlargement (Assuero *et al.*, 2004). At harvest, application of 90 kg $P_2O_5$ $ha^{-1}$ increased pooled number of leaves by 11.2% over control ($P_0$). Significant increase in number of leaves due to phosphorus application has also been reported by various workers (Ayub *et al.*, 2002 and Timlin *et al*, 2017).

From the data (Table 4.23) it can be inferred that effect of boron on number of leaves at 30 DAS was non-significant. However, at 60 DAS and at harvest there was a significant difference among the treatments and maximum number of leaves was recorded in treatment $B_2$, while, minimum number of leaves was recorded in treatment $B_0$ during both the years of experimentation. The $B_2$ level of boron was observed to improve the number of leaves to the extent of 6.1% in comparison to control ($B_0$) during harvest. Favourable conditions for crop growth due to boron application may be due to its role in

Table 4.23: Number of leaves per plant of maize at different growth stages as affected by lime, phosphorus and boron

| Treatment | Number of leaves | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | At 30 DAS | | | At 60 DAS | | | At harvest | | |
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 6.42 | 6.50 | 6.46 | 10.14 | 10.17 | 10.15 | 12.81 | 13.44 | 13.13 |
| $L_{25}$ | 6.69 | 6.75 | 6.72 | 10.83 | 10.86 | 10.85 | 14.17 | 14.53 | 14.35 |
| SEm± | 0.08 | 0.09 | 0.06 | 0.10 | 0.09 | 0.07 | 0.11 | 0.13 | 0.08 |
| CD (P=0.05) | 0.24 | 0.25 | 0.17 | 0.27 | 0.25 | 0.18 | 0.30 | 0.37 | 0.24 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 6.28 | 6.33 | 6.31 | 9.72 | 9.83 | 9.78 | 12.67 | 13.11 | 12.89 |
| $P_{30}$ | 6.50 | 6.56 | 6.53 | 10.33 | 10.50 | 10.42 | 13.50 | 14.28 | 13.89 |
| $P_{60}$ | 6.67 | 6.78 | 6.72 | 10.78 | 10.83 | 10.81 | 13.67 | 14.00 | 13.83 |
| $P_{90}$ | 6.78 | 6.83 | 6.81 | 11.11 | 10.89 | 11.00 | 14.11 | 14.56 | 14.33 |
| SEm± | 0.12 | 0.12 | 0.09 | 0.14 | 0.12 | 0.09 | 0.15 | 0.18 | 0.12 |
| CD (P=0.05) | 0.34 | 0.35 | 0.24 | 0.39 | 0.35 | 0.26 | 0.43 | 0.52 | 0.33 |
| Boron levels | | | | | | | | | |
| $B_0$ | 6.42 | 6.50 | 6.46 | 10.08 | 10.25 | 10.17 | 13.04 | 13.63 | 13.33 |
| $B_1$ | 6.54 | 6.67 | 6.60 | 10.46 | 10.54 | 10.50 | 13.50 | 13.96 | 13.73 |
| $B_2$ | 6.71 | 6.71 | 6.71 | 10.92 | 10.75 | 10.83 | 13.92 | 14.38 | 14.15 |
| SEm± | 0.10 | 0.11 | 0.07 | 0.12 | 0.11 | 0.08 | 0.13 | 0.16 | 0.10 |
| CD (P=0.05) | NS | NS | NS | 0.34 | 0.31 | 0.22 | 0.37 | 0.45 | 0.29 |

forming and strengthening cell walls leading to growth of growing tissues and hence plant development. These results are in accordance with those of Soomro *et al.* (2011) and Borase *et al.* (2018).

**4.2.1.3 Effect on leaf area index**

The results on leaf area index in different treatments have been presented in table 4.24. It is apparent from the data that the leaf area index was greater in the treatment with lime ($L_{25}$) which may be attributed to reduction in aluminium toxicity which led to an overall improvement in plant growth. Lime application significantly increased leaf area index at all growth stages during both the years of experimentation over control. These results are in line with the findings of Muindi *et al.,* 2015 and Bekele *et al.,* 2018.

The leaf area index at all the stages of crop growth was found higher in those treatments where higher amount of phosphorus was applied which can be attributed to its major role in the growth of new tissue and division of cells. It is apparent from table 4.24, the maximum leaf area index was recorded in the treatment $P_{90}$ which was at par with $P_{60}$, while the minimum leaf area index was recorded in the treatment $P_0$ at 30, 60 DAS and at harvest during 2016 and 2017. Positive association of leaf area index with increase in P levels have been reported by Hamdi and Woodard (1995); Amanullah *et al.* (2009) and Amanullah *et al.* (2010).

The effect of boron on leaf area index was found to be non-significant (Table 4.24).

**4.2.1.4 Effect on cob length, cob girth and cob weight**

The results on cob length, cob girth and cob weight in different treatments have been presented in Table 4.25.a. There was a significant increase in cob length, cob girth and cob weight with application of lime @ 25% lime of LR ($L_{25}$) which recorded maximum cob length, cob girth as well

Table 4.24: Leaf area index of maize at different growth stages as affected by lime, phosphorus and boron

| Treatment | Leaf area index | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | At 30 DAS | | | At 60 DAS | | | At harvest | | |
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 0.60 | 0.63 | 0.61 | 1.24 | 1.27 | 1.25 | 1.16 | 1.17 | 1.17 |
| $L_{25}$ | 0.64 | 0.67 | 0.66 | 1.29 | 1.32 | 1.31 | 1.18 | 1.19 | 1.19 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.005 | 0.006 | 0.004 | 0.004 | 0.005 | 0.003 |
| CD (P=0.05) | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 0.56 | 0.59 | 0.57 | 1.24 | 1.26 | 1.25 | 1.16 | 1.16 | 1.16 |
| $P_{30}$ | 0.61 | 0.62 | 0.62 | 1.26 | 1.28 | 1.27 | 1.16 | 1.18 | 1.17 |
| $P_{60}$ | 0.64 | 0.68 | 0.66 | 1.28 | 1.30 | 1.29 | 1.17 | 1.19 | 1.18 |
| $P_{90}$ | 0.67 | 0.71 | 0.69 | 1.29 | 1.33 | 1.31 | 1.18 | 1.20 | 1.19 |
| SEm± | 0.02 | 0.01 | 0.01 | 0.008 | 0.009 | 0.006 | 0.006 | 0.006 | 0.004 |
| CD (P=0.05) | 0.05 | 0.04 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
| Boron levels | | | | | | | | | |
| $B_0$ | 0.60 | 0.65 | 0.63 | 1.27 | 1.29 | 1.28 | 1.17 | 1.18 | 1.17 |
| $B_1$ | 0.63 | 0.65 | 0.64 | 1.27 | 1.30 | 1.28 | 1.16 | 1.18 | 1.17 |
| $B_2$ | 0.63 | 0.66 | 0.64 | 1.27 | 1.30 | 1.28 | 1.18 | 1.19 | 1.18 |
| SEm± | 0.02 | 0.01 | 0.01 | 0.007 | 0.008 | 0.005 | 0.005 | 0.006 | 0.004 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

as cob weight during 2016 and 2017. Application of 25% lime of LR increased cob length, cob girth and cob weight by 2.3%, 3.0% and 21.1%, respectively over control. The beneficial effect of lime in crops is well known, which is reduction of aluminium toxicity by bringing the pH towards neutrality, hence improvement in nutrient solubility which improves yield. Similar findings have been reported by Brajendra *et al.* (2006) and Kumar *et al.* (2012).

The cob length, cob girth and cob weight in both the years was found higher in those treatments with higher level of phosphorus. A critical examination of data indicated that each increasing level of phosphorus enhanced cob length, cob girth and cob weight significantly as compared to preceding lower levels in case of pooled values. It is apparent from table 4.25.a that the maximum cob length, cob girth as well as cob weight was recorded in the treatment $P_{90}$. The $P_{90}$ level of phosphorus increased pooled cob length, cob girth, cob weight by 12.2%, 8.8% and 22.5%, respectively over control which can be ascribed to the important role of phosphorus in cell division and cell enlargement (Assuero *et al.*, 2004). However, treatment $P_{90}$ was at par with treatment $P_{60}$ in case of cob length. As phosphorus is responsible for good root growth which directly affects the overall plant performance, phosphorus at 0 kg ha$^{-1}$ ($P_0$) resulted in minimum cob length, cob girth and cob weight during 2016 as well as 2017. Similar findings have been reported by Khan *et al.* (2017); Pal *et al.* (2017) and Sharma *et al.* (2018).

The effect of boron was observed to have a significant difference among the treatments. The highest cob length, cob girth and cob weight was recorded in treatment $B_2$ while the lowest cob length, cob girth and cob weight was recorded in the treatment $B_0$ during 2016 and 2017. From pooled data, it can be observed that $B_2$ level of boron enhanced cob length, cob girth and cob weight by 3.2%, 2.2% and 5.2%, respectively over control. The significant effect of boron application might be due to its role in pollen tube formation, increasing

Table 4.25.a: Cob length, cob girth and cob weight of maize as affected by lime, phosphorus and boron

| Treatment | Cob length (cm) | | | Cob girth (cm) | | | Cob weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 17.99 | 18.39 | 18.19 | 14.40 | 14.45 | 14.43 | 82.44 | 82.27 | 82.35 |
| $L_{25}$ | 18.49 | 18.73 | 18.61 | 14.86 | 14.87 | 14.87 | 99.55 | 99.86 | 99.71 |
| SEm± | 0.05 | 0.05 | 0.04 | 0.06 | 0.06 | 0.04 | 0.32 | 0.26 | 0.21 |
| CD (P=0.05) | 0.14 | 0.14 | 0.10 | 0.18 | 0.17 | 0.12 | 0.91 | 0.74 | 0.58 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 17.01 | 17.42 | 17.21 | 14.02 | 14.06 | 14.04 | 79.51 | 79.23 | 79.37 |
| $P_{30}$ | 18.00 | 18.48 | 18.24 | 14.44 | 14.46 | 14.45 | 90.10 | 90.72 | 90.41 |
| $P_{60}$ | 18.71 | 18.99 | 18.85 | 14.80 | 14.82 | 14.81 | 97.15 | 97.00 | 97.08 |
| $P_{90}$ | 19.26 | 19.36 | 19.31 | 15.25 | 15.31 | 15.28 | 97.21 | 97.31 | 97.26 |
| SEm± | 0.07 | 0.07 | 0.05 | 0.09 | 0.09 | 0.06 | 0.45 | 0.37 | 0.29 |
| CD (P=0.05) | 0.20 | 0.20 | 0.14 | 0.25 | 0.24 | 0.17 | 1.29 | 1.04 | 0.82 |
| Boron levels | | | | | | | | | |
| $B_0$ | 17.91 | 18.28 | 18.10 | 14.48 | 14.49 | 14.49 | 88.59 | 88.43 | 88.51 |
| $B_1$ | 18.25 | 18.59 | 18.42 | 14.62 | 14.67 | 14.64 | 91.71 | 91.19 | 91.45 |
| $B_2$ | 18.57 | 18.81 | 18.69 | 14.79 | 14.83 | 14.81 | 92.67 | 93.57 | 93.12 |
| SEm± | 0.06 | 0.06 | 0.04 | 0.08 | 0.07 | 0.05 | 0.39 | 0.32 | 0.25 |
| CD (P=0.05) | 0.17 | 0.18 | 0.12 | 0.22 | 0.21 | 0.15 | 1.12 | 0.90 | 0.71 |

the efficiency of fertilization process. This is in congruence with the findings of Tahir *et al.* (2012) and Arunkumar and Srinivasa (2018).

**Interaction effect of lime and phosphorus on cob weight**

From table 4.25.b, it can be observed that in both the years, irrespective of lime application, cob weight increased with increase in P levels. Without lime application ($L_0$), cob weight was found to increase up to 90 kg $ha^{-1}$ ($P_{90}$), while with the application of lime, cob weight increased up to 60 kg $P_2O_5$ $ha^{-1}$ ($P_{60}$) and declined at 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$). The observed increase in cob weight with increasing P rate in treatments with no lime application shows that P might be a limiting factor to maize growth in this soil. Highest cob weight was recorded under $L_{25}P_{60}$ treatment combination and lowest cob weight was observed under $L_0P_0$ treatment combination. Significant reduction of Al in the soil due to liming along with the effect of P on cell division and enlargement (Assuero *et al.,* 2004) in plants may have enhanced the cob parameter.

### 4.2.1.5 Effect on number of grains per row, number of rows and grains per cob

The results obtained on the number of rows per cob, number of grains per row, and number of grains per cob in different treatments has been presented in table 4.26.a. Significant response to application of lime with respect to these parameters were observed. Maximum values of all the three parameters were observed in $L_{25}$ while minimum was recorded in the treatment $L_0$ during 2016 and 2017. The increase in these parameters due to liming might be attributed to the reduction in acidity and increase in nutrient availability. Similar results have also been reported by Sierra *et al.* (2003); Adikuru *et al.* (2019) and Devkota *et al.* (2019).

The number of rows per cob was found to be non-significant, while number of grains per row, and number of grains per cob was found to be significant with phosphorus application. It is apparent from Table 4.26.a that

Table 4.25.b: Interaction effect between lime and phosphorus on cob weight

| Lime levels | Cob weight (g) | | | |
|---|---|---|---|---|
| | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ |
| | 2016 | | | |
| $L_0$ | 70.50 | 80.53 | 87.74 | 90.97 |
| $L_{25}$ | 88.51 | 99.67 | 106.56 | 103.44 |
| SEm± | 0.64 | | | |
| CD (P=0.05) | 1.82 | | | |
| | 2017 | | | |
| $L_0$ | 70.07 | 80.99 | 87.86 | 90.14 |
| $L_{25}$ | 88.40 | 100.46 | 106.13 | 104.47 |
| SEm± | 0.52 | | | |
| CD (P=0.05) | 1.48 | | | |
| | Pooled | | | |
| $L_0$ | 70.28 | 80.76 | 87.80 | 90.56 |
| $L_{25}$ | 88.46 | 100.06 | 106.35 | 103.96 |
| SEm± | 0.41 | | | |
| CD (P=0.05) | 1.16 | | | |

Table 4.26.a: Number of grains per row, number of rows and number of grains per cob as affected by lime, phosphorus and boron

| Treatment | No of grains per row | | | No of rows per cob | | | No of grains per cob | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 20.06 | 20.25 | 20.15 | 13.33 | 13.47 | 13.40 | 283.17 | 287.36 | 285.26 |
| $L_{25}$ | 22.81 | 23.36 | 23.08 | 14.92 | 15.00 | 14.96 | 331.69 | 340.97 | 336.33 |
| SEm± | 0.08 | 0.10 | 0.07 | 0.15 | 0.10 | 0.09 | 6.52 | 3.49 | 3.70 |
| CD (P=0.05) | 0.24 | 0.30 | 0.19 | 0.42 | 0.29 | 0.25 | 18.54 | 9.92 | 10.38 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 19.56 | 19.61 | 19.58 | 13.72 | 13.94 | 13.83 | 264.83 | 270.61 | 267.72 |
| $P_{30}$ | 21.50 | 21.44 | 21.47 | 14.17 | 14.28 | 14.22 | 318.94 | 307.78 | 313.36 |
| $P_{60}$ | 21.83 | 22.72 | 22.28 | 14.28 | 14.44 | 14.36 | 321.06 | 338.50 | 329.78 |
| $P_{90}$ | 22.83 | 23.44 | 23.14 | 14.33 | 14.28 | 14.31 | 324.89 | 339.78 | 332.33 |
| SEm± | 0.12 | 0.15 | 0.09 | 0.21 | 0.14 | 0.13 | 9.22 | 4.93 | 5.23 |
| CD (P=0.05) | 0.34 | 0.42 | 0.26 | NS | NS | NS | 26.23 | 14.02 | 14.68 |
| Boron levels | | | | | | | | | |
| $B_0$ | 20.92 | 21.25 | 21.08 | 13.96 | 14.04 | 14.00 | 290.50 | 298.96 | 294.73 |
| $B_1$ | 21.50 | 21.83 | 21.67 | 14.08 | 14.38 | 14.23 | 308.71 | 315.00 | 311.85 |
| $B_2$ | 21.88 | 22.33 | 22.10 | 14.33 | 14.29 | 14.31 | 323.08 | 328.54 | 325.81 |
| SEm± | 0.10 | 0.13 | 0.08 | 0.18 | 0.13 | 0.11 | 7.99 | 4.27 | 4.53 |
| CD (P=0.05) | 0.29 | 0.36 | 0.23 | NS | NS | NS | 22.71 | 12.14 | 12.71 |

the maximum number of grains per row and grains per cob was recorded in treatment $P_{90}$ while the minimum was recorded in the treatment $P_0$ during 2016 and 2017. From pooled data, $P_{90}$ level of phosphorus increased number of grains per row and number of grains per cob to the extent of 18.8% and 24.1%, respectively, over control. However, from pooled data it was observed that treatment $P_{90}$ was at par with treatment $P_{60}$ in case of number of grains per cob. The increase in phosphorus level might have partitioned greater amount of assimilates to ears which may have resulted in an increase in these cob characteristics. Significant effect of phosphorus on these yield attributes have also been reported by Alias *et al.* (2003); Khan *et al.* (2005) and Sadiq *et al.* (2017).

The data (Table 4.26.a) showed that there was no significant difference in the number of rows per cob with respect to application of boron while significant difference was observed in case of number of grains per row and per cob. The maximum number of grains per row and number of grains per cob was observed in the treatment $B_2$ which elucidates the role of boron in pollen viability and seed production of crops. Minimum reading was observed in treatment $B_0$. The present findings are well in agreement with that of Rahim *et al.* (2004) and Tahir *et al.* (2012).

**Interaction effect of lime and phosphorus on number of grains per row and number of grains per cob**

From the data presented in Table 4.26.b, it can be observed that irrespective of liming, number of grains per row and number of grains per cob increased with application of increasing phosphorus levels. The maximum number of grains per row and number of grains per cob was recorded in $L_{25}P_{90}$ and $L_{25}P_{60}$ treatment combination, respectively, while minimum was recorded in $L_0P_0$ during 2016 as well as 2017. In case of number of grains per row, treatment combination $L_{25}P_{90}$ and $L_{25}P_{60}$ were found to be at par with each

Table 4.26.b: Interaction effect between lime and phosphorus on number of grains per row and number of grains per cob

| Lime levels | Number of grains per row | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Phosphorus levels | | | | Phosphorus levels | | | | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ |
| | 2016 | | | | 2017 | | | | Pooled | | | |
| $L_0$ | 18.22 | 20.00 | 20.11 | 21.89 | 18.33 | 19.67 | 20.89 | 22.11 | 18.28 | 19.83 | 20.50 | 22.00 |
| $L_{25}$ | 20.89 | 23.00 | 23.56 | 23.78 | 20.89 | 23.22 | 24.56 | 24.78 | 20.89 | 23.11 | 24.06 | 24.28 |
| SEm± | 0.17 | | | | 0.21 | | | | 0.13 | | | |
| CD (P=0.05) | 0.47 | | | | 0.59 | | | | 0.37 | | | |

| Lime levels | Number of grains per cob | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Phosphorus levels | | | | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ |
| | 2016 | | | | Pooled | | | |
| $L_0$ | 238.89 | 271.11 | 303.78 | 318.89 | 240.78 | 276.44 | 307.61 | 316.22 |
| $L_{25}$ | 290.78 | 366.78 | 338.33 | 330.89 | 294.67 | 350.28 | 351.94 | 348.44 |
| SEm± | 13.04 | | | | 7.40 | | | |
| CD (P=0.05) | 37.09 | | | | 20.76 | | | |

other. In case of number of grains per cob, treatment combination $L_{25}P_{60}$ was found to be at par with $L_{25}P_{30}$ and $L_{25}P_{90}$.

#### 4.2.1.6 Effect on test weight, grain yield and stover yield of maize

The results on the test weight, grain yield and stover yield of maize in different treatments have been presented in Table 4.27.a and Fig 9. Effect of lime was found to be significant with respect to test weight, grain and stover yield, which was found to be highest in the treatment where lime was applied i.e., at $L_{25}$, while the lowest was observed in the control treatment ($L_0$) during 2016 and 2017. The $L_{25}$ level of lime increased pooled grain and stover yield by 24.6% and 23.0%, respectively over control ($L_0$). Liming is essential in order to achieve optimum yields of crops that are grown on acid soils, because it increases pH and reduces acidity-related constraints (Fageria and Baligar, 2008). Furthermore, lime application enhanced yield attributes which resulted in increased grain yield.

From the Table 4.27.a and Fig 9, it can be observed that effect of phosphorus was significant with respect to grain and stover yield during both the years. The maximum grain and stover yield was recorded in treatment $P_{90}$, whereas the minimum grain and stover yield was recorded in the treatment $P_0$ during 2016 as well as 2017. However, $P_{90}$ was at par with $P_{60}$ in case of both grain and stover yield during 2016 as well as 2017. Irrespective of treatment and year, from pooled, the grain yield ranged from 59.93 to 77.47 g $pot^{-1}$ and stover yield ranged from 101.01 to 125.57 g $pot^{-1}$. Each increasing level of phosphorus significantly enhanced pooled grain and stover yield as compared to preceding lower level of phosphorus. The $P_{90}$ level of phosphorus increased grain and stover yield by 24.3% and 22.1%, respectively over control. The increase in grain and stover yield due to phosphorus application may be due to higher yield components like number of grains per cob and higher growth with the addition of phosphorus as P plays important role in plant metabolism,

Table 4.27.a: Test weight, grain yield and stover yield of maize as affected by lime, phosphorus and boron

| Treatment | Test weight (g) | | | Grain yield (g $pot^{-1}$) | | | Stover yield (g $pot^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 22.41 | 22.53 | 22.47 | 61.93 | 62.43 | 62.18 | 101.66 | 102.47 | 102.06 |
| $L_{25}$ | 24.93 | 24.83 | 24.88 | 77.63 | 77.31 | 77.47 | 126.21 | 124.93 | 125.57 |
| SEm± | 0.17 | 0.20 | 0.13 | 0.26 | 0.38 | 0.23 | 1.00 | 0.80 | 0.64 |
| CD (P=0.05) | 0.48 | 0.57 | 0.37 | 0.73 | 1.08 | 0.64 | 2.83 | 2.28 | 1.79 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 23.45 | 23.66 | 23.56 | 59.70 | 60.15 | 59.93 | 101.46 | 100.56 | 101.01 |
| $P_{30}$ | 23.66 | 23.70 | 23.68 | 70.97 | 71.09 | 71.03 | 110.37 | 109.30 | 109.83 |
| $P_{60}$ | 23.86 | 23.66 | 23.76 | 73.78 | 73.92 | 73.85 | 121.45 | 120.64 | 121.04 |
| $P_{90}$ | 23.70 | 23.70 | 23.70 | 74.66 | 74.30 | 74.48 | 122.46 | 124.28 | 123.37 |
| SEm± | 0.24 | 0.28 | 0.19 | 0.36 | 0.54 | 0.32 | 1.41 | 1.13 | 0.90 |
| CD (P=0.05) | NS | NS | NS | 1.03 | 1.53 | 0.91 | 4.01 | 3.22 | 2.54 |
| Boron levels | | | | | | | | | |
| $B_0$ | 23.57 | 23.61 | 23.59 | 66.19 | 64.79 | 65.49 | 108.57 | 105.85 | 107.21 |
| $B_1$ | 23.68 | 23.70 | 23.69 | 71.19 | 71.52 | 71.35 | 113.88 | 117.36 | 115.62 |
| $B_2$ | 23.75 | 23.73 | 23.74 | 71.96 | 73.30 | 72.63 | 119.35 | 117.88 | 118.61 |
| SEm± | 0.21 | 0.25 | 0.16 | 0.31 | 0.47 | 0.28 | 1.22 | 0.98 | 0.78 |
| CD (P=0.05) | NS | NS | NS | 0.89 | 1.33 | 0.79 | 3.47 | 2.79 | 2.20 |

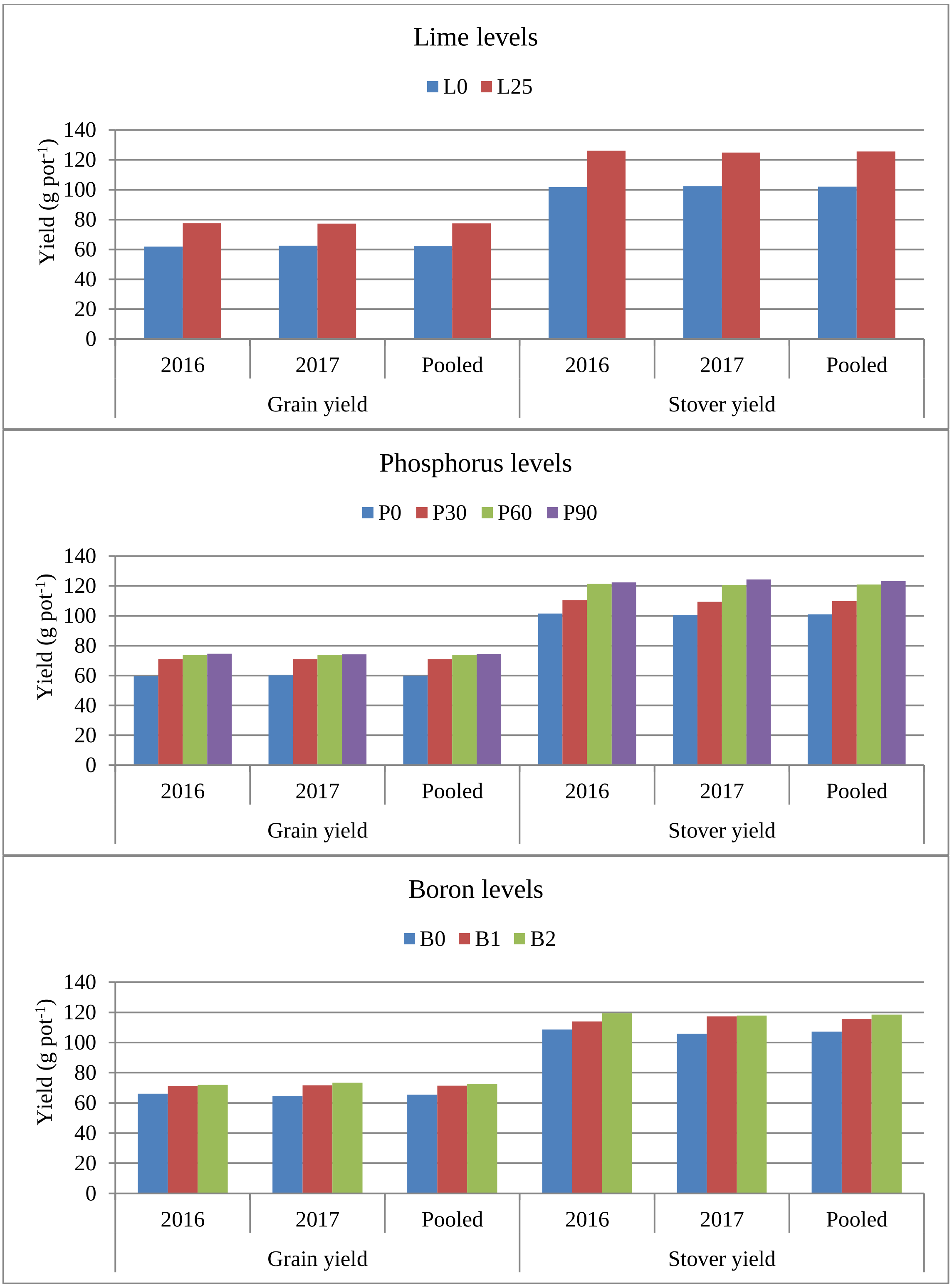


Fig 9: Effect of lime, phosphorus and boron on grain yield and stover yield of maize

finally leading to enhanced yield. Similar results have also been reported by Kumar *et al.* (2017). Results on higher grain and straw yields with higher levels of phosphorus according to the present investigation have also been reported by Arya and Singh (2000).

The effect of boron levels on test weight was non-significant. However, it can be observed that the treatment with higher levels of boron exhibited higher test weight. Significantly highest grain and stover yield was recorded in $B_2$ while the lowest grain and stover yield was recorded in $B_0$ during 2016 and 2017. It was also observed that each increasing level of boron significantly enhanced grain and stover yield in comparison to preceding lower level of boron. From pooled data it can be observed that $B_2$ level of boron increased pooled grain and stover yield by 10.9% and 10.6% over control. The improvement in maize grain and stover yield may be attributed to the complementary role of boron in the reproduction and vegetative stage of plants. The present finding is in agreement with that of Akhter and Mahmud (2009).

**Interaction effect of lime and phosphorus on grain yield**

From the Table 4.27.b it is evident that effect of lime and phosphorus was found to be significant on grain yield in 2016 and 2017. It could be observed that increasing levels of lime as well as phosphorus significantly increased the grain yield in both the years. However, in non-limed pots ($L_0$), highest grain yield was recorded in $P_{90}$, whereas in limed pots ($L_{25}$), highest grain yield was observed in $P_{60}$. Thus, with lime application, phosphorus application up to $P_{60}$ was optimum to achieve the maximum grain yield. Overall, maximum grain yield was observed in treatment combination $L_{25}P_{60}$ and minimum grain yield was observed in $L_0P_0$ during both the years. These results are in line with the findings of Venkatesh (2002); Muindi *et al.* (2015) who reported a significant positive effect of lime and phosphorus on grain yields of crops.

Table 4.27.b: Interaction effect between lime and phosphorus on grain yield

| Lime levels | Grain yield (g $pot^{-1}$) | | | |
|---|---|---|---|---|
| | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ |
| | 2016 | | | |
| $L_0$ | 52.20 | 62.31 | 64.83 | 68.37 |
| $L_{25}$ | 67.21 | 79.64 | 82.73 | 80.96 |
| SEm± | 0.51 | | | |
| CD (P=0.05) | 1.46 | | | |
| | 2017 | | | |
| $L_0$ | 52.52 | 63.41 | 65.61 | 68.16 |
| $L_{25}$ | 67.79 | 78.78 | 82.23 | 80.44 |
| SEm± | 0.76 | | | |
| CD (P=0.05) | 2.16 | | | |
| | Pooled | | | |
| $L_0$ | 52.36 | 62.86 | 65.22 | 68.27 |
| $L_{25}$ | 67.50 | 79.21 | 82.48 | 80.70 |
| SEm± | 0.46 | | | |
| CD (P=0.05) | 1.29 | | | |

#### 4.2.1.7 Nitrogen content in grain and stover

It could be inferred from Table 4.28 that lime had a significant effect on nitrogen content in both grain and stover during 2016 and 2017. From pooled data, it can be seen that irrespective of treatment and year, nitrogen content in grain and stover ranged from 1.00 to 1.20% and from 0.56 to 0.68%, respectively. The nitrogen content in both grain and stover was found to be higher in the treatment where lime was applied ($L_{25}$) as compared to control ($L_0$). Pooled data reflected an increase by 20.0% and 21.4% in the nitrogen content in grain and stover, respectively when lime was applied. Quaggio *et al.* (1991) reported that liming increased root growth and nutrient absorption, mainly nitrogen in maize. Similar findings where application of lime increased the nitrogen content of crop have also been reported by Rosolem and Caires (1998) and Bhat *et al.* (2007).

Effect of phosphorus on nitrogen content in both grain and stover was found to be significant where highest phosphorus content was observed in the treatment $P_{90}$ and the lowest in control ($P_0$). On the basis of pooled data it could be observed that there was an increase in nitrogen content in grain by 10.7% and in stover by 17.5% in the $P_{90}$ treatment when compared to control. However, treatment $P_{90}$ was at par with treatment $P_{60}$ in case of both grain and stover during both the years. The maximum nitrogen content was recorded at higher dose of phosphorus because of the increase in nutrient supply which increased the nutrient contents in both grain and stover. Increase in nutrient supply due to phosphorus application is due to its positive effect on better root system (Sharma *et al.*, 2008) which helps the plant to effectively absorb nutrients from the soil. Similar findings where phosphorus increased the nitrogen content in plants have also been reported by Prajapati *et al.* (2013); Kumar *et al.* (2015); Snehlata (2015) and Etabo *et al.* (2018).

Table 4.28: Nitrogen content in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | N content in grain (%) | | | N content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 0.98 | 1.01 | 1.00 | 0.55 | 0.57 | 0.56 |
| $L_{25}$ | 1.19 | 1.21 | 1.20 | 0.69 | 0.68 | 0.68 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | 0.04 | 0.04 | 0.03 |
| Phosphorus levels | | | | | | |
| $P_0$ | 1.02 | 1.04 | 1.03 | 0.58 | 0.56 | 0.57 |
| $P_{30}$ | 1.10 | 1.11 | 1.10 | 0.61 | 0.59 | 0.60 |
| $P_{60}$ | 1.12 | 1.13 | 1.13 | 0.63 | 0.66 | 0.64 |
| $P_{90}$ | 1.11 | 1.17 | 1.14 | 0.66 | 0.68 | 0.67 |
| SEm± | 0.02 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | 0.04 | 0.04 | 0.03 | 0.06 | 0.05 | 0.04 |
| Boron levels | | | | | | |
| $B_0$ | 1.02 | 1.05 | 1.04 | 0.58 | 0.58 | 0.58 |
| $B_1$ | 1.11 | 1.13 | 1.12 | 0.62 | 0.62 | 0.62 |
| $B_2$ | 1.12 | 1.14 | 1.13 | 0.66 | 0.67 | 0.66 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | 0.04 | 0.04 | 0.03 | 0.05 | 0.05 | 0.03 |

Effect of boron on nitrogen content in grain and stover was significant as evident from Table 4.28. Highest boron content in both grain and stover was observed in the treatment $B_2$, whereas lowest boron content was observed in the treatment $B_0$ during both the years. Boron in $B_2$ treatment increased the nitrogen content by 15% in grain and by 22.2% in stover over $B_0$ treatment. It could also be observed that in case of nitrogen content in grain, $B_2$ was at par with $B_1$. Positive effect of boron on nitrogen content in maize has been reported by Adem *et al.* (2011) and Günes *et al.* (2011).

### 4.2.1.8 Phosphorus content in grain and stover

As evident from Table 4.29, it can be observed that lime had a significant effect on the phosphorus content in both grain and stover, where highest value was observed at 25% lime of LR ($L_{25}$) compared to 0% lime of LR ($L_0$). Irrespective of treatment and year, it can be observed from pooled data that phosphorus content in grain and stover ranged from 0.35 to 0.45% and from 0.12 to 0.16%, respectively. On the basis of pooled data there was an increase by 17.9 % and 13.3% in the phosphorus content in grain and stover, respectively when lime was applied. Verde (2013) reported that lime improved soil acidity preventing P fixation in the soil, enhancing the P solubility which make the nutrient more available and thus increasing its content. Similar findings where lime increased the phosphorus content in plants have been reported by Bhat *et al.* (2007); Busari *et al.* (2008) and Kovacevic and Rastija (2010).

Data pertaining to phosphorus content as affected by phosphorus (Table 4.29) revealed that there was a significant difference among the treatments during 2016 and 2017. The maximum phosphorus content was recorded in $P_{90}$ in grain during both the years, while in stover it was recorded in treatments $P_{60}$ and $P_{90}$ during 2016 and in $P_{60}$ during 2017. Minimum phosphorus content in both grain and stover was recorded in control ($P_0$) during 2016 as well as 2017. On the basis of pooled data there was an increase by 28.6% in case of

Table 4.29: Phosphorus content in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | P content in grain (%) | | | P content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 0.37 | 0.39 | 0.38 | 0.12 | 0.15 | 0.13 |
| $L_{25}$ | 0.43 | 0.46 | 0.45 | 0.15 | 0.16 | 0.16 |
| SEm± | 0.008 | 0.009 | 0.006 | 0.007 | 0.005 | 0.005 |
| CD (P=0.05) | 0.02 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
| Phosphorus levels | | | | | | |
| $P_0$ | 0.34 | 0.36 | 0.35 | 0.11 | 0.14 | 0.12 |
| $P_{30}$ | 0.40 | 0.44 | 0.42 | 0.13 | 0.16 | 0.15 |
| $P_{60}$ | 0.43 | 0.45 | 0.44 | 0.15 | 0.17 | 0.16 |
| $P_{90}$ | 0.44 | 0.45 | 0.45 | 0.15 | 0.16 | 0.16 |
| SEm± | 0.011 | 0.013 | 0.008 | 0.010 | 0.008 | 0.006 |
| CD (P=0.05) | 0.03 | 0.04 | 0.02 | 0.03 | 0.02 | 0.02 |
| Boron levels | | | | | | |
| $B_0$ | 0.38 | 0.39 | 0.38 | 0.12 | 0.13 | 0.13 |
| $B_1$ | 0.40 | 0.44 | 0.42 | 0.13 | 0.17 | 0.15 |
| $B_2$ | 0.43 | 0.45 | 0.44 | 0.15 | 0.17 | 0.16 |
| SEm± | 0.010 | 0.011 | 0.007 | 0.009 | 0.007 | 0.006 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | 0.03 | 0.02 | 0.02 |

phosphorus content in grain and an increase by 33.3% in case of phosphorus content in stover due to $P_{90}$ over control. From pooled data, in case of P content in grain, treatment $P_{90}$ was at par with $P_{60}$, while in case of P content in stover treatment $P_{90}$ was at par with $P_{30}$ and $P_{60}$. Increase in phosphorus content with increasing P application rates have been reported by Rashid and Iqbal (2012) and Saeed *et al.* (2017).

It can be observed from Table 4.29 that there was significant effect of boron on phosphorus content in grain as well as stover during 2016 and 2017. Maximum P content in both grain and stover was observed in treatment $B_2$ and minimum was observed in $B_0$ during both the years of experimentation. On the basis of pooled data there was an increase by 15.8% in boron content in grain and an increase by 23.1% in boron content in stover due to $B_2$ over control. Also from pooled data, it can be observed that treatment $B_2$ was at par with treatment $B_1$. Positive effect of boron on P content in maize has been reported by Adiloglu and Adiloglu (2006); Adem *et al.* (2011) and Gunes *et al.* (2011).

#### 4.2.1.9 Potassium content in grain and stover

The data indicated that the potassium content in both grain and stover significantly increased with the application of lime when compared to control (Table 4.30). Thus, maximum potassium content in grain and stover was observed in $L_{25}$, while, minimum was observed in $L_0$ during 2016 and 2017. Potassium content in grain and stover, irrespective of treatments and years varied from 0.53 to 0.61% and from 1.07 to 1.16%, respectively. It was also observed that stover contained more potassium content than grain. Pooled data reflected an increase by 10.9% in case of potassium content in grain and 4.6% in case of potassium content in stover due to liming. The affirmative influence of liming on K concentration in plants may be due to the synergistic relation between K and Ca. This is in congruence with the findings of Busari *et al.* (2008); Barman *et al.* (2014) and Bhindhu *et al.* (2018).

Table 4.30: Potassium content in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | K content in grain (%) | | | K content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 0.53 | 0.57 | 0.55 | 1.10 | 1.08 | 1.09 |
| $L_{25}$ | 0.59 | 0.62 | 0.61 | 1.15 | 1.14 | 1.14 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | 0.03 | 0.03 | 0.02 |
| Phosphorus levels | | | | | | |
| $P_0$ | 0.52 | 0.54 | 0.53 | 1.08 | 1.05 | 1.07 |
| $P_{30}$ | 0.55 | 0.60 | 0.57 | 1.10 | 1.09 | 1.10 |
| $P_{60}$ | 0.58 | 0.60 | 0.59 | 1.15 | 1.13 | 1.14 |
| $P_{90}$ | 0.59 | 0.63 | 0.61 | 1.17 | 1.16 | 1.16 |
| SEm± | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.05 | 0.05 | 0.03 | 0.04 | 0.04 | 0.03 |
| Boron levels | | | | | | |
| $B_0$ | 0.55 | 0.59 | 0.57 | 1.12 | 1.10 | 1.11 |
| $B_1$ | 0.57 | 0.60 | 0.58 | 1.13 | 1.11 | 1.12 |
| $B_2$ | 0.56 | 0.59 | 0.58 | 1.13 | 1.10 | 1.12 |
| SEm± | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

Effect of phosphorus on potassium content in grain and stover was also found to be significant. Highest potassium content in grain and stover was observed in treatment $P_{90}$ and the lowest in control ($P_0$) during 2016 and 2017. On the basis of pooled data it could be observed that there was an increase in potassium content in grain by 15.1% and in stover by 8.4% in the treatment $P_{90}$ when compared to control. However, treatment $P_{90}$ was at par with treatment $P_{60}$ in case of potassium content in both grain and stover in 2016 as well as 2017. Increase in potassium content due to increasing doses of phosphorus application has been reported by Kumar *et al.* (2015) and Snehlata (2015).

Effect of boron was found to be non- significant in case of potassium content in grain and stover (Table 4.30).

### 4.2.1.10 Calcium content in grain and stover

The data presented in Table 4.31 shows that there was a significant influence of lime on calcium content in grain and stover over control. Thus, highest calcium content in grain and stover was recorded in $L_{25}$ level and lowest calcium content in grain and stover was recorded in $L_0$ during 2016 and 2017. A critical examination of the pooled data indicated that irrespective of treatments and year, calcium content in grain and stover ranged from 0.32 to 0.53% and from 0.35 to 0.49%, respectively. Pooled data observation showed that due to liming there was an increase by 60.0% in case of calcium content in grain and 58.3% in case of calcium content in stover over $L_0$. Enhanced concentration of calcium in plant as a result of liming is related to the addition of significant amount of Ca through lime ($CaCO_3$) which is in line with the findings of Kovacevic and Rastija (2010); Barman *et al.* (2014) and Bhindhu *et al.* (2018).

Effect of phosphorus on calcium content in grain and stover was found to be significant (Table 4.31). Highest calcium content was observed in

Table 4.31: Calcium content in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | Ca content in grain (%) | | | Ca content in stover (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 0.35 | 0.34 | 0.35 | 0.36 | 0.35 | 0.36 |
| $L_{25}$ | 0.56 | 0.55 | 0.56 | 0.57 | 0.57 | 0.57 |
| SEm± | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.05 | 0.05 | 0.04 | 0.03 | 0.04 | 0.02 |
| Phosphorus levels | | | | | | |
| $P_0$ | 0.38 | 0.38 | 0.38 | 0.40 | 0.41 | 0.40 |
| $P_{30}$ | 0.47 | 0.44 | 0.46 | 0.47 | 0.48 | 0.47 |
| $P_{60}$ | 0.49 | 0.48 | 0.48 | 0.46 | 0.48 | 0.47 |
| $P_{90}$ | 0.49 | 0.49 | 0.49 | 0.52 | 0.49 | 0.50 |
| SEm± | 0.03 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | 0.07 | 0.08 | 0.05 | 0.05 | 0.05 | 0.04 |
| Boron levels | | | | | | |
| $B_0$ | 0.47 | 0.46 | 0.47 | 0.47 | 0.47 | 0.47 |
| $B_1$ | 0.46 | 0.44 | 0.45 | 0.47 | 0.47 | 0.47 |
| $B_2$ | 0.45 | 0.44 | 0.45 | 0.46 | 0.46 | 0.46 |
| SEm± | 0.02 | 0.02 | 0.02 | 0.01 | 0.02 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

treatment $P_{90}$ while lowest was observed in control ($P_0$) in case of both grain and stover in both the years. Pooled data reflected an increase in calcium content by 28.9% and 24.9% in grain and stover, respectively in treatment $P_{90}$ over $P_0$. Treatment $P_{90}$ was found to be at par with treatments $P_{30}$ and $P_{60}$ in Ca content in both grain and stover. This result is in line with the findings of Kumar *et al.* (2017) and Wafula *et al.* (2018) where they observed an increase in plant calcium contents with increase in rate of phosphorus application.

The effect of boron on calcium content in grain and stover was found to be non-significant as can be observed from Table 4.31.

#### 4.2.1.11 Boron content in grain and stover

The data (Table 4.32.a) indicated that B content in grain and stover was recorded highest in the treatment $L_{25}$ and lowest in treatment $L_0$ during 2016 and 2017, where on the basis of pooled data, liming ($L_{25}$) increased the boron content in grain by 2.1% and in stover by 5.0%. Irrespective of treatments and year, from pooled data it can be observed that boron content in grain and stover ranged from 9.04 to 12.57 mg $kg^{-1}$ and from 3.18 to 4.19 mg $kg^{-1}$, respectively. The increase in boron content in the plant due to liming may be due to increase in its availability in the soil as a result of neutralization of soil acidity which releases boron in the soil solution (Sarkar *et al.,* 2015). Similar findings have also been reported by Barman *et al.* (2014).

The data pertaining to effect of phosphorus on boron content (Table 4.32.a) revealed that there was no significant difference among the treatments during 2016 and 2017.

The effect of boron on boron content in grain and stover was significant where there was an increase in the content with increasing levels of boron. The highest boron content for both grain and stover was recorded in $B_2$ while the minimum boron content in grain and stover was observed in $B_0$ during 2016 and 2017. The $B_2$ level of boron enhanced pooled B content in grain and stover

Table 4.32.a: Boron content in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | B content in grain (mg kg$^{-1}$) | | | B content in stover (mg kg$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 10.81 | 10.86 | 10.83 | 3.73 | 3.76 | 3.75 |
| $L_{25}$ | 11.03 | 11.08 | 11.06 | 3.93 | 3.95 | 3.94 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.02 |
| Phosphorus levels | | | | | | |
| $P_0$ | 10.91 | 10.97 | 10.94 | 3.82 | 3.84 | 3.83 |
| $P_{30}$ | 10.93 | 10.96 | 10.94 | 3.83 | 3.85 | 3.84 |
| $P_{60}$ | 10.92 | 10.98 | 10.95 | 3.85 | 3.87 | 3.86 |
| $P_{90}$ | 10.91 | 10.96 | 10.94 | 3.84 | 3.87 | 3.85 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| Boron levels | | | | | | |
| $B_0$ | 9.01 | 9.07 | 9.04 | 3.16 | 3.20 | 3.18 |
| $B_1$ | 11.20 | 11.25 | 11.22 | 4.16 | 4.18 | 4.17 |
| $B_2$ | 12.55 | 12.60 | 12.57 | 4.18 | 4.21 | 4.19 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.03 | 0.02 | 0.04 | 0.03 | 0.02 |

Table 4.32.b: Interaction effect between lime and boron on boron content in stover

| Lime levels | B content in stover (%) | | |
|---|---|---|---|
| | Boron levels | | |
| | $B_0$ | $B_1$ | $B_2$ |
| | 2016 | | |
| $L_0$ | 3.09 | 4.04 | 4.07 |
| $L_{25}$ | 3.24 | 4.27 | 4.29 |
| SEm± | 0.02 | | |
| CD (P=0.05) | 0.05 | | |
| | 2017 | | |
| $L_0$ | 3.14 | 4.07 | 4.09 |
| $L_{25}$ | 3.26 | 4.28 | 4.32 |
| SEm± | 0.02 | | |
| CD (P=0.05) | 0.04 | | |
| | Pooled | | |
| $L_0$ | 3.12 | 4.05 | 4.08 |
| $L_{25}$ | 3.25 | 4.28 | 4.31 |
| SEm± | 0.01 | | |
| CD (P=0.05) | 0.03 | | |

by 39.0% and 31.8%, respectively over control. However, in case of B content in stover treatment $B_2$ was at par with treatment $B_1$. The present finding where B content in the plant increased with application of boron is in line with the findings of Barman *et al.* (2014) and Sahin (2014) who reported that where B was supplemented through external sources, B concentration in plant increased.

**Interaction effect of lime and boron on boron content in stover**

From Table 4.32.b, it is evident that interaction effect of lime and boron had a significant positive effect on boron content in stover during 2016 and 2017. The highest B content in both lime levels of $L_0$ (control) and $L_{25}$ (25% lime of LR) was observed in $B_2$ (2 kg B $ha^{-1}$) level during both the years. Also, in both the years in both lime levels, treatment $B_2$ was observed to be at par with $B_1$. Thus, in both the treatments, $L_0$ (control) and $L_{25}$ (25% lime of LR), boron level of $B_1$ was found to be optimum for increasing B content in stover.

**4.2.1.12 Nitrogen uptake in grain and stover**

The results on nitrogen uptake in grain and stover due to different treatments have been presented in Table 4.33.a and Fig 10. The nitrogen uptake in grain and stover showed significant response to lime. It is apparent from the data that maximum nitrogen uptake was recorded in $L_{25}$ while the minimum was recorded in $L_0$ for grain and stover during 2016 and 2017. Pooled data reflected that there was an increase in nitrogen uptake by 49.8% and 50.3% in grain and stover, respectively due to liming ($L_{25}$) over control ($L_0$). The B content in the plant increased with application of boron is in line with the findings of Barman *et al.* (2014) and Sahin (2014) who reported that where B was supplemented through external sources, B concentration in plant increased. increase in nitrogen uptake might be due to the increase in the available soil nitrogen content. Increase in nitrogen uptake due to liming has been reported in earlier works, where maize recorded maximum uptake of N, P

Table 4.33.a: Nitrogen uptake in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | N uptake in grain (mg $pot^{-1}$) | | | N uptake in stover (mg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 611.59 | 634.12 | 622.86 | 561.71 | 586.36 | 574.04 |
| $L_{25}$ | 927.10 | 939.50 | 933.30 | 872.27 | 853.79 | 863.03 |
| SEm± | 7.24 | 7.28 | 5.13 | 15.31 | 14.91 | 10.69 |
| CD (P=0.05) | 20.58 | 20.71 | 14.41 | 43.54 | 42.40 | 30.00 |
| Phosphorus levels | | | | | | |
| $P_0$ | 614.93 | 633.70 | 624.32 | 591.81 | 569.63 | 580.72 |
| $P_{30}$ | 787.23 | 794.95 | 791.09 | 679.58 | 657.49 | 668.53 |
| $P_{60}$ | 839.74 | 841.95 | 840.84 | 775.89 | 797.13 | 786.51 |
| $P_{90}$ | 835.47 | 876.64 | 856.06 | 820.69 | 856.05 | 838.37 |
| SEm± | 10.24 | 10.30 | 7.26 | 21.66 | 21.09 | 15.11 |
| CD (P=0.05) | 29.10 | 29.29 | 20.38 | 61.58 | 59.96 | 42.43 |
| Boron levels | | | | | | |
| $B_0$ | 687.89 | 691.33 | 689.61 | 637.35 | 619.29 | 628.32 |
| $B_1$ | 803.40 | 821.22 | 812.31 | 718.38 | 743.08 | 730.73 |
| $B_2$ | 816.74 | 847.89 | 832.31 | 795.25 | 797.85 | 796.55 |
| SEm± | 8.86 | 8.92 | 6.29 | 18.75 | 18.26 | 13.09 |
| CD (P=0.05) | 25.20 | 25.37 | 17.65 | 53.33 | 51.93 | 36.74 |

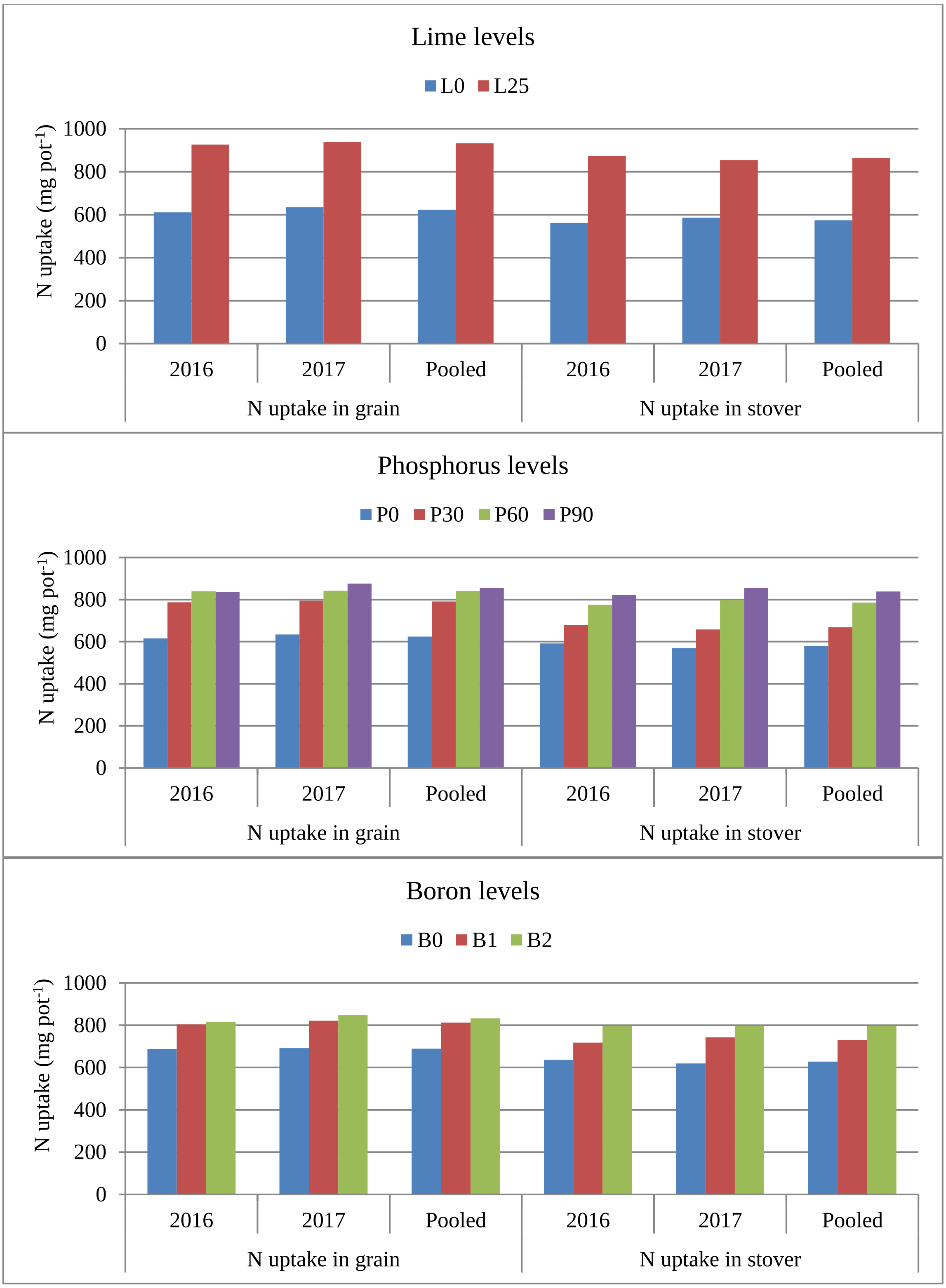


Fig 10: Effect of lime, phosphorus and boron on nitrogen uptake in grain and stover of maize

and K next to soybean in a study conducted by Gupta *et al.* (1989). Increased N uptake with lime on various crops have also been reported by Kanwar and Paliyal (2002); Busari *et al.* (2005); Ranjit *et al.* (2007) and Lynrah and Nongmaithem (2017).

The maximum nitrogen uptake was recorded in $P_{90}$ while the minimum was recorded in control ($P_0$) in both grain as well as stover during 2016 and 2017. Pooled data reflected that there was an increase in nitrogen uptake by 37.1% and 44.4% in grain and stover, respectively due to $P_{90}$ level over control ($P_0$). The results are in congruence with the findings of Kumar *et al.* (2006); Awomi *et al.* (2012) and Etabo *et al.* (2018). Positive response in nitrogen uptake due to application of phosphorus may be as a result of the role of phosphorus in cell division of shoot and extended growth of meristematic tissues or foliage (Jaetzold *et al.,* 2006 and Etabo *et al.,* 2018).

The results on effect of boron on nitrogen uptake revealed that there was a significant difference among the treatments in case of nitrogen uptake in grain, and stover, where maximum uptake was recorded in treatment $B_2$ while the minimum uptake was recorded in $B_0$ during 2016 and 2017. On the basis of pooled data, $B_2$ level increased nitrogen uptake in grain by 20.7% and in stover by 26.7% over control. It was thus observed that the presence of nutritional element such as boron may have increased the nitrogen uptake in plants. Similar result where the effect of boron on N uptake and metabolism was found to be positive was reported by Inal and Tarakcioglu (2001); Aref (2011) and Sahin (2014).

**Interaction effect of lime and phosphorus on nitrogen uptake in grain**

From Table 4.33.b, it is apparent that interaction effect of lime and phosphorus on nitrogen uptake in grain was found to be significant in the year 2016 along with pooled data. Highest nitrogen uptake was observed in treatment combination $L_{25}P_{60}$ and minimum was observed in treatment

Table 4.33.b: Interaction effect between lime and phosphorus on nitrogen uptake in grain

| Lime levels | N uptake in grain (mg $pot^{-1}$) | | | |
|---|---|---|---|---|
| | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ |
| | 2016 | | | |
| $L_0$ | 480.35 | 617.65 | 664.22 | 684.16 |
| $L_{25}$ | 749.52 | 956.81 | 1015.26 | 986.79 |
| SEm± | 14.48 | | | |
| CD (P=0.05) | 41.16 | | | |

combination $L_0P_0$. It could also be observed that at lime level $L_0$, N uptake was highest at phosphorus level $P_{90}$ and at lime level $L_{25}$, it was highest at $P_{60}$. Thus, lime and phosphorus together had a significant positive impact on nitrogen uptake.

#### 4.2.1.13 Phosphorus uptake in grain and stover

The results on effect of lime revealed that there was a significant effect on the treatments (Table 4.34.a and Fig 11). During 2016 and 2017, the maximum phosphorus uptake in both grain and stover was recorded in $L_{25}$ while the minimum phosphorus uptake in both grain and stover was recorded in $L_0$. On the basis of pooled data, phosphorus uptake in grain and stover increased by 45.9% and 44.4%, respectively due to liming ($L_{25}$) over control ($L_0$). The increase in phosphorus uptake due to liming may be because it breaks the Al and Fe phosphates in soil, thereby making it available to plant. Also, available phosphorus may increase due to increase in mineralization of organic phosphorus as affected by lime (Haynes, 1982). Increased P uptake due to liming in maize has been reported by Busari *et al.* (2005); Singh *et al.* (2009) and Yadesa *et al.* (2019).

The phosphorus uptake by grain and stover was found to be higher in treatments with higher levels of phosphorus as can be seen from table 4.34.a. The maximum phosphorus uptake in grain was recorded in treatment $P_{90}$ during 2016 as well as 2017, while in stover it was recorded in $P_{90}$ in 2016 and $P_{60}$ in 2017. On the basis of pooled data there was an increase in phosphorus uptake by 58.5% and 55.7%, respectively in grain and stover due to application of 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$) and 60 kg $P_2O_5$ $ha^{-1}$ ($P_{60}$), respectively over control. Treatments $P_{60}$ and $P_{90}$ were found to be at par with each other in case of P uptake in grain and stover. The minimum phosphorus uptake in both grain and stover was observed in the treatment $P_0$ during 2016 and 2017. Increase in uptake of nutrients was attributed to higher concentration of nutrients as a result of increased availability of nutrients from soil and fertilizer

Table 4.34.a: Phosphorus uptake in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | P uptake in grain (mg pot$^{-1}$) | | | P uptake in stover (mg pot$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 230.08 | 247.77 | 238.93 | 123.16 | 152.73 | 137.94 |
| $L_{25}$ | 338.52 | 358.87 | 348.69 | 190.53 | 208.03 | 199.28 |
| SEm± | 5.29 | 5.86 | 3.95 | 8.14 | 5.95 | 5.04 |
| CD (P=0.05) | 15.04 | 16.66 | 11.08 | 23.16 | 16.91 | 14.15 |
| Phosphorus levels | | | | | | |
| $P_0$ | 204.73 | 218.84 | 211.79 | 111.25 | 137.53 | 124.39 |
| $P_{30}$ | 283.86 | 316.39 | 300.13 | 150.10 | 177.42 | 163.76 |
| $P_{60}$ | 317.77 | 337.42 | 327.59 | 181.16 | 206.15 | 193.66 |
| $P_{90}$ | 330.84 | 340.63 | 335.73 | 184.87 | 200.42 | 192.64 |
| SEm± | 7.48 | 8.29 | 5.58 | 11.52 | 8.41 | 7.13 |
| CD (P=0.05) | 21.27 | 23.56 | 15.67 | 32.75 | 23.91 | 20.01 |
| Boron levels | | | | | | |
| $B_0$ | 253.34 | 256.33 | 254.83 | 133.99 | 140.52 | 137.26 |
| $B_1$ | 287.16 | 318.38 | 302.77 | 149.48 | 199.77 | 174.62 |
| $B_2$ | 312.40 | 335.24 | 323.82 | 187.06 | 200.85 | 193.96 |
| SEm± | 6.48 | 7.18 | 4.83 | 9.97 | 7.28 | 6.17 |
| CD (P=0.05) | 18.42 | 20.41 | 13.57 | 28.36 | 20.70 | 17.33 |

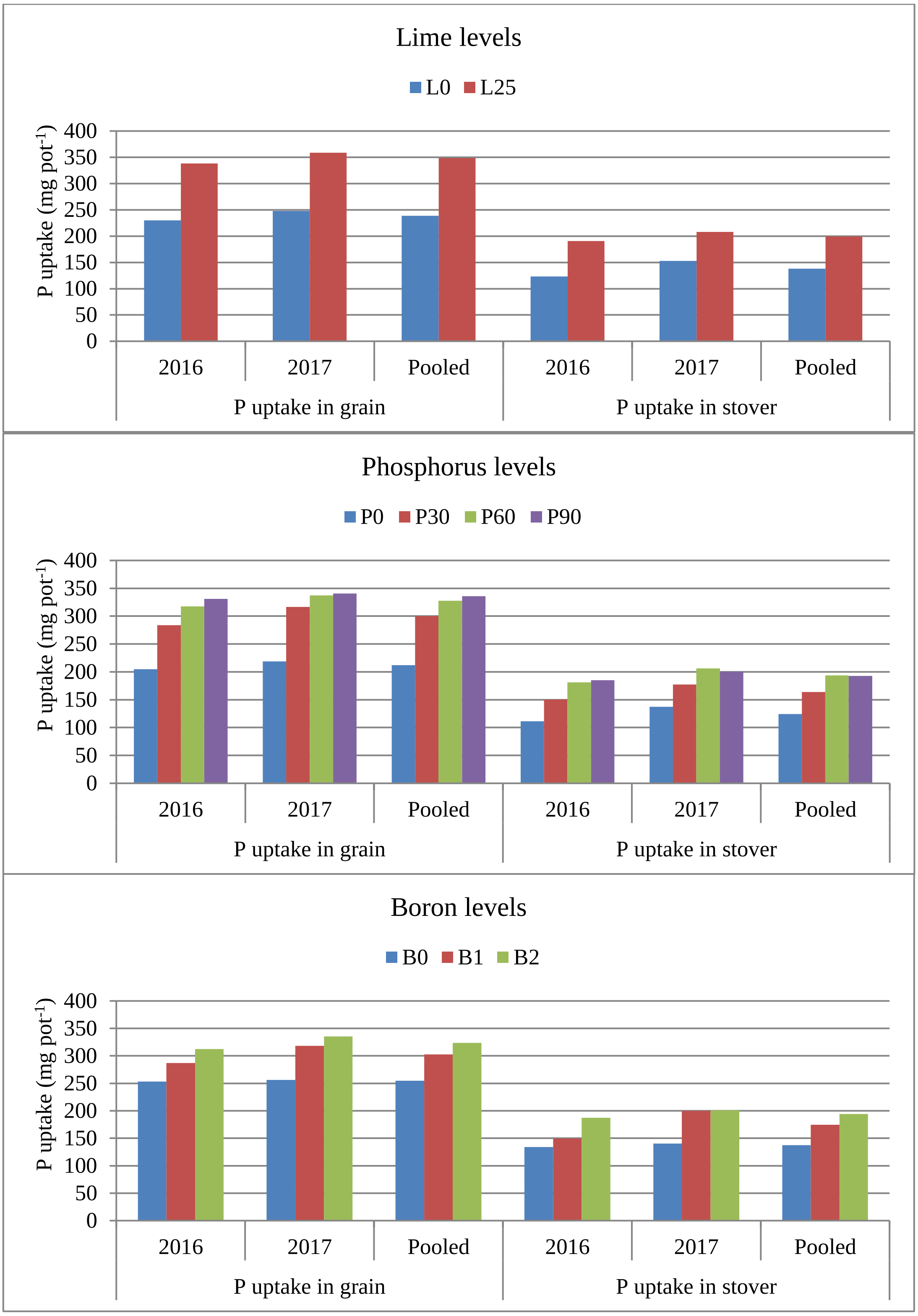


Fig 11: Effect of lime, phosphorus and boron on phosphorus uptake in grain and stover of maize

(Shankarlingappa *et al.*, 2000). Nutrient uptake was recorded maximum with highest dose which was significantly superior to its lower level and control. This was because under these treatments, there was higher biological production which must have increased the nutrient uptake. Affirmative effect of P on phosphorus uptake was observed by Khan *et al.* (2002); Kumar *et al.* (2006); Singh and Singh (2012) and Kumar *et al.* (2015).

Effect of boron on phosphorus uptake in both grain and stover was found to be significant during both the years. Maximum P uptake was recorded in treatment $B_2$ and minimum was recorded in treatment $B_0$ in both grain and stover during 2016 as well as 2017. On the basis of pooled data there was an increase in phosphorus uptake by 27.1% and 41.3%, respectively in grain and stover due to application of 2 kg B $ha^{-1}$ ($B_2$) over control ($B_0$). Similar findings have been reported by Aref (2011); Sentimenla *et al.* (2013) and Singh *et al.* (2012), where boron application enhanced the P uptake in plant.

**Interaction effect of lime and phosphorus on phosphorus uptake in grain**

Interaction effect of lime and phosphorus on phosphorus uptake in grain was significant during 2016 along with pooled data as can be seen from Table 4.34.b. It can be observed that P uptake increased with increase in levels of P application with maximum uptake in $P_{90}$ level in both lime levels of $L_0$ (control) and $L_{25}$ (25% lime of LR). The highest P uptake in grain was observed in treatment combination $L_{25}P_{90}$ which was at par with $L_{25}P_{60}$. Treatments with lime application gave higher P uptake compared to treatments without lime application at all levels of phosphorus application. Also, in $L_{25}$ lime level, treatment $P_{90}$ was at par with $P_{60}$. Thus, in treatment $L_0$ (control), phosphorus level of $P_{90}$ was found to be the optimum level, whereas in the treatment $L_{25}$ (25% lime of LR), phosphorus level of $P_{60}$ was found to be the optimum level for increasing phosphorus uptake in grain.

Table 4.34.b: Interaction effect between lime and phosphorus on phosphorus uptake in grain

| Lime levels | P uptake in grain (mg $pot^{-1}$) | | | |
|---|---|---|---|---|
| | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{90}$ |
| | 2016 | | | |
| $L_0$ | 171.59 | 224.03 | 250.36 | 274.36 |
| $L_{25}$ | 237.88 | 343.69 | 385.18 | 387.33 |
| SEm± | 10.58 | | | |
| CD (P=0.05) | 30.08 | | | |

### 4.2.1.14 Potassium uptake in grain and stover

It is evident from Table 4.35 and Fig 12 that effect of lime on potassium uptake in grain and stover showed significant difference. The maximum potassium uptake in both grain and stover was recorded in $L_{25}$ while the minimum potassium uptake was recorded in $L_0$ during 2016 and 2017. Percent increase by 37.7% and 29.5%, respectively in grain and stover was observed in pooled data due to application of $L_{25}$ level of lime over control. Increase in potassium uptake due to liming has been reported in earlier works, where maize recorded maximum uptake of N, P and K next to soybean in a study conducted by Gupta *et al.* (1989). Significant effect of liming on potassium uptake in various crops including maize has been reported by Ranjit *et al.* (2007); Beukes *et al.* (2012); Otieno *et al.* (2018) and Zhihao *et al.* (2019).

Effect of phosphorus on potassium uptake in grain and stover was found to be significant in both the years. It is apparent from table 4.35 that maximum potassium uptake in grain and stover was observed in $P_{90}$ and minimum uptake in both grain and stover was observed in treatment $P_0$. Pooled data reflected an increase in potassium uptake in grain by 42.7% and in stover by 33.1% due to application of 90 kg $P_2O_5$ $ha^{-1}$ over control. However, potassium uptake in stover in treatment $P_{90}$ was at par with treatment $P_{60}$. Increase in potassium uptake due to phosphorus fertilizer application may be explained on the ground that the addition of phosphorus increased the nutrient content of plant by enhancing the root growth and increasing the root hair length, besides increasing the root surface area (Darwesh *et al.*, 2013). Significant increase in potassium uptake due to increasing doses of phosphorus application was also reported by Shankarlingappa *et al.* (2000); Kumar *et al.* (2006) and Kumar *et al.* (2015).

Effect of boron on potassium uptake in both grain and stover was found to be significant in both the years. Maximum potassium uptake in both grain and stover was recorded in the treatment $B_2$ and minimum was recorded in $B_0$

Table 4.35: Potassium uptake in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | K uptake in grain (mg $pot^{-1}$) | | | K uptake in stover (mg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 329.24 | 355.39 | 342.32 | 1120.73 | 1105.61 | 1113.17 |
| $L_{25}$ | 459.03 | 483.68 | 471.36 | 1459.08 | 1423.81 | 1441.45 |
| SEm± | 7.34 | 8.26 | 5.53 | 15.45 | 13.78 | 10.35 |
| CD (P=0.05) | 20.88 | 23.50 | 15.52 | 43.94 | 39.18 | 29.06 |
| Phosphorus levels | | | | | | |
| $P_0$ | 312.60 | 329.72 | 321.16 | 1100.57 | 1058.12 | 1079.34 |
| $P_{30}$ | 389.78 | 429.03 | 409.41 | 1219.78 | 1195.08 | 1207.43 |
| $P_{60}$ | 430.07 | 446.93 | 438.50 | 1404.56 | 1366.05 | 1385.31 |
| $P_{90}$ | 444.10 | 472.46 | 458.28 | 1434.71 | 1439.58 | 1437.15 |
| SEm± | 10.39 | 11.69 | 7.82 | 21.85 | 19.49 | 14.64 |
| CD (P=0.05) | 29.53 | 33.23 | 21.94 | 62.14 | 55.41 | 41.10 |
| Boron levels | | | | | | |
| $B_0$ | 367.48 | 386.98 | 377.23 | 1221.20 | 1172.84 | 1197.02 |
| $B_1$ | 407.00 | 432.68 | 419.84 | 1293.72 | 1312.76 | 1303.24 |
| $B_2$ | 407.93 | 438.95 | 423.44 | 1354.79 | 1308.51 | 1331.65 |
| SEm± | 9.00 | 10.12 | 6.77 | 18.92 | 16.88 | 12.68 |
| CD (P=0.05) | 25.58 | 28.78 | 19.00 | 53.81 | 47.99 | 35.59 |

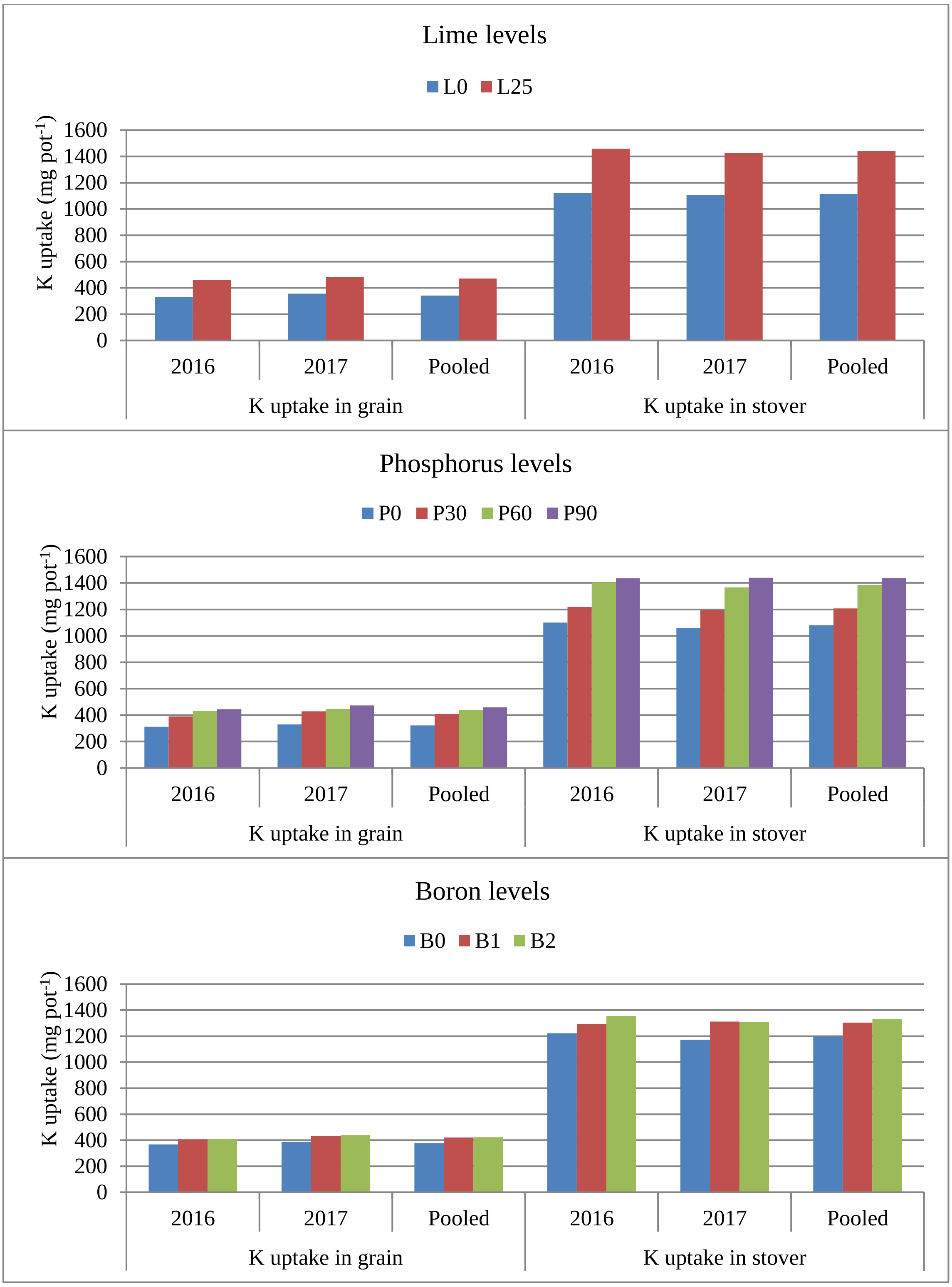


Fig 12: Effect of lime, phosphorus and boron on potassium uptake in grain and stover of maize

in both the years. From pooled data, it can be observed that K uptake in grain and stover increased by 12.2% and 11.2%, respectively from treatment $B_0$ to $B_2$. Similar observations where B enhanced potassium uptake in plant has been reported by Günes *et al.* (2011) and Sentimenla *et al.* (2013).

### 4.2.1.15 Calcium uptake in grain and stover

From Table 4.36 and Fig 13, it can be seen that effect of lime on calcium uptake was significant, where maximum calcium uptake was recorded in treatment $L_{25}$ while minimum uptake was recorded in $L_0$ during 2016 as well as 2017. According to pooled data, an increase by 98.6% and 97.4% in calcium uptake by grain and stover, respectively could be observed with application of $L_{25}$ over $L_0$. Liming might have contributed to Ca uptake by improving the Ca nutrition of crop in addition to neutralizing the Al toxicity. Significant increase in uptake of calcium with increasing doses of lime has been reported by Prasad (1992); Ranjit *et al.* (2007); Singh *et al.* (2009) and Sultana *et al.* (2009).

Effect of phosphorus on calcium uptake in grain and stover was found to be significant in both the years. It is apparent from table 4.36.a that maximum calcium uptake in grain and stover was observed in treatment $P_{90}$ and minimum in treatment $P_0$. Pooled data reflected an increase by 60.8% and 50.3% on calcium uptake in grain and stover, respectively due to 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$) over control ($P_0$). In case of Ca uptake in grain treatment $P_{90}$ was at par with $P_{60}$. This result is in line with the findings of Kumar *et al.* (2017) and Wafula *et al.* (2018) where they observed an increase in calcium contents with increase in rate of phosphorus.

It is apparent from table 4.36 that effect of phosphorus and boron levels was found to be non-significant in case of Ca uptake in both grain and stover during 2016 as well as 2017.

Table 4.36: Calcium uptake in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | Ca uptake in grain (mg $pot^{-1}$) | | | Ca uptake in stover (mg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 220.70 | 216.06 | 218.38 | 366.79 | 364.43 | 365.61 |
| $L_{25}$ | 440.23 | 427.27 | 433.75 | 723.49 | 719.83 | 721.66 |
| SEm± | 13.15 | 13.61 | 9.46 | 14.85 | 13.86 | 10.16 |
| CD (P=0.05) | 37.41 | 38.70 | 26.57 | 42.21 | 39.42 | 28.51 |
| Phosphorus levels | | | | | | |
| $P_0$ | 232.06 | 231.86 | 231.96 | 419.43 | 424.03 | 421.73 |
| $P_{30}$ | 345.65 | 322.54 | 334.09 | 532.50 | 534.48 | 533.49 |
| $P_{60}$ | 369.50 | 360.63 | 365.07 | 579.40 | 591.15 | 585.27 |
| $P_{90}$ | 374.64 | 371.63 | 373.13 | 649.25 | 618.87 | 634.06 |
| SEm± | 18.60 | 19.25 | 13.38 | 21.00 | 19.60 | 14.36 |
| CD (P=0.05) | 52.90 | 54.73 | 37.57 | 59.70 | 55.74 | 40.32 |
| Boron levels | | | | | | |
| $B_0$ | 324.02 | 305.97 | 314.99 | 523.51 | 509.49 | 516.50 |
| $B_1$ | 335.83 | 324.01 | 329.92 | 551.50 | 562.26 | 556.88 |
| $B_2$ | 331.54 | 335.01 | 333.28 | 560.42 | 554.64 | 557.53 |
| SEm± | 16.11 | 16.67 | 11.59 | 18.18 | 16.98 | 12.44 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

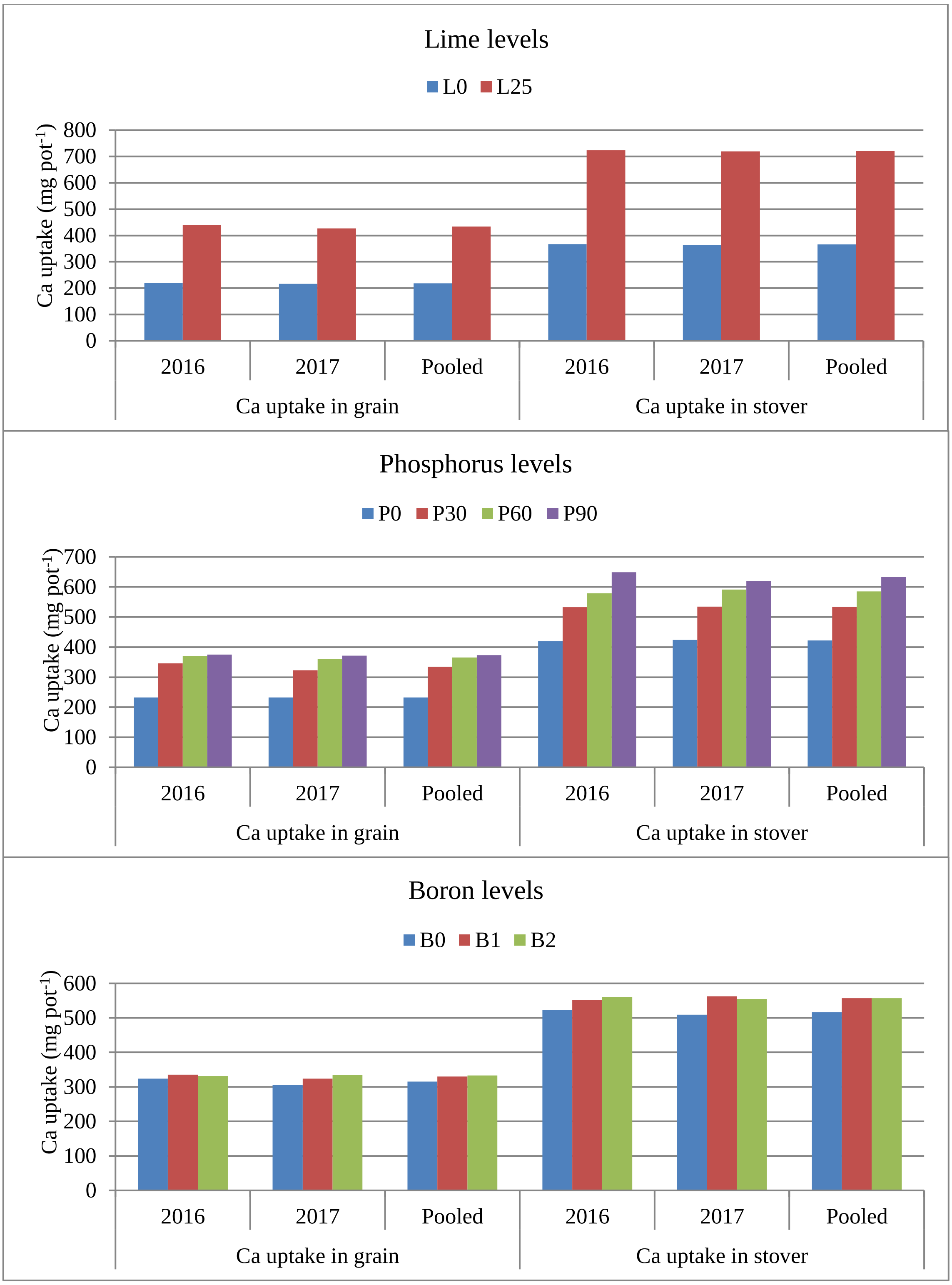


Fig 13: Effect of lime, phosphorus and boron on calcium uptake in grain and stover of maize

#### 4.2.1.16 Boron uptake in grain and stover

The data indicates that boron uptake in grain and stover was found to be significantly affected by the application of lime (Table 4.37.a and Fig 14). The maximum boron uptake in both grain and stover was recorded in $L_{25}$ while minimum boron uptake in both grain and stover was recorded in $L_0$ in both the years 2016 and 2017. Due to $L_{25}$ level of lime, an increase in boron uptake by 27.0% and 29.3% in grain and stover, respectively was observed from the pooled data. This is parallel with the findings of Singh *et al.* (2009) and Barman *et al.* (2014) who stated a significantly higher uptake of boron by maize crop with application of lime.

B uptake in grain and stover showed significant difference among different levels of phosphorus. It is apparent from the data that maximum B uptake in both grain and stover was recorded with $P_{90}$ while minimum B uptake in both grain and stover was observed in $P_0$ during 2016 and 2017. Due to $P_{90}$ level of phosphorus application, an increase in boron uptake by 23.9% and 22.7% in grain and stover, respectively could be observed from pooled data. In both the years, $P_{90}$ was found to be at par with $P_{60}$ in case of B uptake in both grain and stover. Muhlbachova *et al.* (2017) also reported a positive effect of phosphorus fertilization on boron uptake by plants.

It is clear from the data presented in Table 4.37.a that boron application enhanced boron uptake significantly during both the years.The maximum B uptake in both grain and stover was recorded in $B_2$, while the minimum uptake was recorded in $B_0$ in both grain and stover during 2016 and 2017. An increase in boron uptake by 54.2% and 45.9% in grain and stover, respectively due to $B_2$ level of boron application could be observed from the pooled data. Various workers (Sahin, 2014 and Barman *et al.*, 2014) have also reported a significant increase in plant's boron uptake due to boron fertilization.

Table 4.37.a: Boron uptake in grain and stover of maize as affected by lime, phosphorus and boron

| Treatment | B uptake in grain (µg $pot^{-1}$) | | | B uptake in stover (µg $pot^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 672.92 | 682.83 | 677.87 | 381.32 | 388.26 | 384.79 |
| $L_{25}$ | 859.82 | 862.05 | 860.93 | 498.46 | 496.66 | 497.56 |
| SEm± | 2.84 | 3.99 | 2.45 | 4.01 | 3.11 | 2.53 |
| CD (P=0.05) | 8.07 | 11.34 | 6.87 | 11.39 | 8.84 | 7.12 |
| Phosphorus levels | | | | | | |
| $P_0$ | 656.42 | 666.23 | 661.32 | 390.00 | 390.09 | 390.04 |
| $P_{30}$ | 779.68 | 785.76 | 782.72 | 425.79 | 424.28 | 425.04 |
| $P_{60}$ | 810.61 | 817.64 | 814.12 | 470.81 | 470.92 | 470.87 |
| $P_{90}$ | 818.77 | 820.13 | 819.45 | 472.95 | 484.54 | 478.74 |
| SEm± | 4.01 | 5.64 | 3.46 | 5.67 | 4.39 | 3.58 |
| CD (P=0.05) | 11.41 | 16.04 | 9.72 | 16.11 | 12.49 | 10.06 |
| Boron levels | | | | | | |
| $B_0$ | 597.10 | 588.13 | 592.62 | 344.57 | 339.00 | 341.79 |
| $B_1$ | 798.03 | 805.10 | 801.56 | 474.77 | 491.32 | 483.05 |
| $B_2$ | 903.98 | 924.09 | 914.04 | 500.32 | 497.05 | 498.69 |
| SEm± | 3.47 | 4.89 | 3.00 | 4.91 | 3.81 | 3.10 |
| CD (P=0.05) | 9.88 | 13.89 | 8.41 | 13.95 | 10.82 | 8.72 |

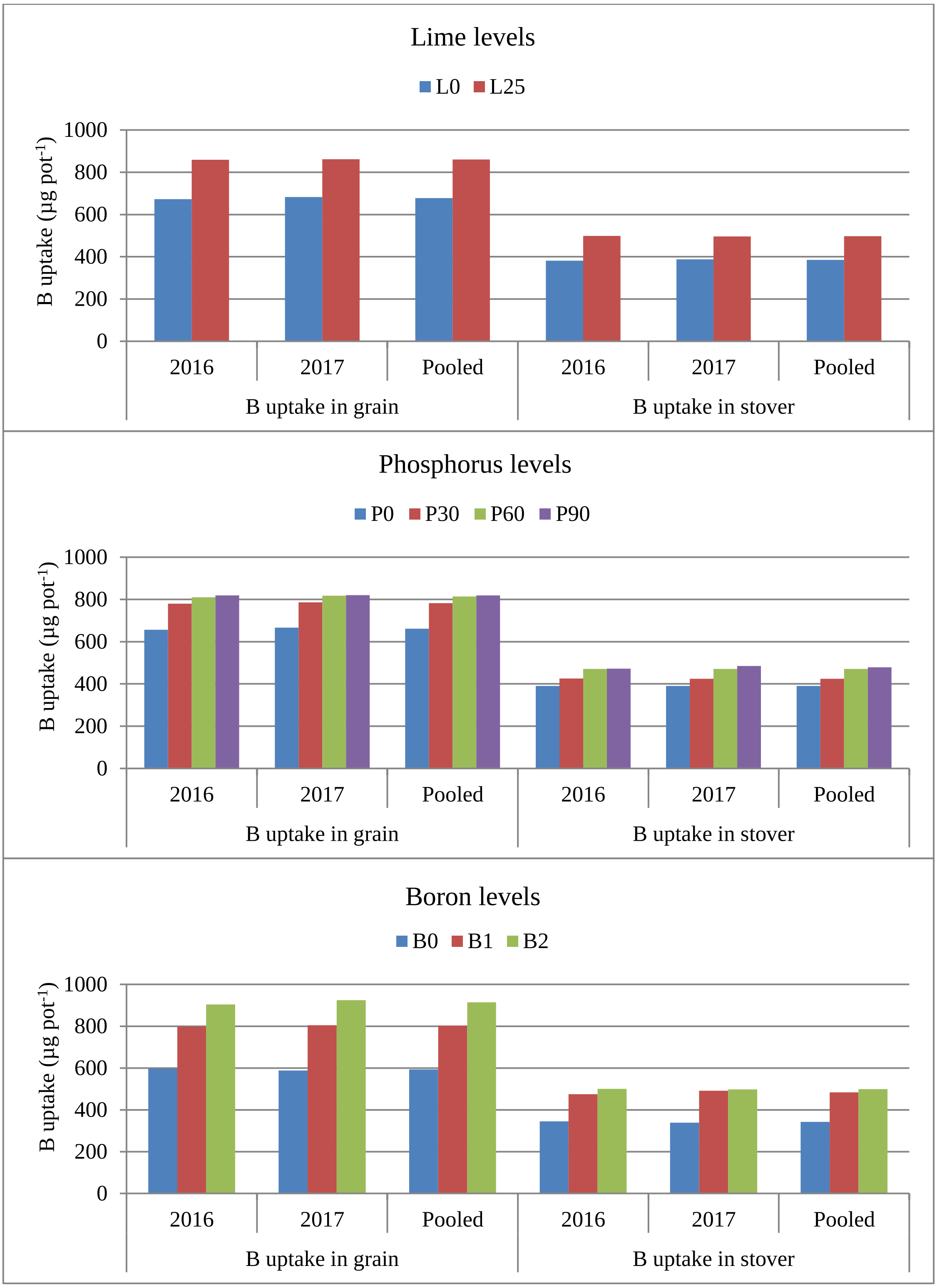


Fig 14: Effect of lime, phosphorus and boron on boron uptake in grain and stover of maize

**Interaction effect of lime and phosphorus on boron uptake in grain**

It is evident from Table 4.37.b that boron uptake in grain due to effect of lime and phosphorus was found to be significant. In case of treatments with lime, phosphorus level up to 60 kg $ha^{-1}$ showed maximum boron uptake, while in case of treatments without lime, phosphorus level up to 90 kg $ha^{-1}$ showed maximum boron uptake. Irrespective of liming, it can also be observed that the boron uptake in grain increased with increase in phosphorus levels and vice versa. Highest uptake was observed in the treatment combination $L_{25}P_{60}$ and lowest uptake in $L_0P_0$ during 2016 as well as 2017.

**Interaction effect of phosphorus and boron on boron uptake in grain**

From Table 4.37.c, it can be observed that interaction effect of phosphorus and boron on boron uptake in grain was significant during 2016 along with pooled data. The boron uptake in grain was observed to increase linearly with increase in phosphorus levels as well as boron levels, the maximum of which was observed in the treatment combination $P_{90}B_2$ and minimum was observed in $P_0B_0$. Significant increase in B uptake with increase in phosphorus and boron levels has been reported by Sentimenla *et al.* (2013) in soybean.

**Interaction effect of lime and boron on boron uptake in grain and stover**

As observed from Table 4.37.d, interaction effect of lime and boron on boron uptake in grain and stover was significant during 2016 and 2017. It can be observed that B uptake in grain and stover increased with lime application and also increased with increasing levels of boron in both the years of experimentation. Maximum boron uptake in both grain and stover was observed in treatment combination $L_{25}B_2$ and minimum was observed in treatment combination $L_0B_0$ during 2016 as well as 2017.

Table 4.37.b: Interaction effect between lime and phosphorus on boron uptake in grain

| Lime levels | B uptake in grain (µg $pot^{-1}$) | | | |
|---|---|---|---|---|
| | Phosphorus levels | | | |
| | $P_0$ | $P_{30}$ | $P_{60}$ | $P_{100}$ |
| | 2016 | | | |
| $L_0$ | 568.04 | 677.11 | 704.33 | 742.20 |
| $L_{25}$ | 744.79 | 882.25 | 916.89 | 895.35 |
| SEm± | 5.67 | | | |
| CD (P=0.05) | 16.13 | | | |
| | 2017 | | | |
| $L_0$ | 575.43 | 693.69 | 718.16 | 744.05 |
| $L_{25}$ | 757.03 | 877.84 | 917.13 | 896.21 |
| SEm± | 7.98 | | | |
| CD (P=0.05) | 22.69 | | | |
| | Pooled | | | |
| $L_0$ | 571.73 | 685.40 | 711.24 | 743.12 |
| $L_{25}$ | 750.91 | 880.05 | 917.01 | 895.78 |
| SEm± | 4.89 | | | |
| CD (P=0.05) | 13.74 | | | |

Table 4.37.c: Interaction effect between phosphorus and boron on boron uptake in grain

| Phosphorus levels | B uptake in grain (µg pot$^{-1}$) | | |
|---|---|---|---|
| | Boron levels | | |
| | $B_1$ | $B_2$ | $B_3$ |
| | 2016 | | |
| $P_0$ | 503.45 | 686.56 | 779.24 |
| $P_{30}$ | 612.09 | 813.89 | 913.07 |
| $P_{60}$ | 631.56 | 842.10 | 958.17 |
| $P_{100}$ | 641.31 | 849.56 | 965.45 |
| SEm± | 6.95 | | |
| CD (P=0.05) | 19.76 | | |

Table 4.37.d: Interaction effect between lime and boron on boron uptake in grain and stover

| Lime levels | B uptake in grain (µg $pot^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Boron levels | | | Boron levels | | | Boron levels | | |
| | $B_0$ | $B_1$ | $B_2$ | $B_0$ | $B_1$ | $B_2$ | $B_0$ | $B_1$ | $B_2$ |
| | 2016 | | | 2017 | | | Pooled | | |
| $L_0$ | 517.93 | 701.38 | 799.45 | 514.41 | 711.80 | 822.27 | 516.17 | 706.59 | 810.86 |
| $L_{25}$ | 676.27 | 894.67 | 1008.51 | 661.86 | 898.39 | 1025.91 | 669.06 | 896.53 | 1017.21 |
| SEm± | 4.91 | | | 6.91 | | | 4.24 | | |
| CD (P=0.05) | 13.97 | | | 19.65 | | | 11.90 | | |
| | B uptake in stover (µg $pot^{-1}$) | | | | | | | | |
| | 2016 | | | 2017 | | | Pooled | | |
| $L_0$ | 298.44 | 410.24 | 435.27 | 297.49 | 431.01 | 436.28 | 297.96 | 420.63 | 435.77 |
| $L_{25}$ | 390.71 | 539.29 | 565.38 | 380.51 | 551.64 | 557.82 | 385.61 | 545.46 | 561.60 |
| SEm± | 6.94 | | | 5.38 | | | 4.39 | | |
| CD (P=0.05) | 19.73 | | | 15.30 | | | 12.33 | | |

### 4.2.2 Effect of lime, phosphorus and boron on soil properties

#### 4.2.2.1 Effect on soil pH and electrical conductivity

The results on soil pH and electrical conductivity after crop harvest in different treatments have been presented in Table 4.38. It is apparent from the data that lime had a significant effect on soil pH, whereas it had no significant effect on electrical conductivity. The maximum pH was recorded in the treatment $L_{25}$, while the minimum was recorded in the treatment $L_0$ during 2016 and 2017. Pooled data reflected an increase by 8.8% in the soil pH due to liming over control ($L_0$). Lime increased soil pH because of the release of $Ca^{2+}$ ions which displaces $Al^{3+}$, $H^+$ and $Fe^{3+}$ ions in the soil (Kisinyo *et al.*, 2013).

The treatment effect of phosphorus as well as boron on soil pH and electrical conductivity after crop harvest was found to be non- significant as can be observed from Table 4.38.

#### 4.2.2.2 Effect on percent base saturation and organic carbon

From Table 4.39 it is apparent that effect of lime on soil organic carbon in post harvest soil was non-significant, whereas significant effect of lime application on percent base saturation of post harvest soil was observed during both the years. Maximum percent base saturation was recorded in treatment $L_{25}$ and minimum was recorded in $L_0$. A critical examination of data indicated that $L_{25}$ level of lime increased percent base saturation from 26.32 to 31.30%. Increase in percent base saturation due to liming is because liming releases calcium into the soil solution which replaces a large part of the acidic cations in the exchange complex, thereby increasing the percent base saturation.

The results on effect of phosphorus levels and boron levels on percent base saturation and organic carbon were found to be non-significant (Table 4.39).

Table 4.38: Soil pH and electrical conductivity of post-harvest soil as affected by lime, phosphorus and boron

| Treatment | Soil pH | | | Electrical conductivity ($dSm^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 5.22 | 5.20 | 5.21 | 0.20 | 0.19 | 0.20 |
| $L_{25}$ | 5.65 | 5.69 | 5.67 | 0.18 | 0.18 | 0.18 |
| SEm± | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | 0.07 | 0.06 | 0.04 | NS | NS | NS |
| Phosphorus levels | | | | | | |
| $P_0$ | 5.40 | 5.41 | 5.41 | 0.21 | 0.19 | 0.20 |
| $P_{30}$ | 5.49 | 5.48 | 5.49 | 0.19 | 0.18 | 0.19 |
| $P_{60}$ | 5.44 | 5.45 | 5.45 | 0.19 | 0.19 | 0.19 |
| $P_{90}$ | 5.41 | 5.43 | 5.42 | 0.18 | 0.18 | 0.18 |
| SEm± | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| Boron levels | | | | | | |
| $B_0$ | 5.44 | 5.44 | 5.44 | 0.20 | 0.19 | 0.19 |
| $B_1$ | 5.43 | 5.44 | 5.43 | 0.19 | 0.18 | 0.19 |
| $B_2$ | 5.44 | 5.45 | 5.44 | 0.19 | 0.19 | 0.19 |
| SEm± | 0.03 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

Table 4.39: Percent base saturation and soil organic carbon of post-harvest soil as affected by lime, phosphorus and boron

| Treatment | Percent base saturation (%) | | | Organic carbon (%) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 26.00 | 26.65 | 26.32 | 1.56 | 1.58 | 1.57 |
| $L_{25}$ | 30.95 | 31.64 | 31.30 | 1.57 | 1.59 | 1.58 |
| SEm± | 0.30 | 0.30 | 0.21 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | 0.84 | 0.86 | 0.59 | NS | NS | NS |
| Phosphorus levels | | | | | | |
| $P_0$ | 28.56 | 29.29 | 28.93 | 1.55 | 1.57 | 1.56 |
| $P_{30}$ | 28.66 | 29.33 | 28.99 | 1.57 | 1.59 | 1.58 |
| $P_{60}$ | 28.46 | 29.10 | 28.78 | 1.58 | 1.60 | 1.59 |
| $P_{90}$ | 28.21 | 28.87 | 28.54 | 1.57 | 1.59 | 1.58 |
| SEm± | 0.42 | 0.43 | 0.30 | 0.02 | 0.02 | 0.02 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |
| Boron levels | | | | | | |
| $B_0$ | 28.45 | 29.12 | 28.79 | 1.55 | 1.58 | 1.57 |
| $B_1$ | 28.50 | 29.18 | 28.84 | 1.57 | 1.58 | 1.58 |
| $B_2$ | 28.46 | 29.14 | 28.80 | 1.58 | 1.59 | 1.58 |
| SEm± | 0.36 | 0.37 | 0.26 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS |

#### 4.2.2.3 Effect on available nitrogen, phosphorus and potassium

It is apparent from the data (Table 4.40) that effect of lime on available nitrogen, phosphorus and potassium was significant during both the years of experimentation. Maximum available nitrogen, phosphorus and potassium in soil were recorded in $L_{25}$ while the minimum was recorded in $L_0$ during 2016 and 2017. The amount of these nutrients were found to be more in the limed treatment because of the mineralization of organic matter, a process which is known to be enhanced by liming and whereby inorganic nutrients such as N and P are released into the soil solution (Andersson and Nilsson (2001). In case of phosphorus, it may also be due to release of phosphate from Fe and Al complex. The increase in potassium availability may be due to the displacement of exchangeable K by Ca as reported by Haynes and Naidu (1998). Significant increase in potassium content in soil due to liming has also been reported by Barman *et al.* (2014) and Kamaruzzaman *et al.* (2014).

The effect of phosphorus on phosphorus content in soil at harvest was found to be significant, while its effect on available nitrogen and potassium was found to be non-significant. Soil available phosphorus was found to be higher where higher rate of phosphorus was applied. It is apparent from Table 4.40.a that maximum available phosphorus was recorded in $P_{90}$, while the minimum was recorded in treatment $P_0$ during both the years. However, treatment $P_{90}$ was found to be at par with $P_{60}$. Thus, increasing levels of phosphorus significantly increased phosphorus content in soil which must be primarily due to the release of P from fertilizer. Similar results have also been reported on P deficient acid soils (Weisz *et al.,* 2003; Kisinyo *et al.,* 2014).

The data presented in table 4.40.a revealed that there was no significant difference among the treatments with respect to boron application on soil available nitrogen, phosphorus and potassium which is in congruence to the findings of Barman *et al.* (2014).

Table 4.40: Available nitrogen, phosphorus and potassium of post-harvest soil as affected by lime, phosphorus and boron

| Treatment | Available nitrogen (kg ha$^{-1}$) | | | Available phosphorus (kg ha$^{-1}$) | | | Available potassium (kg ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 238.65 | 239.85 | 239.25 | 10.61 | 10.40 | 10.51 | 149.85 | 150.00 | 149.92 |
| $L_{25}$ | 248.73 | 248.99 | 248.86 | 12.23 | 12.46 | 12.35 | 150.95 | 151.60 | 151.27 |
| SEm± | 0.31 | 0.24 | 0.19 | 0.15 | 0.19 | 0.12 | 0.24 | 0.28 | 0.18 |
| CD (P=0.05) | 0.88 | 0.68 | 0.55 | 0.41 | 0.54 | 0.34 | 0.68 | 0.78 | 0.51 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 242.97 | 243.81 | 243.39 | 10.07 | 10.00 | 10.04 | 150.67 | 150.73 | 150.70 |
| $P_{30}$ | 243.51 | 244.37 | 243.94 | 11.19 | 11.21 | 11.20 | 150.41 | 150.63 | 150.52 |
| $P_{60}$ | 244.12 | 244.54 | 244.33 | 12.12 | 12.17 | 12.15 | 150.33 | 150.57 | 150.45 |
| $P_{90}$ | 244.15 | 244.97 | 244.56 | 12.30 | 12.36 | 12.33 | 150.19 | 151.26 | 150.72 |
| SEm± | 0.44 | 0.34 | 0.28 | 0.21 | 0.27 | 0.17 | 0.34 | 0.39 | 0.26 |
| CD (P=0.05) | NS | NS | NS | 0.58 | 0.77 | 0.48 | NS | NS | NS |
| Boron levels | | | | | | | | | |
| $B_0$ | 243.34 | 243.97 | 243.65 | 11.36 | 11.28 | 11.32 | 150.48 | 150.83 | 150.65 |
| $B_1$ | 243.89 | 244.65 | 244.27 | 11.41 | 11.47 | 11.44 | 150.16 | 150.54 | 150.35 |
| $B_2$ | 243.84 | 244.65 | 244.25 | 11.49 | 11.55 | 11.52 | 150.57 | 151.03 | 150.80 |
| SEm± | 0.38 | 0.29 | 0.24 | 0.18 | 0.23 | 0.15 | 0.29 | 0.34 | 0.22 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

### 4.2.2.4 Effect on exchangeable calcium and available boron

It is evident from table 4.41 that liming had a significant effect on available boron and exchangeable calcium content in soil at harvest where maximum was recorded in $L_{25}$ and minimum was recorded in $L_0$ during 2016 and 2017. Liming supplies Ca to the soil and also increases the CEC by raising the soil pH. This condition makes it ideal for Ca to freely occupy the exchange complex and hence its availability increases. Similar findings have been reported by Rahman *et al.* (2005); Beukes *et al.* (2012) and Han *et al.* (2019). Increase in boron availability due to liming may be due to neutralization of soil acidity which may have released boron into the soil solution (Sarkar *et al.*, 2015).

Effect of phosphorus on exchangeable calcium content in soil was significant. It can be observed that exchangeable calcium increased with increase in P levels and maximum value was recorded in treatments $P_{60}$ and $P_{90}$, while minimum was recorded in treatment $P_0$. Similar findings where P application increased Ca content in soil have been reported by Venkatesh *et al.* (2002). Result on the effect of boron on exchangeable calcium revealed that there was no significant difference among the treatments.

From Table 4.41 it can be observed that there was no significant effect of boron on exchangeable calcium, whereas there was significant effect of boron on available boron. The application of boron @ 2 kg $ha^{-1}$ ($B_2$) reflected the highest value while minimum soil available boron was observed in the control treatment *i.e.*, $B_0$ during 2016 and 2017. The increase in extractable B in soil with increasing rate of B application has been reported by Barman *et al.* (2014).

Table 4.41: Exchangeable calcium and available boron of post-harvest soil as affected by lime, phosphorus and boron

| Treatment | Exchangeable $Ca^{2+}$ [cmol $(p^+)$ $kg^{-1}$] | | | Available boron (mg $kg^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | |
| $L_0$ | 3.04 | 3.06 | 3.05 | 0.51 | 0.54 | 0.52 |
| $L_{25}$ | 4.23 | 4.27 | 4.25 | 0.56 | 0.58 | 0.57 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 |
| CD (P=0.05) | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.03 |
| Phosphorus levels | | | | | | |
| $P_0$ | 2.89 | 2.93 | 2.91 | 0.54 | 0.55 | 0.54 |
| $P_{30}$ | 3.80 | 3.83 | 3.82 | 0.52 | 0.57 | 0.54 |
| $P_{60}$ | 3.92 | 3.94 | 3.93 | 0.53 | 0.56 | 0.55 |
| $P_{90}$ | 3.92 | 3.95 | 3.93 | 0.54 | 0.57 | 0.55 |
| SEm± | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | 0.06 | 0.05 | 0.04 | NS | NS | NS |
| Boron levels | | | | | | |
| $B_0$ | 3.64 | 3.66 | 3.65 | 0.47 | 0.52 | 0.49 |
| $B_1$ | 3.64 | 3.67 | 3.65 | 0.54 | 0.56 | 0.55 |
| $B_2$ | 3.63 | 3.66 | 3.64 | 0.59 | 0.61 | 0.60 |
| SEm± | 0.02 | 0.02 | 0.01 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | NS | NS | NS | 0.05 | 0.05 | 0.04 |

### 4.2.2.5 Effect on exchangeable hydrogen, aluminium and total potential acidity

The data on exchangeable hydrogen, aluminium and total potential acidity in soil at harvest (Table 4.42) showed a decreasing trend with application of lime. Thus, maximum exchangeable hydrogen, aluminium and total potential acidity in post harvest soil were recorded in $L_0$ and minimum in $L_{25}$ during 2016 and 2017. From pooled data, a percent decrease in exchangeable hydrogen, aluminium and total potential acidity by 37.9%, 8.3% and 11.3%, respectively was observed with application of $L_{25}$ level. A decrease in all forms of soil acidity due to liming has also been reported by Badole *et al.* (2015). Chatterjee *et al.* (2005) also reported that addition of lime shows significant decrease in exchangeable H, Al and total potential acidity.

There was no significant effect of phosphorus and boron on exchangeable hydrogen, aluminium and total potential acidity in soil at harvest as can be observed in Table 4.42.

## 4.3. Agronomic efficiency and nutrient use efficiency

### 4.3.1 Agronomic efficiency

From Table 4.43 it can be observed that agronomic efficiency (AE) of P decreased with increase in the dose of phosphorus. Agronomic efficiency of P was highest at 30 kg $P_2O_5$ $ha^{-1}$ ($P_{30}$), which declined with further increase in P levels. Minimum was observed in the highest level at 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$). Similar findings where AE of P decreased with increasing levels of phosphorus doses have been reported by Kumar *et al.* (2006) in maize and Sentimenla *et al.* (2013) in soybean. Agronomic efficiency of applied boron was highest at 1 kg B $ha^{-1}$ ($B_1$) and minimum at 2 kg B $ha^{-1}$ $B_2$. This is also in line with the findings of Khurana and Arora (2012) who recorded a decrease in AE of B applied through borax with increase in B levels. Higher AE values reflect the optimum nutrient management practice (Chuan *et al.,* 2013).

Table 4.42: Exchangeable $H^+$, $Al^{3+}$ and total potential acidity of post-harvest soil as affected by lime, phosphorus and boron

| Treatments | Exchangeable $H^+$ [cmol ($p^+$) $kg^{-1}$] | | | Exchangeable $Al^{3+}$ [cmol ($p^+$) $kg^{-1}$] | | | Total potential acidity [cmol ($p^+$) $kg^{-1}$] | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled | 2016 | 2017 | Pooled |
| Lime levels | | | | | | | | | |
| $L_0$ | 0.99 | 0.92 | 0.95 | 1.32 | 1.34 | 1.33 | 14.90 | 14.83 | 14.87 |
| $L_{25}$ | 0.55 | 0.64 | 0.59 | 1.22 | 1.21 | 1.22 | 13.20 | 13.17 | 13.19 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 |
| CD (P=0.05) | 0.03 | 0.02 | 0.02 | 0.03 | 0.02 | 0.02 | 0.05 | 0.03 | 0.03 |
| Phosphorus levels | | | | | | | | | |
| $P_0$ | 0.78 | 0.79 | 0.78 | 1.27 | 1.27 | 1.27 | 14.07 | 14.02 | 14.05 |
| $P_{30}$ | 0.75 | 0.76 | 0.76 | 1.28 | 1.29 | 1.28 | 14.04 | 14.00 | 14.02 |
| $P_{60}$ | 0.78 | 0.79 | 0.78 | 1.26 | 1.28 | 1.27 | 14.06 | 13.99 | 14.03 |
| $P_{90}$ | 0.76 | 0.78 | 0.77 | 1.27 | 1.28 | 1.27 | 14.04 | 13.98 | 14.01 |
| SEm± | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| Boron levels | | | | | | | | | |
| $B_0$ | 0.77 | 0.78 | 0.78 | 1.26 | 1.27 | 1.27 | 14.04 | 13.99 | 14.02 |
| $B_1$ | 0.77 | 0.78 | 0.78 | 1.27 | 1.28 | 1.28 | 14.05 | 14.00 | 14.03 |
| $B_2$ | 0.77 | 0.77 | 0.77 | 1.28 | 1.29 | 1.28 | 14.07 | 14.01 | 14.04 |
| SEm± | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.02 | 0.01 | 0.01 |
| CD (P=0.05) | NS | NS | NS | NS | NS | NS | NS | NS | NS |

### 4.3.2 Nutrient use efficiency

As shown in Table 4.44, during 2016 and 2017, the phosphorus use efficiency (PUE) by maize was observed to decrease with increase in level of phosphorus. This decreasing trend is in accordance with von Leibig's Law of the Minimum which states that the most limiting factor determines the yield potentials (Giller *et al.*, 2002). Lower the P application rate better was the use efficiency. Higher PUE among treatments was obtained at 30 kg $P_2O_5$ $ha^{-1}$ ($P_{30}$), thereafter it significantly reduced, where lowest PUE was recorded at 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$). PUE decreases at higher doses of P due to the fact that plants grown in P deficient soil exhibit greater P sorption at lower doses of P (Dubey, 2000). Similar findings have also been reported by Hussein (2009); Nekesa (2007) and Kisinyo *et al.* (2014).

From Table 4.44, the boron use efficiency (BUE) by maize was maximum at 1 kg B $ha^{-1}$ ($B_1$) and minimum at 2 kg B $ha^{-1}$ ($B_2$) during both the years. Thus, the BUE decreased with increment of B levels applied which can be attributed to loss of boron. Boron may encounter greater losses and less utilization by the crops when applied in excess, since plant nutritional demand is limited. The excess of applied B may not be absorbed by plant and can be lost decreasing the efficiency of fertilization with higher B rates. This result is in accordance with the findings of Byju *et al.* (2007) where it was found that application of B at 1.0 kg $ha^{-1}$ gave the highest BUE. The efficiency of boron fertilization as a function of doses and forms of application was low when compared to phosphorus. It is mainly due to the complex dynamics of this nutrient with low mobility within the phloem (Mantovani *et al.*, 2013), but with high mobility in soil, high solubility in water and low reactivity with the soil making it susceptible to leaching (Trautmann *et al.*, 2014).

Table 4.43: Agronomic efficiency of phosphorus and boron

| Treatment | Agronomic efficiency (g $g^{-1}$) | | |
| --- | --- | --- | --- |
| | 2016 | 2017 | Pooled |
| $P_0$ | - | - | - |
| $P_{30}$ | 56.07 | 54.43 | 55.22 |
| $P_{60}$ | 35.02 | 34.25 | 34.63 |
| $P_{90}$ | 24.81 | 23.47 | 24.13 |
| $B_0$ | - | - | - |
| $B_1$ | 746.27 | 1004.48 | 874.63 |
| $B_2$ | 430.60 | 635.07 | 532.84 |

Table 4.44: Nutrient use efficiency of phosphorus and boron

| Treatment | Phosphorus use efficiency (%) | | |
| --- | --- | --- | --- |
| | 2016 | 2017 | Pooled |
| $P_0$ | - | - | - |
| $P_{30}$ | 39.37 | 48.53 | 43.95 |
| $P_{60}$ | 28.12 | 29.50 | 28.81 |
| $P_{90}$ | 20.91 | 20.20 | 20.55 |
| | Boron use efficiency (%) | | |
| $B_0$ | - | - | - |
| $B_1$ | 3.00 | 3.24 | 3.12 |
| $B_2$ | 2.29 | 2.51 | 2.40 |

# CHAPTER V

# SUMMARY AND CONCLUSION

# SUMMARY AND CONCLUSION

Two pot experiments were conducted in the greenhouse, Department of Agricultural Chemistry and Soil Science, School of Agricultural Sciences and Rural Development (SASRD), Nagaland University, Medziphema, Nagaland during the *kharif* season of 2016 and 2017 to carry out the investigation entitled, "Study on Acidity Tolerance of Maize and its Response to Phosphorus and Boron". The main findings of the investigations are summarized below:

## EFFECT OF SOIL pH, LIME AND VARIETIES ON THE PERFORMANCE OF MAIZE AND SOIL PROPERTIES (EXPT-I)

1. Maximum plant height at all growth stages was recorded in $pH_2$ (pH 5.2) over $pH_1$ (pH 4.6). Effect of liming on plant height was recorded maximum at 100% lime of LR ($L_{100}$) at 30, 60 DAS and at harvest. At harvest, application of 100% lime enhanced the pooled plant height by 22% over control. Treatments $L_{100}$ and $L_{60}$ were found to be at par with each other at all growth stages. At harvest, superiority of varieties in terms of plant height was recorded in the order RCM-76 > RCM-1-1 > RCM-75. Significant interaction effect of pH and lime on plant height at 30 DAS was observed. Higher soil pH level along with higher lime levels yielded in higher plant height. Maximum plant height was recorded in treatment combination $pH_2L_{60}$ and minimum was recorded in treatment combination $pH_1L_0$.
2. The effect of pH on number of leaves was non-significant. The effect of lime on the number of leaves was significant and at 30 and 60 DAS, highest value was recorded at 100% lime of LR ($L_{100}$) and at harvest highest value was recorded at 60% lime of LR ($L_{60}$). Lowest value was observed in control ($L_0$) at all growth stages. Treatments $L_{60}$ and $L_{100}$ were at par at all growth stages. Varietal effect was also significant and

maximum number of leaves was recorded in the variety RCM-76 ($V_2$) and minimum in the variety RCM-75 ($V_1$) at all growth stages.

**3.** The effect of pH on leaf area index was non-significant at all growth stages. Significant effect of lime on leaf area index was observed at 60 DAS and at harvest, where maximum leaf area index was recorded at 60% lime of LR ($L_{60}$) and minimum leaf area index was recorded in control ($L_0$) in both crop stages. At 60 DAS, treatment $L_{60}$ was at par with $L_{100}$ and at harvest, treatment $L_{60}$ was at par with $L_{30}$ and $L_{100}$. Varieties did not have any significant effect on the leaf area index at any growth stages.

**4.** Effect of pH on cob length, cob girth and cob weight was significant and maximum value was recorded in pH 5.2 ($pH_2$) and minimum in pH 4.6 ($pH_1$). Effect of lime was significant and maximum cob length was recorded at 60% lime of LR ($L_{60}$), whereas, maximum cob girth and cob weight was recorded at 100% lime of LR ($L_{100}$). Minimum cob length, cob girth and cob weight was observed in control ($L_0$). In case of cob length and cob weight, treatment $L_{100}$ was at par with $L_{60}$ and in case of cob girth, treatment $L_{100}$ was at par with $L_{30}$ and $L_{60}$. Varieties also showed significant response and maximum cob length, cob girth and cob weight was recorded in variety RCM-76 ($V_2$), whereas, minimum cob length and cob weight was recorded in RCM-1-1 ($V_3$) and minimum cob girth was recorded in RCM-75 ($V_1$).

**5.** Effect of pH was significant on the number of grains per row and number of grains per cob, where highest value was recorded in pH 5.2 ($pH_2$) and minimum was recorded in pH 4.6 ($pH_1$). Effect of lime was significant on number of grains per row, number of rows per cob and number of grains per cob where maximum number of grains per row was recorded in $L_{60}$, while number of rows per cob and number of grains per cob was recorded in $L_{100}$. $L_{60}$ enhanced pooled number of grains per row to the extent of 8.0% over control, while $L_{100}$ enhanced number of rows per cob and grains per cob to the extent of 9.0 and 27.0%, respectively over control. For number of grains per row and number of rows per cob, treatments $L_{60}$ and $L_{100}$ were found to be at par with each other. Effect of varieties was significant and variety RCM-76 ($V_2$) recorded maximum number of grains per row, number of rows per cob and number of grains per cob followed by RCM-75 ($V_1$) and RCM-1-1 ($V_3$). The RCM-76 variety increased pooled grains per row by 2.0% and 5.3%, rows per cob by 1.5 and 4.2% and grains per cob by 4.1 and 10.3% over RCM-75 and RCM-1-1, respectively. Interaction effect of pH and lime on number of rows per cob was significant, where maximum rows per cob were recorded in treatment combination $pH_1L_{100}$. However, treatment combination $pH_1L_{100}$ was at par with $pH_2L_{60}$. Interaction effect of pH and varieties on number of grains per row was found to be significant during 2016, where highest value was obtained in pH 5.2 with variety RCM-76 ($pH_2V_2$) and lowest value in pH 4.6 with variety RCM-75 ($pH_1V_1$).

**6.** Effect of pH on test weight, grain yield and stover yield of maize was significant, where highest response was observed in pH 5.2 ($pH_2$) and lowest in pH 4.6 ($pH_1$). Grain and stover yield increased by 13.3% and 9.6%, respectively in pH 5.2 ($pH_2$) soil as compared to pH 4.6 ($pH_1$) soil. Effect of lime was also significant and maximum test weight, grain yield and stover yield was observed @ 100% lime of LR ($L_{100}$) and minimum in control treatment ($L_0$). Grain yield increased by 28.7% and stover yield by 23.7% in treatment $L_{100}$ over $L_0$. However, $L_{100}$ was at par with $L_{60}$ for all the three parameters. Significant response of varieties was also observed and variety RCM-76 ($V_2$) gave the highest grain as well as stover yield, while RCM-1-1 ($V_3$) gave the lowest grain and stover yield. RCM-76 ($V_2$) gave 3.0% and 9.0% higher grain yield over RCM-75 ($V_1$) and RCM-1-1 ($V_3$), respectively

7. Effect of pH on N content in grain as well as stover was non-significant in both the years. Effect of lime on N content in grain and stover was significant with highest value in the treatment $L_{100}$ and lowest in $L_0$. N content increased by 27.4% and 23.0%, respectively in grain and stover in $L_{100}$ over $L_0$. Effect of varieties on N content in grain and stover was non-significant.
8. Effect of pH on P content in grain and stover was significant and highest value was observed in pH 5.2 ($pH_2$). P content in grain increased by 14.7% and in stover by 23.07% in $pH_2$ over $pH_1$. Effect of lime on P content in grain and stover was significant where maximum was recorded in treatment $L_{100}$ in grain and in $L_{60}$ in stover. Minimum P content for both grain and stover was observed in $L_0$. P content in both grain and stover was found to increase by 33.3% each in treatment $L_{100}$ in grain and in $L_{60}$ in stover over $L_0$. In both P content in grain and stover, treatments $L_{60}$ and $L_{100}$ were at par with each other. Significant effect of varieties on P content was observed only in grain, where variety RCM-76 showed highest P content followed by RCM-75 and RCM-1-1. Interaction effect of pH and lime on P content in grain was significant and maximum P content was recorded in treatment combination $pH_2L_{60}$ and minimum P content in treatment combination $pH_1L_0$. Treatment combination $pH_2L_{60}$ was at par with $pH_1L_{100}$, $pH_2L_{30}$, and $pH_2L_{100}$.
9. Effect of pH on K content in grain and stover was significant and recorded highest in pH 5.2 ($pH_2$) and lowest in pH 4.6 ($pH_1$). K content in grain and stover increased by 14.9% and 3.5%, respectively in $pH_2$ over $pH_1$. Effect of lime on K content in grain and stover was significant and recorded highest in treatment $L_{100}$ and lowest in $L_0$. $L_{100}$ level of

lime enhanced K content in grain and stover which increased by 21.7% and 14.2%, respectively over $L_0$.In case of K content in stover, $L_{100}$ was at par with $L_{60}$. Effect of varieties on K content was found to be significant only in grain. Maximum K content in grain was reported in the variety RCM-76 ($V_2$) and minimum in variety RCM-75 ($V_1$).

**10.** Effect of pH on Ca content in grain and stover was significant and highest value was recorded in pH 5.2 ($pH_2$) and lowest in pH 4.6 ($pH_1$). A percent increase of 18.6% in grain and 15.2% in stover was observed in $pH_2$ over $pH_1$. Lime had a significant effect on Ca content in grain and stover, where treatment $L_{100}$ recorded highest Ca content and $L_0$ recorded lowest Ca content in both grain and stover. A percent increase of 96.4% and 87.1% in grain and stover, respectively in $L_{100}$ over $L_0$ was observed. However, treatment $L_{100}$ was at par with $L_{60}$ in case of calcium content in both grain and stover. Effect of varieties on Ca content was non-significant.

**11.** Effect of pH was non-significant on B content in grain. It was significant on B content in stover and highest value was recorded in pH 5.2 ($pH_2$) and lowest in pH 4.6 ($pH_1$). Effect of lime was significant and maximum B content in both grain and stover was recorded in $L_{30}$ which was at par with $L_{60}$. An increase in grain and boron content in grain and stover by 2.3% and 6.0%, respectively at $L_{30}$ over $L_0$ was observed. Minimum B content in grain and stover was recorded in $L_0$. The effect of varieties on B content in grain and stover was non-significant.

**12.** Effect of pH on N uptake in grain and stover was significant and highest value was recorded in pH 5.2 ($pH_2$) and minimum value in pH 4.6 ($pH_1$). $pH_2$ enhanced nitrogen uptake in grain by 14.8% and in stover by 12.5% over $pH_1$. Lime effect was significant and maximum N uptake in both grain and stover was recorded at 100% lime of LR ($L_{100}$), and minimum in control ($L_0$). Treatment $L_{100}$ enhanced nitrogen uptake to the extent of 64.3% and 50.6% in grain and stover, respectively over control. Among the varieties, significant difference was also observed, where maximum N uptake in grain and stover was observed in variety RCM-76 ($V_2$), and minimum in RCM-1-1 ($V_3$). N uptake in $V_2$ was 4.2% and 13.0% higher than $V_1$ and $V_3$, respectively. Variety RCM-75 ($V_1$) was at par with variety RCM-76 ($V_2$) with respect to N uptake in stover.

**13.** Effect of pH on P uptake in grain and stover was significant and recorded highest value in pH 5.2 ($pH_2$) over pH 4.6 ($pH_1$). P uptake increased by 29.1% in grain and by 31.8% in stover in $pH_2$ compared to $pH_1$. Effect of lime was significant on P uptake in grain and stover and highest value was recorded @ 100% lime of LR ($L_{100}$), and minimum in control ($L_0$). An increase by 72.6% and 64.5% in grain and stover, respectively in $L_{100}$ as compared to $L_0$ was observed. Treatment $L_{100}$ was found to be at par with treatment $L_{60}$ in case of P uptake in both grain and stover. Variety exhibited significant effect on P uptake in grain and non-significant effect on stover. In grain, variety RCM-76 ($V_2$) exhibited highest P uptake followed by RCM-75 ($V_1$) and RCM-1-1 ($V_3$). P uptake in grain of RCM-76 ($V_2$) variety was 9.1% and 20.6% higher as compared to $V_1$ and $V_2$ varieties, respectively. Interaction effect of pH and lime on P uptake in grain was significant during 2017, where maximum P uptake in grain was observed in pH 5.2 at 60% lime of LR ($pH_2L_{60}$) and minimum in pH 4.6 at 0% lime of LR ($pH_1L_0$). It was observed that irrespective of pH levels, lime enhanced P uptake in grain.

**14.** Significant effect of pH on K uptake in grain and stover was recorded highest in pH 5.2 ($pH_2$) and minimum in pH 4.6 ($pH_1$). There was an increase by 29.9% and 13.3% in potassium uptake in grain and stover, respectively in $pH_2$ over $pH_1$. Effect of lime was significant, where maximum K uptake in grain and stover was recorded @ 100% lime of LR ($L_{100}$). Minimum K uptake in both grain and stover was recorded in control treatment ($L_0$). There was an increase in K uptake in grain by 54.7% and in stover by 41.0% in $L_{100}$ over control. Variety showed significant effect, where maximum K uptake in grain and stover was recorded in variety RCM-76 ($V_1$) and minimum was recorded in variety RCM-1-1 ($V_3$). K uptake in grain of $V_2$ was 15.3% and 16.1% higher over $V_1$ and $V_3$, respectively.

**15.** Effect of pH was significant on Ca uptake in grain and stover, where highest value was recorded in pH 5.2 ($pH_2$) and lowest value in pH 4.6 ($pH_1$). Ca uptake in grain and stover increased by 34.7% and 25.3%, respectively in $pH_2$ over $pH_1$. Effect of lime on Ca uptake in grain and stover was significant which recorded highest value @ 100% lime of LR ($L_{100}$) and lowest value in control treatment ($L_0$). An increase by 149.9% in grain and 131.9% in stover, respectively at 100% lime of LR over control was observed. In case of Ca uptake in grain, treatment $L_{100}$ was at par with $L_{60}$. Effect of varieties was significant on Ca uptake in grain and non-significant on Ca uptake in stover. Maximum Ca uptake in grain was observed in variety RCM-76 ($V_2$) followed by RCM-75 ($V_1$) and RCM-1-1 ($V_3$).

**16.** Significant effect of pH on B uptake in grain and stover was observed and maximum value was recorded in pH 5.2 ($pH_2$) and minimum value in pH 4.6 ($pH_{4.6}$). B uptake in grain increased by 13.7% and in stover by 10.8% in pH 5.2 over pH 4.6. Effect of lime was significant on B uptake in grain and stover. Maximum value of B uptake in both grain and stover was recorded @ 60% lime of LR ($L_{60}$) and minimum in control treatment ($L_0$). The $L_{60}$ level of lime increased boron uptake in grain and stover to the extent of 31.2% and 28.1% over control. Treatment $L_{60}$ was at par with $L_{100}$ in case of B uptake in grain, whereas treatment $L_{60}$

was at par with $L_{30}$, and $L_{100}$ in case of B uptake in stover. Variety had a significant effect where maximum B uptake in grain and stover was recorded in RCM-76 ($V_2$) and minimum was recorded in RCM-1-1 ($V_3$). B uptake in grains of $V_2$ variety was 2.8 and 9.2% higher than $V_1$ and $V_3$ varieties, respectively. In case of B uptake in stover, RCM-75 ($V_1$) and RCM-76 ($V_2$) were found to be at par with each other.

**17.** Significant effect of pH on soil pH of post harvest soil was observed where highest pH value was recorded in pH 5.2 ($pH_2$) over pH 4.6 ($pH_1$). Lime had a significant effect on soil pH and maximum pH value was recorded @ 100% lime of LR ($L_{100}$), while, minimum pH value was observed in control ($L_0$). On the other hand, effect of pH and lime on electrical conductivity of post harvest soil was non-significant. Effect of varieties was non-significant on both soil pH and electrical conductivity. Interaction effect of pH and lime on soil pH was significant, where maximum soil pH value was recorded in $pH_2L_{100}$ which was at par with $pH_1L_{100}$, and minimum was recorded in $pH_1L_0$ treatment combination.

**18.** Effect of pH was non-significant on base saturation and organic carbon content in post harvest soil. Effect of lime was non-significant on soil organic carbon content and significant on base saturation of post harvest soil. Highest base saturation value was observed in treatment of 100% lime of LR ($L_{100}$) and lowest in control treatment ($L_0$). No significant effect of varieties on percent base saturation and organic carbon in post harvest soil was observed. Interaction effect of pH and lime on percent base saturation was significant during 2017, where maximum value was recorded in $pH_2L_{60}$. It was observed that increase in lime levels led to an increase in the percent base saturation under both the soil pH.

**19.** Effect of pH on available N and K of post harvest soil was non-significant, whereas it was significant on P content of post harvest soil. Maximum available P content in post harvest soil was recorded in $pH_2$

and minimum was recorded in $pH_1$. The $pH_2$ level enhanced available phosphorus by 10.6% over $pH_1$. Effect of liming on NPK content of post harvest soil was significant where maximum N content was recorded in $L_{60}$ and maximum P and K content was recorded in $L_{100}$. $L_{60}$ level of lime enhanced available nitrogen by 15.7% over control, while $L_{100}$ level of lime enhanced availability of phosphorus and potassium by 33% and 2.8% over control. Treatments $L_{60}$ and $L_{100}$ were found to be at par with each other for all the three parameters. Minimum N, P and K were recorded in the control treatment ($L_0$). Effect of varieties on available NPK content in post harvest soil was non-significant.

**20.** Effect of pH was non-significant on exchangeable Ca and significant on available B. Maximum available B content in soil at harvest was recorded in pH 5.2 ($pH_2$) soil, whereas minimum was recorded in pH 4.6 ($pH_1$) soil. Availability of boron was improved by 17.4% in $pH_2$ soil over $pH_1$. Effect of lime on exchangeable Ca and available B of post harvest soil was significant and maximum value of Ca was observed in 100% lime of LR ($L_{100}$) and maximum value of B was observed in 30% lime of LR ($L_{30}$). Lowest Ca and B content were observed in control treatment ($L_0$). The $L_{100}$ level of lime enhanced exchangeable calcium to the extent of 119.9%, while $L_{30}$ level of lime was observed to enhance available B by 8.3% over control. No significant effect of varieties was recorded on Ca and B content in soil.

**21.** Significant effect of pH on exchangeable hydrogen, exchangeable aluminium and total potential acidity was observed, where highest values were observed in pH 4.6 ($p_{H1}$) soil and lowest values were observed in pH 5.2 ($pH_2$) soil. Exchangeable hydrogen, exchangeable aluminium and total potential acidity decreased by 32.6%, 9.2% and 6.3%, respectively in $pH_2$ as compared to $pH_1$. Effect of lime on exchangeable hydrogen, aluminium and total potential acidity in post-harvest soil was significant where highest values were observed in control ($L_0$) and lowest in treatment of 100% lime of lime requirement ($L_{100}$). Exchangeable hydrogen, exchangeable aluminium and total potential acidity registered a decline of 65.8%, 43.6% and 28.8%, respectively in $L_{100}$ when compared to $L_0$. Varieties did not have any significant effect on exchangeable hydrogen, exchangeable aluminium and total potential acidity in post harvest soil. Interaction effect of pH and lime on exchangeable hydrogen and aluminium was significant where highest value was observed in the treatment combination $pH_1L_0$ and lowest in $pH_2L_{100}$. Irrespective of soil pH, exchangeable hydrogen and aluminium decreased as lime levels increased under each level of soil pH.

**EFFECT OF LIME, PHOSPHORUS AND BORON ON PERFORMANCE OF MAIZE AND SOIL PROPERTIES (EXPT-II)**

1. Effect of lime was significant on plant height and maximum plant height was recorded in the treatment $L_{25}$ (25% lime of LR) and minimum was recorded in control ($L_0$) at 30, 60 DAS and at harvest. Effect of phosphorus on plant height was significant where 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$) produced taller plants at all crop stages. $P_{90}$ was statistically at par with $P_{60}$ at 60 DAS and at harvest. Application of 90 kg $P_2O_5$ $ha^{-1}$ increased pooled plant height at 30, 60 DAS and at harvest by 12.04%, 21.2% and 21.7%, respectively over control. Minimum plant height at 30, 60 DAS and at harvest was recorded in control ($P_0$). Effect of boron was significant and maximum plant height was recorded at 2 kg B $ha^{-1}$ ($B_2$) while minimum plant height was recorded in control ($B_0$) at all the growth stages. $B_2$ level of boron increased plant height to the extent of 12.0%, 7.5% and 4.9%, respectively at 30, 60 DAS and at harvest over control. Interaction effect of lime and P on plant height was significant during 2016, where maximum was observed in $L_{25}P_{60}$ and minimum in

control ($L_0P_0$). It was observed that in treatments with lime, plant height increased up to 60 kg $P_2O_5$ $ha^{-1}$, while in treatments without lime, plant height increased at P level of 90 kg $P_2O_5$ $ha^{-1}$. Interaction effect of lime, P and B on plant height was significant at harvest during 2017, where maximum plant height was recorded in $L_{25}P_{60}B_2$ and minimum plant height was recorded in $L_0P_0B_0$. Thus, application of lime along with increased nutrient input led to better plant height. However, treatment combination $L_{25}P_{60}B_2$ was at par with $L_{25}P_{30}B_2$, and $L_{25}P_{90}B_2$.

**2.** Significant effect of lime on number of leaves was recorded and maximum value was found in the treatment $L_{25}$ at 30, 60 DAS and at harvest, while minimum number of leaves was recorded in control ($L_0$). Effect of phosphorus was significant and maximum number of leaves was recorded in the treatment $P_{90}$ at 30, 60 DAS and at harvest, while minimum was recorded in the treatment $P_0$ at all growth stages. At harvest, application of 90 kg $P_2O_5$ $ha^{-1}$ increased pooled number of leaves by 11.2% over control ($P_0$). Effect of boron on number of leaves at 60 DAS and at harvest was significant where maximum number of leaves was recorded in the treatment $B_2$, while minimum was recorded in control ($B_0$). At harvest, $B_2$ level of boron was observed to improve the number of leaves to the extent of 6.1% in comparison to control ($B_0$).

**3.** Effect of lime on leaf area index was significant and maximum leaf area index was recorded in $L_{25}$, while minimum was recorded in $L_0$ at 30, 60 DAS and at harvest. Effect of phosphorus was significant and maximum leaf area index at all growth stages was recorded in the treatment $P_{90}$ which was at par with $L_{60}$, while minimum was recorded in the treatment $P_0$. Effect of boron on leaf area index was non-significant.

**4.** Effect of lime on cob length, cob girth and cob weight was significant and maximum value was recorded at 25% lime of LR ($L_{25}$) over control

($L_0$). Application of 25% lime of LR increased cob length, cob girth and cob weight by 2.3%, 3.0% and 21.1%, respectively over control. Effect of phosphorus was significant on cob length, cob girth and cob weight and was recorded maximum in treatment $P_{90}$ and minimum in $P_0$. The $P_{90}$ level of phosphorus increased pooled cob length, cob girth, cob weight by 12.2%, 8.8% and 22.5%, respectively over control. Treatment $P_{90}$ was at par with $P_{60}$ in case of cob weight. Effect of boron on cob length, cob girth and cob weight was also significant and recorded maximum in treatment $B_2$ and minimum in control ($B_0$). The $B_2$ level of boron enhanced cob length, cob girth and cob weight by 3.2%, 2.2% and 5.2%, respectively over control. Interaction effect of lime and phosphorus on cob weight was significant and highest cob weight was recorded in $L_{25}P_{60}$ treatment combination and minimum in $L_0P_0$. Cob weight increased up to the maximum P level ($P_{90}$) in the treatments without lime, whereas cob weight increased up to 60 kg $P_2O_5$ $ha^{-1}$ and declined at 90 kg $P_2O_5$ $ha^{-1}$ in the treatments with lime.

**5.** Significant effect of lime on number of grains per row, number of rows per cob and number of grains per cob was observed which recorded highest values in $L_{25}$ and lowest values in $L_0$. Phosphorus effect on number of rows per cob was non-significant, while effect on number of grains per row, and number of grains per cob were significant. Maximum number of grains per row and grains per co**b** were recorded in treatment $P_{90}$, while minimum was recorded in control ($P_0$). The $P_{90}$ level of phosphorus increased number of grains per row and number of grains per cob to the extent of 18.8% and 24.1%, respectively, over control. Treatment $P_{90}$ was at par with treatment $P_{60}$ in case of number of grains per cob. There was no significant effect of boron on number of rows per cob, while significant effect was observed on number of grains per row and per cob. Maximum number of grains per row and number of grains per cob was observed in the treatment $B_2$ and minimum was observed in control ($B_0$). Interaction effect of lime and phosphorus on number of grains per row was significant during both the years, while on number of grains per cob, it was significant during 2016. Maximum value was recorded in $L_{25}P_{90}$ treatment combination in case of number of grains per row and in $L_{25}P_{60}$ treatment combination in case of number of grains per cob. Treatment combination $L_{25}P_{90}$ was found to be at par with $L_{25}P_{60}$ in case of number of grains per row, while treatment combination $L_{25}P_{60}$ was found to be at par with $L_{25}P_{30}$ and $L_{25}P_{90}$. It was observed that irrespective of lime treatments, number of grains per row increased with increase in P levels and vice versa.

**6.** Effect of lime on test weight of maize was non-significant, whereas effect of lime on grain and stover yield was significant, where highest grain and stover yield was observed in the treatment $L_{25}$ and lowest in control ($L_0$). The $L_{25}$ level of lime increased pooled grain and stover yield by 24.6% and 23.0%, respectively over control ($L_0$). Effect of phosphorus on test weight of maize was non-significant, whereas significant effect was observed in grain and stover yield. Maximum grain and stover yield was recorded in the treatment $P_{90}$, whereas minimum was recorded in control ($P_0$). The $P_{90}$ level of phosphorus increased grain and stover yield by 24.3% and 22.1%, respectively over control. Treatment $P_{90}$ was at par with treatment $P_{60}$ in case of both grain and stover yield. Effect of boron on test weight was non-significant, whereas significant effect on grain and stover yield was observed. Highest grain and stover yield was recorded in $B_2$, while lowest was recorded in $B_0$. The $B_2$ level of boron increased pooled grain and stover yield by 10.9% and 10.6% over control. Interaction effect of lime and phosphorus on grain yield was significant, where maximum grain yield was recorded in the treatment combination $L_{25}P_{60}$, whereas minimum was recorded in $L_0P_0$**.**

**7.** Significant effect of lime on N content in grain and stover was significant where 25% lime of LR ($L_{25}$) recorded the highest values over control ($L_0$). An increase by 20.0% and 21.4% in the nitrogen content in grain and stover, respectively was observed when lime was applied. Effect of phosphorus on N content in grain and stover was also significant, where highest N content in grain and stover was observed @ 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$) and lowest in control ($P_0$). An increase in nitrogen content in grain by 10.7% and in stover by 17.5% in the $P_{90}$ treatment over control was observed. Treatment $P_{90}$ was at par with treatment $P_{60}$ in case of both grain and stover. Effect of boron on N content in grain and stover was significant, where highest N content in grain and stover was observed @ 2 kg B $ha^{-1}$ ($B_2$) and lowest in control ($B_0$). $B_2$ treatment increased the nitrogen content by 15% in grain and by 22.2% in stover over $B_0$ treatment. Treatment $B_2$ was at par with treatment $B_1$ in case of N content in grain.

**8.** Lime had a significant effect on the P content in grain and stover, where highest value was observed @ 25% lime of LR ($L_{25}$) over control ($L_0$). There was an increase by 17.9 % and 13.3% in the phosphorus content in grain and stover, respectively when lime was applied. Significant effect of phosphorus was observed, where maximum P content in both grain and stover was recorded in $P_{90}$, while minimum was recorded in control ($P_0$). There was an increase by 28.6% in case of phosphorus content in grain and an increase by 33.3% in case of phosphorus content in stover due to $P_{90}$ over control. Treatment $P_{90}$ was at par with treatment $P_{60}$ in case of P content in both grain and stover. Effect of boron on P content in grain and stover was significant, where highest P content in grain and stover was observed @ 2 kg B $ha^{-1}$ ($B_2$) which was at par with treatment $B_1$, while lowest P content was observed in control ($B_0$). There was an increase by 15.8% in boron content in grain and an increase by 23.1% in boron content in stover due to $B_2$ over control.

**9.** Significant effect of lime on K content in grain and stover was observed to be highest in the treatment $L_{25}$ over $L_0$. There was an increase by 10.9% in case of potassium content in grain and 4.6% in case of potassium content in stover due to liming. Highest K content in both grain and stover was recorded in the treatment $P_{90}$ and lowest K content was recorded in control ($P_0$) in both grain and stover. There was an increase in potassium content in grain by 15.1% and in stover by 8.4% in the treatment $P_{90}$ when compared to control. Treatment $P_{90}$ was at par with treatment $P_{60}$ in case of K content in both grain and stover. Effect of boron was non-significant on K content in grain and stover**.**

**10.** Effect of lime on Ca content in grain and stover was significant where highest value was recorded in $L_{25}$. There was an increase by 60.0% in case of calcium content in grain and 58.3% in case of calcium content in stover in $L_{25}$ over $L_0$. Effect of phosphorus was significant and highest Ca content in grain and stover was observed in treatment $P_{90}$, while lowest was observed in control ($P_0$). An increase in calcium content by 28.9% and 24.9% in grain and stover, respectively in treatment $P_{90}$ over $P_0$ was observed. Effect of boron on Ca content in grain and stover was non-significant.

**11.** Significant effect of lime on B content in grain and stover was recorded highest in the treatment $L_{25}$ and lowest in control ($L_0$). Liming ($L_{25}$) increased the boron content in grain by 2.1% and in stover by 5.0%. Effect of phosphorus on B content was non-significant. Effect of boron on B content in grain and stover was significant, where highest B content for both grain and stover was recorded in $B_2$, while minimum was recorded in $B_0$. The $B_2$ level of boron enhanced pooled B content in grain and stover by 39.0% and 31.8%, respectively over control. Treatment $B_2$ was at par with treatment $B_1$ in case of B content in stover. Interaction effect of lime and boron on boron content in stover was significant, where highest B content was observed in treatment combination $L_{25}B_2$ which was at par with $L_{25}B_1$ and lowest B content was observed in treatment combination $L_0B_0$.

**12.** Significant effect of lime on N uptake was recorded and highest value was recorded in $L_{25}$ in both grain and stover. There was an increase in nitrogen uptake by 49.8% and 50.3% in grain and stover, respectively due to liming ($L_{25}$) over control ($L_0$). Significant effect of phosphorus on N uptake was recorded in $P_{90}$, while minimum was recorded in control ($P_0$) in both grain and stover. There was an increase in nitrogen uptake by 37.1% and 44.4% in grain and stover, respectively due to $P_{90}$ level over control ($P_0$). Treatment $P_{90}$ was at par with treatment $P_{60}$ in case of N uptake in grain. Effect of boron on N uptake in grain as well as stover was significant and maximum uptake was recorded in the treatment $B_2$, while minimum was recorded in control ($B_0$). $B_2$ level increased nitrogen uptake in grain by 20.7% and in stover by 26.7% over control. Interaction effect of lime and phosphorus on N uptake in grain was significant during 2016, where highest N uptake was observed in treatment combination $L_{25}P_{60}$ and minimum was observed in treatment combination $L_0P_0$.

**13.** Effect of lime on P uptake in grain and stover was significant which recorded a maximum in $L_{25}$. Phosphorus uptake in grain and stover increased by 45.9% and 44.4%, respectively due to liming ($L_{25}$) over control ($L_0$). Effect of phosphorus on P uptake in grain and stover was significant with maximum P uptake in $P_{90}$ in both grain and stover. There was an increase in phosphorus uptake by 58.5% and 55.7%, respectively in grain and stover due to application of 90 kg $P_2O_5$ $ha^{-1}$

($P_{90}$) and 60 kg $P_2O_5$ $ha^{-1}$ ($P_{60}$), respectively over control. P uptake in stover in treatment $P_{90}$ was at par with treatment $P_{60}$. Minimum P uptake was observed in the treatment $P_0$ in both grain and stover. Effect of boron on P uptake in grain and stover was significant, where maximum uptake was recorded in the treatment $B_2$, while minimum was recorded in control ($B_0$). There was an increase in phosphorus uptake by 27.1% and 41.3%, respectively in grain and stover due to application of 2 kg B $ha^{-1}$ ($B_2$) over control ($B_0$). Interaction effect between lime and phosphorus on P uptake in grain was significant during 2016, where maximum uptake was recorded in the treatment combination $L_{25}P_{90}$ and minimum was observed in treatment combination $L_0P_0$.Treatment combination $L_{25}P_{90}$ was at par with $L_{25}P_{60}$.

**14.** Effect of lime on K uptake in grain and stover was significant which recorded the highest uptake in limed treatment ($L_{25}$) over control ($L_0$). Percent increase by 37.7% and 29.5%, respectively in grain and stover was observed in pooled data due to application of $L_{25}$ level of lime over control. Phosphorus effect was significant and highest K uptake in grain and stover was recorded in $P_{90}$, while minimum K uptake was recorded in treatment $P_0$. An increase in potassium uptake in grain by 42.7% and in stover by 33.1% due to application of 90 kg $P_2O_5$ $ha^{-1}$ over control was observed. However, in case of K uptake in stover, treatment $P_{90}$ was at par with treatment $P_{60}$. Effect of boron on K uptake in grain and stover was significant, where maximum uptake was recorded in the treatment $B_2$, while minimum was recorded in control ($B_0$). K uptake in grain and stover increased by 12.2% and 11.2%, respectively from treatment $B_0$ to $B_2$. Treatment $B_2$ was at par with $B_1$ in case of K uptake in both grain and stover.

**15.** Effect of lime on Ca uptake was significant, where maximum Ca uptake was recorded in treatment $L_{25}$ over $L_0$. An increase by 98.6% and 97.4%

in calcium uptake by grain and stover, respectively could be observed with application of $L_{25}$ over $L_0$. Phosphorus effect was significant on Ca uptake and maximum value was observed in the treatment $P_{90}$ and minimum in the treatment $P_0$ in both grain and stover. There was an increase by 60.8% and 50.3% on calcium uptake in grain and stover, respectively due to 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$) application over control. Effect of boron was non-significant for Ca uptake in both grain and stover.

**16.** Effect of lime was significant on B uptake in grain and stover and highest uptake was recorded in lime treatment ($L_{25}$) over control ($L_0$). Due to $L_{25}$ level of lime, an increase in boron uptake by 27.0% and 29.3% in grain and stover, respectively was observed. Effect of phosphorus was significant and treatment $P_{90}$ recorded maximum B uptake in both grain and stover which was however found to be at par with $P_{60}$. Control treatment ($P_0$) recorded minimum B uptake in both grain and stover. Due to $P_{90}$ level of phosphorus, an increase in boron uptake by 23.9% and 22.7% in grain and stover, respectively could be observed. Effect of boron was also significant and treatment $B_2$ recorded maximum B uptake, while treatment $B_0$ recorded minimum in both grain and stover. An increase in boron uptake by 54.2% and 45.9% in grain and stover, respectively due to $B_2$ level of boron application could be observed. Interaction effect of lime and phosphorus on boron uptake was significant in case of grain and highest value was observed in the treatment combination $L_{25}P_{60}$ and lowest in $L_0P_0$. It was observed that in lime applied treatments, 60 kg $P_2O_5$ $ha^{-1}$ ($P_{60}$) showed maximum B uptake, while in treatments without lime, 90 kg $P_2O_5$ $ha^{-1}$ ($P_{90}$) showed maximum B uptake. Irrespective of liming, B uptake in grain increased with increase in P levels and vice versa. Interaction effect of lime and boron on boron uptake was significant in case of both grain and stover, where maximum boron uptake in both grain and stover was observed in treatment combination $L_{25}B_2$ and minimum was observed in treatment combination $L_0B_0$. Interaction effect of phosphorus and boron on boron uptake was significant in case of grain during 2016, where maximum was observed in treatment combination $P_{90}B_2$ and minimum in $P_0B_0$.

**17.** Lime had a significant effect on soil pH and non-significant effect on electrical conductivity. Maximum pH was recorded in the treatment $L_{25}$, while minimum was recorded in the treatment $L_0$. An increase by 8.8% in the soil pH was observed due to liming ($L_{25}$) over control ($L_0$). Treatment effect of phosphorus and boron on soil pH and electrical conductivity was non- significant.

**18.** Lime application was significant on percent base saturation and non-significant on soil organic carbon. Maximum percent base saturation of post harvest soil was recorded in $L_{25}$ and minimum in $L_0$. Effect of phosphorus and boron levels on percent base saturation and organic carbon were non-significant.

**19.** Effect of lime on available N, P and K of post harvest soil was significant. Maximum available N, P and K was recorded in $L_{25}$, while minimum was recorded in $L_0$. Effect of phosphorus on available N and P was significant, while its effect on available K was non-significant. There was no significant difference among the treatments with respect to boron application on available N, P and K.

**20.** Lime had a significant effect on exchangeable Ca and available B of post harvest soil, where maximum values for both parameters were recorded in $L_{25}$ and minimum in $L_{0.}$ Effect of phosphorus on available B and exchangeable Ca was non-significant. There was no significant effect of boron on exchangeable Ca, whereas significant effect of boron on available boron was observed. The application of boron @ 2 kg $ha^{-1}$ ($B_2$) recorded the highest value while control treatment ($B_0$) recorded the lowest value.

21. Effect of liming on exchangeable hydrogen, exchangeable aluminium and total potential acidity in post harvest soil was significant, where maximum value was recorded in control treatment ($L_0$) and minimum value was recorded @ 25% lime of LR ($L_{25}$). A percent decrease in exchangeable hydrogen, aluminium and total potential acidity by 37.9%, 8.3% and 11.3%, respectively was observed with application of $L_{25}$ level. There was no significant effect of phosphorus and boron on exchangeable hydrogen, aluminium and total potential acidity in post harvest soil.
22. Agronomic efficiency of P and B decreased with increase in the dose of phosphorus and boron, respectively. Agronomic efficiency of P was maximum in $P_{30}$ and minimum in $P_{90}$, whereas AE of boron was maximum in $B_1$ and minimum in $B_2$.
23. The nutrient use efficiency of P and B was observed to decrease with increase in level of phosphorus and boron, respectively. Higher phosphorus use efficiency among treatments was obtained at 30 kg $P_2O_5$ $ha^{-1}$ ($P_{30}$), thereafter it significantly reduced, where lowest was obtained in $P_{90}$. Boron use efficiency by maize was higher at 1 kg B $ha^{-1}$ ($B_1$) as compared to 2 kg B $ha^{-1}$ ($B_2$).

**CONCLUSION**

The following conclusions can be drawn from the following summary:

1. Low pH soil affected adversely the plant growth, yield attributes, grain and stover yield, nutrient uptake of maize and soil properties.
2. Plant growth, yield attributes, yield, nutrient content and their uptake by maize significantly enhanced on application of lime. Liming at 60% lime of LR proved to be optimum in order to get the desired yield. Application of lime enhanced the pH, base saturation and nutrient content of post harvest soil, while it reduced the exchangeable hydrogen, exchangeable aluminium and total potential acidity of the

soil. Among the maize varieties, RCM-76 proved superior over RCM-75 and RCM-1-1 under both soil pH levels. Superiority on the performance of maize varieties in both soil pH 4.6 and 5.2 followed the order: RCM-76 > RCM-75 > RCM-1-1.

3. Plant growth, yield attributes, grain and stover yield, nutrient content and nutrient uptake by maize improved with application of phosphorus and boron. Available P and B of post harvest soil also improved with application of the respective nutrients. Application of 60 kg $P_2O_5$ $ha^{-1}$ and 2 kg B $ha^{-1}$ proved optimum in order to get good performance of maize. However, higher nutrient use efficiency and agronomic efficiency was observed on application of 30 kg $P_2O_5$ $ha^{-1}$ and 1 kg B $ha^{-1}$.
4. As observed from the outcome of the experiment, cultivation of maize variety RCM-76 along with liming at 60% lime of LR may be recommended for cultivation of maize in very strongly acidic sandy clay loam soils. In strongly acid soils application of 60 kg $P_2O_5$ $ha^{-1}$ and 2 kg B $ha^{-1}$ combined with liming at 25% lime of LR may be recommended for cultivation of maize in sandy clay loam soils of Nagaland.

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# APPENDIX

Appendix I: Effect of pH, lime and varieties on plant height of maize at 30 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 108.29 | 108.29 | 12.41* | 492.46 | 492.46 | 81.60* | 600.75 | 300.37 | 40.70* | 4.04 |
| Lime (L) | 3 | 1373.42 | 457.81 | 52.47* | 853.01 | 284.34 | 47.12* | 2226.44 | 371.07 | 50.28* | 2.80 |
| Variety(V) | 2 | 316.80 | 158.40 | 18.15* | 324.80 | 162.40 | 26.91* | 641.60 | 160.40 | 21.73* | 3.19 |
| pH x L | 3 | 84.27 | 28.09 | 3.22* | 84.88 | 28.29 | 4.69* | 169.14 | 28.19 | 3.82* | 2.80 |
| L x V | 6 | 6.75 | 1.12 | 0.13 | 15.62 | 2.60 | 0.43 | 22.37 | 1.86 | 0.25 | 2.29 |
| pH x V | 2 | 2.76 | 1.38 | 0.16 | 1.55 | 0.78 | 0.13 | 4.31 | 1.08 | 0.15 | 3.19 |
| pHxLxV | 6 | 11.30 | 1.88 | 0.22 | 8.34 | 1.39 | 0.23 | 19.64 | 1.64 | 0.22 | 2.29 |
| Error | 48 | 418.81 | 8.73 | | 289.67 | 6.03 | | 708.48 | 7.38 | | |
| TSS | 71 | 2322.40 | 32.71 | | 2070.33 | 29.16 | | 4393.18 | 30.72 | | |

Appendix II: Effect of pH, lime and varieties on plant height of maize at 60 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 4180.03 | 4180.03 | 205.69* | 4278.12 | 4278.12 | 178.10* | 8458.15 | 4229.08 | 190.74* | 4.04 |
| Lime (L) | 3 | 13938.48 | 4646.16 | 228.63* | 14053.14 | 4684.38 | 195.01* | 27991.62 | 4665.27 | 210.42* | 2.80 |
| Variety(V) | 2 | 975.35 | 487.68 | 24.00* | 1016.05 | 508.03 | 21.15* | 1991.40 | 497.85 | 22.45* | 3.19 |
| pH x L | 3 | 44.97 | 14.99 | 0.74 | 156.58 | 52.19 | 2.17 | 201.55 | 33.59 | 1.52 | 2.80 |
| L x V | 6 | 64.07 | 10.68 | 0.53 | 129.64 | 21.61 | 0.90 | 193.72 | 16.14 | 0.73 | 2.29 |
| pH x V | 2 | 3.94 | 1.97 | 0.10 | 145.76 | 72.88 | 3.03 | 149.69 | 37.42 | 1.69 | 3.19 |
| pHxLxV | 6 | 20.46 | 3.41 | 0.17 | 33.87 | 5.64 | 0.23 | 54.33 | 4.53 | 0.20 | 2.29 |
| Error | 48 | 975.45 | 20.32 | | 1153.02 | 24.02 | | 2128.47 | 22.17 | | |
| TSS | 71 | 20202.75 | 284.55 | | 20966.18 | 295.30 | | 42626.01 | 298.08 | | |

Appendix III: Effect of pH, lime and varieties on plant height of maize at harvest

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 295.65 | 295.65 | 12.71* | 509.87 | 509.87 | 20.97* | 805.52 | 402.76 | 16.93* | 4.04 |
| Lime (L) | 3 | 19551.42 | 6517.14 | 280.23* | 19910.52 | 6636.84 | 272.94* | 39461.93 | 6576.99 | 276.50* | 2.80 |
| Variety(V) | 2 | 1452.00 | 726.00 | 31.22* | 1117.16 | 558.58 | 22.97* | 2569.16 | 642.29 | 27.00* | 3.19 |
| pH x L | 3 | 139.12 | 46.37 | 1.99 | 166.21 | 55.40 | 2.28 | 305.33 | 50.89 | 2.14 | 2.80 |
| L x V | 6 | 32.79 | 5.47 | 0.24 | 54.19 | 9.03 | 0.37 | 86.99 | 7.25 | 0.30 | 2.29 |
| pH x V | 2 | 77.11 | 38.56 | 1.66 | 39.49 | 19.74 | 0.81 | 116.60 | 29.15 | 1.23 | 3.19 |
| pHxLxV | 6 | 42.97 | 7.16 | 0.31 | 108.70 | 18.12 | 0.75 | 151.68 | 12.64 | 0.53 | 2.29 |
| Error | 48 | 1116.31 | 23.26 | | 1167.19 | 24.32 | | 2283.51 | 23.79 | | |
| TSS | 71 | 22707.38 | 319.82 | | 23073.33 | 324.98 | | 48058.39 | 336.07 | | |

* Significant at 5% level

Appendix IV: Effect of pH, lime and varieties on number of leaves of maize at 30 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.13 | 0.13 | 0.60 | 0.35 | 0.35 | 1.19 | 0.47 | 0.24 | 0.94 | 4.04 |
| Lime (L) | 3 | 13.49 | 4.50 | 21.58* | 5.26 | 1.75 | 6.02* | 18.75 | 3.13 | 12.50* | 2.80 |
| Variety(V) | 2 | 4.08 | 2.04 | 9.80* | 3.03 | 1.51 | 5.19* | 7.11 | 1.78 | 7.11* | 3.19 |
| pH x L | 3 | 0.38 | 0.13 | 0.60 | 0.82 | 0.27 | 0.94 | 1.19 | 0.20 | 0.80 | 2.80 |
| L x V | 6 | 0.81 | 0.13 | 0.64 | 0.19 | 0.03 | 0.11 | 1.00 | 0.08 | 0.33 | 2.29 |
| pH x V | 2 | 0.75 | 0.38 | 1.80 | 0.36 | 0.18 | 0.62 | 1.11 | 0.28 | 1.11 | 3.19 |
| pHxLxV | 6 | 1.25 | 0.21 | 1.00 | 2.64 | 0.44 | 1.51 | 3.89 | 0.32 | 1.30 | 2.29 |
| Error | 48 | 10.00 | 0.21 | | 14.00 | 0.29 | | 24.00 | 0.25 | | |
| TSS | 71 | 30.88 | 0.43 | | 26.65 | 0.38 | | 59.31 | 0.84 | | |

Appendix V: Effect of pH, lime and varieties on number of leaves of maize at 60 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.50 | 0.50 | 2.40 | 0.89 | 0.89 | 3.05 | 1.39 | 0.69 | 2.78 | 4.04 |
| Lime (L) | 3 | 10.50 | 3.50 | 16.80* | 6.11 | 2.04 | 6.98* | 16.61 | 2.77 | 11.07* | 2.80 |
| Variety(V) | 2 | 7.53 | 3.76 | 18.07* | 6.03 | 3.01 | 10.33* | 13.56 | 3.39 | 13.56* | 3.19 |
| pH x L | 3 | 0.94 | 0.31 | 1.51 | 0.11 | 0.04 | 0.13 | 1.06 | 0.18 | 0.70 | 2.80 |
| L x V | 6 | 0.25 | 0.04 | 0.20 | 0.31 | 0.05 | 0.17 | 0.56 | 0.05 | 0.19 | 2.29 |
| pH x V | 2 | 0.08 | 0.04 | 0.20 | 0.53 | 0.26 | 0.90 | 0.61 | 0.15 | 0.61 | 3.19 |
| pHxLxV | 6 | 0.14 | 0.02 | 0.11 | 0.47 | 0.08 | 0.27 | 0.61 | 0.05 | 0.20 | 2.29 |
| Error | 48 | 10.00 | 0.21 | | 14.00 | 0.29 | | 24.00 | 0.25 | | |
| TSS | 71 | 29.94 | 0.42 | | 28.44 | 0.40 | | 60.64 | 0.85 | | |

Appendix VI: Effect of pH, lime and varieties on number of leaves of maize at harvest

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.89 | 0.89 | 3.05 | 0.68 | 0.68 | 3.77 | 1.57 | 0.78 | 3.32 | 4.04 |
| Lime (L) | 3 | 5.00 | 1.67 | 5.71* | 4.04 | 1.35 | 7.46* | 9.04 | 1.51 | 6.38* | 2.80 |
| Variety(V) | 2 | 4.11 | 2.06 | 7.05* | 1.36 | 0.68 | 3.77* | 5.47 | 1.37 | 5.79* | 3.19 |
| pH x L | 3 | 1.67 | 0.56 | 1.90 | 0.04 | 0.01 | 0.08 | 1.71 | 0.28 | 1.21 | 2.80 |
| L x V | 6 | 2.67 | 0.44 | 1.52 | 2.08 | 0.35 | 1.92 | 4.75 | 0.40 | 1.68 | 2.29 |
| pH x V | 2 | 0.44 | 0.22 | 0.76 | 0.86 | 0.43 | 2.38 | 1.31 | 0.33 | 1.38 | 3.19 |
| pHxLxV | 6 | 0.33 | 0.06 | 0.19 | 1.92 | 0.32 | 1.77 | 2.25 | 0.19 | 0.79 | 2.29 |
| Error | 48 | 14.00 | 0.29 | | 8.67 | 0.18 | | 22.67 | 0.24 | | |
| TSS | 71 | 29.11 | 0.41 | | 19.65 | 0.28 | | 52.44 | 0.74 | | |

* Significant at 5% level

Appendix VII: Effect of pH, lime and varieties on leaf area index of maize at 30 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.00 | 0.00 | 0.44 | 0.04 | 0.04 | 2.29 | 0.04 | 0.02 | 1.70 | 4.04 |
| Lime (L) | 3 | 0.05 | 0.02 | 2.14 | 0.06 | 0.02 | 1.14 | 0.11 | 0.02 | 1.47 | 2.80 |
| Variety(V) | 2 | 0.02 | 0.01 | 1.14 | 0.05 | 0.03 | 1.65 | 0.07 | 0.02 | 1.48 | 3.19 |
| pH x L | 3 | 0.01 | 0.00 | 0.40 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.14 | 2.80 |
| L x V | 6 | 0.01 | 0.00 | 0.21 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.08 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.12 | 0.01 | 0.01 | 0.32 | 0.01 | 0.00 | 0.25 | 3.19 |
| pHxLxV | 6 | 0.02 | 0.00 | 0.45 | 0.01 | 0.00 | 0.09 | 0.03 | 0.00 | 0.20 | 2.29 |
| Error | 48 | 0.38 | 0.01 | | 0.79 | 0.02 | | 1.17 | 0.01 | | |
| TSS | 71 | 0.49 | 0.0069 | | 0.96 | 0.014 | | 1.53 | 0.022 | | |

Appendix VIII: Effect of pH, lime and varieties on leaf area index of maize at 60 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.01 | 0.01 | 1.83 | 0.00 | 0.00 | 0.04 | 0.01 | 0.00 | 0.87 | 4.04 |
| Lime (L) | 3 | 0.04 | 0.01 | 2.83* | 0.05 | 0.02 | 3.11* | 0.08 | 0.01 | 2.98* | 2.80 |
| Variety(V) | 2 | 0.01 | 0.01 | 1.39 | 0.02 | 0.01 | 1.88 | 0.03 | 0.01 | 1.65 | 3.19 |
| pH x L | 3 | 0.01 | 0.00 | 0.47 | 0.00 | 0.00 | 0.31 | 0.01 | 0.00 | 0.38 | 2.80 |
| L x V | 6 | 0.02 | 0.00 | 0.69 | 0.01 | 0.00 | 0.29 | 0.03 | 0.00 | 0.48 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.25 | 0.01 | 0.01 | 1.04 | 0.01 | 0.00 | 0.67 | 3.19 |
| pHxLxV | 6 | 0.02 | 0.00 | 0.65 | 0.02 | 0.00 | 0.54 | 0.03 | 0.00 | 0.59 | 2.29 |
| Error | 48 | 0.21 | 0.00 | | 0.24 | 0.01 | | 0.45 | 0.00 | | |
| TSS | 71 | 0.31 | 0.0044 | | 0.35 | 0.0049 | | 0.78 | 0.011 | | |

Appendix IX: Effect of pH, lime and varieties on leaf area index of maize at harvest

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.46 | 4.04 |
| Lime (L) | 3 | 0.04 | 0.01 | 3.44* | 0.03 | 0.01 | 3.92* | 0.07 | 0.01 | 3.61* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.07 | 0.01 | 0.00 | 1.59 | 0.01 | 0.00 | 0.61 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.26 | 0.00 | 0.00 | 0.31 | 0.01 | 0.00 | 0.28 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.13 | 2.29 |
| pH x V | 2 | 0.01 | 0.00 | 1.10 | 0.00 | 0.00 | 0.15 | 0.01 | 0.00 | 0.76 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.09 | 2.29 |
| Error | 48 | 0.20 | 0.00 | | 0.11 | 0.00 | | 0.31 | 0.00 | | |
| TSS | 71 | 0.27 | 0.0038 | | 0.15 | 0.0021 | | 0.45 | 0.0063 | | |

* Significant at 5% level

Appendix X: Effect of pH, lime and varieties on cob length of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 3.65 | 3.65 | 34.89* | 3.08 | 3.08 | 35.47* | 6.73 | 3.36 | 35.15* | 4.04 |
| Lime (L) | 3 | 8.64 | 2.88 | 27.50* | 5.51 | 1.84 | 21.18* | 14.15 | 2.36 | 24.64* | 2.80 |
| Variety(V) | 2 | 1.80 | 0.90 | 8.60* | 0.70 | 0.35 | 4.03* | 2.50 | 0.62 | 6.53* | 3.19 |
| pH x L | 3 | 0.82 | 0.27 | 2.61 | 0.33 | 0.11 | 1.26 | 1.15 | 0.19 | 2.00 | 2.80 |
| L x V | 6 | 0.42 | 0.07 | 0.67 | 0.25 | 0.04 | 0.49 | 0.68 | 0.06 | 0.59 | 2.29 |
| pH x V | 2 | 0.26 | 0.13 | 1.22 | 0.02 | 0.01 | 0.10 | 0.27 | 0.07 | 0.71 | 3.19 |
| pHxLxV | 6 | 0.23 | 0.04 | 0.36 | 0.29 | 0.05 | 0.56 | 0.52 | 0.04 | 0.45 | 2.29 |
| Error | 48 | 5.03 | 0.10 | | 4.16 | 0.09 | | 9.19 | 0.10 | | |
| TSS | 71 | 20.85 | 0.29 | | 14.33 | 0.20 | | 39.14 | 0.27 | | |

Appendix XI: Effect of pH, lime and varieties on cob girth of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 2.38 | 2.38 | 11.67* | 1.93 | 1.93 | 17.30* | 4.31 | 2.16 | 13.66* | 4.04 |
| Lime (L) | 3 | 4.22 | 1.41 | 6.89* | 3.98 | 1.33 | 11.90* | 8.20 | 1.37 | 8.66* | 2.80 |
| Variety(V) | 2 | 1.36 | 0.68 | 3.32* | 1.24 | 0.62 | 5.57* | 2.60 | 0.65 | 4.11* | 3.19 |
| pH x L | 3 | 0.59 | 0.20 | 0.96 | 0.54 | 0.18 | 1.61 | 1.13 | 0.19 | 1.19 | 2.80 |
| L x V | 6 | 0.18 | 0.03 | 0.15 | 0.62 | 0.10 | 0.93 | 0.80 | 0.07 | 0.42 | 2.29 |
| pH x V | 2 | 0.03 | 0.02 | 0.08 | 0.39 | 0.19 | 1.74 | 0.42 | 0.11 | 0.67 | 3.19 |
| pHxLxV | 6 | 0.43 | 0.07 | 0.35 | 0.77 | 0.13 | 1.15 | 1.20 | 0.10 | 0.64 | 2.29 |
| Error | 48 | 9.80 | 0.20 | | 5.35 | 0.11 | | 15.15 | 0.16 | | |
| TSS | 71 | 19.00 | 0.27 | | 14.81 | 0.21 | | 33.92 | 0.24 | | |

Appendix XII: Effect of pH, lime and varieties on cob weight of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 1005.31 | 1005.31 | 75.45* | 1146.49 | 1146.49* | 62.16 | 2151.80 | 1075.90* | 67.74 | 4.04 |
| Lime (L) | 3 | 5079.58 | 1693.19 | 127.07* | 5248.03 | 1749.34* | 94.85 | 10327.61 | 1721.27* | 108.37 | 2.80 |
| Variety(V) | 2 | 529.34 | 264.67 | 19.86* | 477.80 | 238.90* | 12.95 | 1007.14 | 251.79* | 15.85 | 3.19 |
| pH x L | 3 | 7.10 | 2.37 | 0.18 | 1.42 | 0.47 | 0.03 | 8.51 | 1.42 | 0.09 | 2.80 |
| L x V | 6 | 12.82 | 2.14 | 0.16 | 8.63 | 1.44 | 0.08 | 21.46 | 1.79 | 0.11 | 2.29 |
| pH x V | 2 | 1.56 | 0.78 | 0.06 | 0.25 | 0.12 | 0.01 | 1.81 | 0.45 | 0.03 | 3.19 |
| pHxLxV | 6 | 6.55 | 1.09 | 0.08 | 12.13 | 2.02 | 0.11 | 18.68 | 1.56 | 0.10 | 2.29 |
| Error | 48 | 639.57 | 13.32 | | 885.28 | 18.44 | | 1524.85 | 15.88 | | |
| TSS | 71 | 7281.84 | 102.56 | | 7780.02 | 109.58 | | 15134.81 | 105.84 | | |

* Significant at 5% level

Appendix XIII: Effect of pH, lime and varieties on number of grains per row of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 102.72 | 102.72 | 308.17* | 105.13 | 105.13 | 189.23* | 207.85 | 103.92 | 233.83* | 4.04 |
| Lime (L) | 3 | 29.00 | 9.67 | 29.00* | 32.38 | 10.79 | 19.43* | 61.38 | 10.23 | 23.02* | 2.80 |
| Variety(V) | 2 | 13.36 | 6.68 | 20.04* | 20.08 | 10.04 | 18.08* | 33.44 | 8.36 | 18.81* | 3.19 |
| pH x L | 3 | 1.17 | 0.39 | 1.17 | 2.60 | 0.87 | 1.56 | 3.76 | 0.63 | 1.41 | 2.80 |
| L x V | 6 | 1.42 | 0.24 | 0.71 | 0.58 | 0.10 | 0.17 | 2.00 | 0.17 | 0.37 | 2.29 |
| pH x V | 2 | 4.36 | 2.18 | 6.54* | 1.75 | 0.88 | 1.58 | 6.11 | 1.53 | 3.44* | 3.19 |
| pHxLxV | 6 | 1.75 | 0.29 | 0.88 | 2.69 | 0.45 | 0.81 | 4.44 | 0.37 | 0.83 | 2.29 |
| Error | 48 | 16.00 | 0.33 | | 26.67 | 0.56 | | 42.67 | 0.44 | | |
| TSS | 71 | 169.78 | 2.39 | | 191.88 | 2.70 | | 361.83 | 2.53 | | |

Appendix XIV: Effect of pH, lime and varieties on number of rows per cob of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.35 | 0.35 | 1.39 | 0.06 | 0.06 | 0.19 | 0.40 | 0.20 | 0.74 | 4.04 |
| Lime (L) | 3 | 15.15 | 5.05 | 20.20* | 22.28 | 7.43 | 25.46* | 37.43 | 6.24 | 23.03* | 2.80 |
| Variety(V) | 2 | 4.33 | 2.17 | 8.67* | 4.69 | 2.35 | 8.05* | 9.03 | 2.26 | 8.33* | 3.19 |
| pH x L | 3 | 3.60 | 1.20 | 4.80* | 4.06 | 1.35 | 4.63* | 7.65 | 1.28 | 4.71* | 2.80 |
| L x V | 6 | 0.56 | 0.09 | 0.37 | 0.31 | 0.05 | 0.17 | 0.86 | 0.07 | 0.26 | 2.29 |
| pH x V | 2 | 0.44 | 0.22 | 0.89 | 0.36 | 0.18 | 0.62 | 0.81 | 0.20 | 0.74 | 3.19 |
| pHxLxV | 6 | 0.44 | 0.07 | 0.30 | 0.86 | 0.14 | 0.49 | 1.31 | 0.11 | 0.40 | 2.29 |
| Error | 48 | 12.00 | 0.25 | | 14.00 | 0.29 | | 26.00 | 0.27 | | |
| TSS | 71 | 36.88 | 0.52 | | 46.61 | 0.66 | | 85.49 | 0.60 | | |

Appendix XV: Effect of pH, lime and varieties on number of grains per cob of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 29484.01 | 29484.01 | 41.88* | 34892.01 | 34892.01 | 55.12* | 64376.03 | 32188.01 | 48.15* | 4.04 |
| Lime (L) | 3 | 57159.15 | 19053.05 | 27.06* | 59965.82 | 19988.61 | 31.58* | 117124.97 | 19520.83 | 29.20* | 2.80 |
| Variety(V) | 2 | 12826.69 | 6413.35 | 9.11* | 11998.58 | 5999.29 | 9.48* | 24825.28 | 6206.32 | 9.28* | 3.19 |
| pH x L | 3 | 1650.71 | 550.24 | 0.78 | 2585.82 | 861.94 | 1.36 | 4236.53 | 706.09 | 1.06 | 2.80 |
| L x V | 6 | 1025.31 | 170.88 | 0.24 | 3074.64 | 512.44 | 0.81 | 4099.94 | 341.66 | 0.51 | 2.29 |
| pH x V | 2 | 1155.19 | 577.60 | 0.82 | 1377.19 | 688.60 | 1.09 | 2532.39 | 633.10 | 0.95 | 3.19 |
| pHxLxV | 6 | 1269.25 | 211.54 | 0.30 | 2472.47 | 412.08 | 0.65 | 3741.72 | 311.81 | 0.47 | 2.29 |
| Error | 48 | 33791.33 | 703.99 | | 30383.33 | 632.99 | | 64174.67 | 668.49 | | |
| TSS | 71 | 138361.65 | 1948.76 | | 146749.88 | 2066.90 | | 288379.56 | 2016.64 | | |

* Significant at 5% level

Appendix XVI: Effect of pH, lime and varieties on test weight of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 6.31 | 6.31 | 19.89* | 7.32 | 7.32 | 8.86* | 13.63 | 6.82 | 11.92* | 4.04 |
| Lime (L) | 3 | 30.28 | 10.09 | 31.79* | 26.26 | 8.75 | 10.59* | 56.54 | 9.42 | 16.47* | 2.80 |
| Variety(V) | 2 | 1.17 | 0.59 | 1.85 | 1.19 | 0.60 | 0.72 | 2.36 | 0.59 | 1.03 | 3.19 |
| pH x L | 3 | 0.58 | 0.19 | 0.61 | 0.81 | 0.27 | 0.33 | 1.39 | 0.23 | 0.41 | 2.80 |
| L x V | 6 | 1.79 | 0.30 | 0.94 | 0.58 | 0.10 | 0.12 | 2.37 | 0.20 | 0.35 | 2.29 |
| pH x V | 2 | 0.73 | 0.37 | 1.16 | 0.10 | 0.05 | 0.06 | 0.84 | 0.21 | 0.37 | 3.19 |
| pHxLxV | 6 | 3.04 | 0.51 | 1.60 | 0.44 | 0.07 | 0.09 | 3.48 | 0.29 | 0.51 | 2.29 |
| Error | 48 | 15.24 | 0.32 | | 39.68 | 0.83 | | 54.92 | 0.57 | | |
| TSS | 71 | 59.14 | 0.83 | | 76.40 | 1.08 | | 136.23 | 0.95 | | |

Appendix XVII: Effect of pH, lime and varieties on grain yield of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 1059.61 | 1059.61 | 198.74* | 1581.38 | 1581.38 | 304.87* | 2640.99 | 1320.49 | 251.08* | 4.04 |
| Lime (L) | 3 | 3200.22 | 1066.74 | 200.08* | 3296.79 | 1098.93 | 211.86* | 6497.01 | 1082.84 | 205.89* | 2.80 |
| Variety(V) | 2 | 457.47 | 228.73 | 42.90* | 397.63 | 198.82 | 38.33* | 855.10 | 213.77 | 40.65* | 3.19 |
| pH x L | 3 | 30.20 | 10.07 | 1.89 | 32.65 | 10.88 | 2.10 | 62.86 | 10.48 | 1.99 | 2.80 |
| L x V | 6 | 38.37 | 6.39 | 1.20 | 12.16 | 2.03 | 0.39 | 50.53 | 4.21 | 0.80 | 2.29 |
| pH x V | 2 | 3.67 | 1.83 | 0.34 | 9.51 | 4.75 | 0.92 | 13.18 | 3.29 | 0.63 | 3.19 |
| pHxLxV | 6 | 14.08 | 2.35 | 0.44 | 4.53 | 0.76 | 0.15 | 18.61 | 1.55 | 0.29 | 2.29 |
| Error | 48 | 255.92 | 5.33 | | 248.98 | 5.19 | | 504.90 | 5.26 | | |
| TSS | 71 | 5059.53 | 71.26 | | 5583.63 | 78.64 | | 10652.68 | 74.49 | | |

Appendix XVIII: Effect of pH, lime and varieties on stover yield of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 2322.21 | 2322.21 | 49.59* | 2522.87 | 2522.87 | 56.30* | 4845.08 | 2422.54 | 52.88* | 4.04 |
| Lime (L) | 3 | 7554.97 | 2518.32 | 53.78* | 7337.55 | 2445.85 | 54.59* | 14892.52 | 2482.09 | 54.18* | 2.80 |
| Variety(V) | 2 | 518.97 | 259.49 | 5.54* | 727.10 | 363.55 | 8.11* | 1246.07 | 311.52 | 6.80* | 3.19 |
| pH x L | 3 | 3.26 | 1.09 | 0.02 | 3.83 | 1.28 | 0.03 | 7.09 | 1.18 | 0.03 | 2.80 |
| L x V | 6 | 9.45 | 1.58 | 0.03 | 6.63 | 1.11 | 0.02 | 16.09 | 1.34 | 0.03 | 2.29 |
| pH x V | 2 | 2.69 | 1.35 | 0.03 | 0.22 | 0.11 | 0.00 | 2.91 | 0.73 | 0.02 | 3.19 |
| pHxLxV | 6 | 11.76 | 1.96 | 0.04 | 1.24 | 0.21 | 0.00 | 13.00 | 1.08 | 0.02 | 2.29 |
| Error | 48 | 2247.59 | 46.82 | | 2150.75 | 44.81 | | 4398.33 | 45.82 | | |
| TSS | 71 | 12670.90 | 178.46 | | 12750.18 | 179.58 | | 25696.92 | 179.70 | | |

* Significant at 5% level

Appendix XIX: Effect of pH, lime and varieties on nitrogen content in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.01 | 0.01 | 3.17 | 0.00 | 0.00 | 0.71 | 0.02 | 0.01 | 2.01 | 4.04 |
| Lime (L) | 3 | 0.73 | 0.24 | 56.57* | 0.95 | 0.32 | 83.33* | 1.68 | 0.28 | 69.14* | 2.80 |
| Variety(V) | 2 | 0.03 | 0.01 | 2.99 | 0.02 | 0.01 | 2.29 | 0.04 | 0.01 | 2.66 | 3.19 |
| pH x L | 3 | 0.01 | 0.00 | 1.04 | 0.02 | 0.01 | 1.75 | 0.03 | 0.01 | 1.38 | 2.80 |
| L x V | 6 | 0.01 | 0.00 | 0.24 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 | 0.14 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.16 | 3.19 |
| pHxLxV | 6 | 0.01 | 0.00 | 0.24 | 0.00 | 0.00 | 0.21 | 0.01 | 0.00 | 0.23 | 2.29 |
| Error | 48 | 0.21 | 0.00 | | 0.18 | 0.00 | | 0.39 | 0.00 | | |
| TSS | 71 | 1.00 | 0.0141 | | 1.18 | 0.0166 | | 2.20 | 0.0154 | | |

Appendix XX: Effect of pH, lime and varieties on nitrogen content in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.01 | 0.01 | 2.30 | 0.01 | 0.01 | 2.30 | 0.01 | 0.01 | 2.30 | 4.04 |
| Lime (L) | 3 | 0.20 | 0.07 | 29.99* | 0.18 | 0.06 | 26.47* | 0.38 | 0.06 | 28.23* | 2.80 |
| Variety(V) | 2 | 0.01 | 0.00 | 1.68 | 0.01 | 0.00 | 1.68 | 0.02 | 0.00 | 1.68 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.46 | 0.00 | 0.00 | 0.46 | 0.01 | 0.00 | 0.46 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.31 | 0.01 | 0.00 | 0.31 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 | 0.57 | 0.01 | 0.00 | 0.57 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.10 | 2.29 |
| Error | 48 | 0.11 | 0.00 | | 0.11 | 0.00 | | 0.22 | 0.00 | | |
| TSS | 71 | 0.33 | 0.0046 | | 0.31 | 0.0044 | | 0.67 | 0.0047 | | |

Appendix XXI: Effect of pH, lime and varieties on phosphorus content in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.04 | 0.04 | 57.00* | 0.05 | 0.05 | 48.27* | 0.09 | 0.05 | 51.85* | 4.04 |
| Lime (L) | 3 | 0.08 | 0.03 | 38.83* | 0.16 | 0.05 | 52.70* | 0.25 | 0.04 | 47.02* | 2.80 |
| Variety(V) | 2 | 0.01 | 0.00 | 6.20* | 0.03 | 0.02 | 14.68* | 0.04 | 0.01 | 11.21* | 3.19 |
| pH x L | 3 | 0.01 | 0.00 | 3.34* | 0.01 | 0.00 | 2.87* | 0.02 | 0.00 | 3.06* | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.10 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.09 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.05 | 2.29 |
| Error | 48 | 0.03 | 0.00 | | 0.05 | 0.00 | | 0.08 | 0.00 | | |
| TSS | 71 | 0.17 | 0.0024 | | 0.30 | 0.0042 | | 0.53 | 0.0037 | | |

* Significant at 5%

Appendix XXII: Effect of pH, lime and varieties on phosphorus content in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.02 | 0.02 | 18.30* | 0.01 | 0.01 | 6.62* | 0.03 | 0.01 | 12.08* | 4.04 |
| Lime (L) | 3 | 0.03 | 0.01 | 8.51* | 0.02 | 0.01 | 4.18* | 0.04 | 0.01 | 6.20* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 2.20 | 0.01 | 0.00 | 2.13 | 0.01 | 0.00 | 2.16 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.38 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.40 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.05 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.03 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.09 | 2.29 |
| Error | 48 | 0.05 | 0.00 | | 0.06 | 0.00 | | 0.11 | 0.00 | | |
| TSS | 71 | 0.11 | 0.0015 | | 0.09 | 0.0013 | | 0.20 | 0.0014 | | |

Appendix XXIII: Effect of pH, lime and varieties on potassium content in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.09 | 0.09 | 23.89* | 0.09 | 0.09 | 27.04* | 0.17 | 0.09 | 25.40* | 4.04 |
| Lime (L) | 3 | 0.08 | 0.03 | 7.70* | 0.09 | 0.03 | 8.67* | 0.17 | 0.03 | 8.16* | 2.80 |
| Variety(V) | 2 | 0.04 | 0.02 | 6.15* | 0.04 | 0.02 | 5.83* | 0.08 | 0.02 | 6.00* | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.42 | 0.00 | 0.00 | 0.38 | 0.01 | 0.00 | 0.40 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.06 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.17 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.05 | 2.29 |
| Error | 48 | 0.17 | 0.00 | | 0.16 | 0.00 | | 0.33 | 0.00 | | |
| TSS | 71 | 0.39 | 0.0055 | | 0.38 | 0.0054 | | 0.78 | 0.0055 | | |

Appendix XXIV: Effect of pH, lime and varieties on potassium content in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.02 | 0.02 | 11.10* | 0.03 | 0.03 | 11.94* | 0.05 | 0.03 | 11.54* | 4.04 |
| Lime (L) | 3 | 0.22 | 0.07 | 34.53* | 0.26 | 0.09 | 37.37* | 0.47 | 0.08 | 36.00* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.95 | 0.01 | 0.00 | 1.63 | 0.01 | 0.00 | 1.30 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.73 | 0.01 | 0.00 | 1.00 | 0.01 | 0.00 | 0.87 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.04 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.11 | 2.29 |
| Error | 48 | 0.10 | 0.00 | | 0.11 | 0.00 | | 0.21 | 0.00 | | |
| TSS | 71 | 0.36 | 0.0051 | | 0.41 | 0.0058 | | 0.76 | 0.0053 | | |

* Significant at 5%

Appendix XXV: Effect of pH, lime and varieties on calcium content in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.12 | 0.12 | 57.53* | 0.15 | 0.15 | 56.56* | 0.26 | 0.13 | 56.99* | 4.04 |
| Lime (L) | 3 | 0.81 | 0.27 | 131.68* | 0.95 | 0.32 | 122.25* | 1.75 | 0.29 | 126.42* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.36 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.10 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.05 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.09 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.04 | 2.29 |
| Error | 48 | 0.10 | 0.00 | | 0.12 | 0.00 | | 0.22 | 0.00 | | |
| TSS | 71 | 1.03 | 0.0145 | | 1.22 | 0.0172 | | 2.25 | 0.0157 | | |

Appendix XXVI: Effect of pH, lime and varieties on calcium content in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.12 | 0.12 | 64.40* | 0.06 | 0.06 | 33.27* | 0.18 | 0.09 | 48.68* | 4.04 |
| Lime (L) | 3 | 0.94 | 0.31 | 174.50* | 0.81 | 0.27 | 148.90* | 1.75 | 0.29 | 161.58* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.16 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.84 | 0.00 | 0.00 | 0.52 | 0.01 | 0.00 | 0.68 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.09 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.07 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.12 | 2.29 |
| Error | 48 | 0.09 | 0.00 | | 0.09 | 0.00 | | 0.17 | 0.00 | | |
| TSS | 71 | 1.15 | 0.0162 | | 0.97 | 0.0137 | | 2.12 | 0.0148 | | |

Appendix XXVII: Effect of pH, lime and varieties on boron content in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.01 | 0.01 | 2.72 | 0.02 | 0.02 | 2.66 | 0.04 | 0.02 | 2.68 | 4.04 |
| Lime (L) | 3 | 0.58 | 0.19 | 38.40* | 0.63 | 0.21 | 23.63* | 1.20 | 0.20 | 28.98* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.46 | 0.01 | 0.00 | 0.55 | 0.01 | 0.00 | 0.51 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.12 | 0.01 | 0.00 | 0.13 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.05 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.07 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.09 | 0.01 | 0.00 | 0.10 | 0.01 | 0.00 | 0.10 | 2.29 |
| Error | 48 | 0.24 | 0.01 | | 0.42 | 0.01 | | 0.66 | 0.01 | | |
| TSS | 71 | 0.84 | 0.0118 | | 1.10 | 0.0155 | | 1.96 | 0.0137 | | |

* Significant at 5%

Appendix XVIII: Effect of pH, lime and varieties on boron content in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.03 | 0.03 | 17.03* | 0.02 | 0.02 | 11.01* | 0.05 | 0.02 | 13.57* | 4.04 |
| Lime (L) | 3 | 0.41 | 0.14 | 87.78* | 0.42 | 0.14 | 67.42* | 0.83 | 0.14 | 76.08* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 0.39 | 0.00 | 0.00 | 0.40 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.88 | 0.01 | 0.00 | 0.82 | 0.01 | 0.00 | 0.85 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.07 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.13 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.03 | 2.29 |
| Error | 48 | 0.07 | 0.00 | | 0.10 | 0.00 | | 0.18 | 0.00 | | |
| TSS | 71 | 0.52 | 0.0073 | | 0.56 | 0.0079 | | 1.13 | 0.0079 | | |

Appendix XXIX: Effect of pH, lime and varieties on nitrogen uptake in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 203847.51 | 203847.51 | 71.35* | 262046.97 | 262046.97 | 124.95* | 465894.48 | 232947.24 | 94.04* | 4.04 |
| Lime (L) | 3 | 1399535.44 | 466511.81 | 163.28* | 1667930.65 | 555976.88 | 265.10* | 3067466.08 | 511244.35 | 206.38* | 2.80 |
| Variety(V) | 2 | 134282.26 | 67141.13 | 23.50* | 112391.20 | 56195.60 | 26.79* | 246673.45 | 61668.36 | 24.89* | 3.19 |
| pH x L | 3 | 8610.77 | 2870.26 | 1.00 | 2403.00 | 801.00 | 0.38 | 11013.77 | 1835.63 | 0.74 | 2.80 |
| L x V | 6 | 7726.06 | 1287.68 | 0.45 | 4394.81 | 732.47 | 0.35 | 12120.87 | 1010.07 | 0.41 | 2.29 |
| pH x V | 2 | 1023.13 | 511.56 | 0.18 | 153.82 | 76.91 | 0.04 | 1176.94 | 294.24 | 0.12 | 3.19 |
| pHxLxV | 6 | 8279.62 | 1379.94 | 0.48 | 2919.38 | 486.56 | 0.23 | 11199.00 | 933.25 | 0.38 | 2.29 |
| Error | 48 | 137139.66 | 2857.08 | | 100668.35 | 2097.26 | | 237808.01 | 2477.17 | | |
| TSS | 71 | 1900444.44 | 26766.82 | | 2152908.17 | 30322.65 | | 4072681.49 | 28480.29 | | |

Appendix XXX: Effect of pH, lime and varieties on nitrogen uptake in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 172280.59 | 172280.59 | 32.95* | 201368.10 | 201368.10 | 26.56* | 373648.69 | 186824.34 | 29.17* | 4.04 |
| Lime (L) | 3 | 1161270.02 | 387090.01 | 74.04* | 1166250.23 | 388750.08 | 51.28* | 2327520.26 | 387920.04 | 60.57* | 2.80 |
| Variety(V) | 2 | 68347.59 | 34173.80 | 6.54* | 90163.62 | 45081.81 | 5.95* | 158511.22 | 39627.80 | 6.19* | 3.19 |
| pH x L | 3 | 7581.49 | 2527.16 | 0.48 | 9117.21 | 3039.07 | 0.40 | 16698.69 | 2783.12 | 0.43 | 2.80 |
| L x V | 6 | 7554.43 | 1259.07 | 0.24 | 7261.85 | 1210.31 | 0.16 | 14816.28 | 1234.69 | 0.19 | 2.29 |
| pH x V | 2 | 5743.91 | 2871.95 | 0.55 | 4889.33 | 2444.66 | 0.32 | 10633.23 | 2658.31 | 0.42 | 3.19 |
| pHxLxV | 6 | 4521.04 | 753.51 | 0.14 | 2643.17 | 440.53 | 0.06 | 7164.21 | 597.02 | 0.09 | 2.29 |
| Error | 48 | 250944.39 | 5228.01 | | 363863.06 | 7580.48 | | 614807.44 | 6404.24 | | |
| TSS | 71 | 1678243.45 | 23637.23 | | 1845556.56 | 25993.75 | | 3629003.48 | 25377.65 | | |

* Significant at 5%

Appendix XXXI: Effect of pH, lime and varieties on phosphorus uptake in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 59272.39 | 59272.39 | 134.20* | 91651.22 | 91651.22 | 174.10* | 150923.61 | 75461.80 | 155.90* | 4.04 |
| Lime (L) | 3 | 135847.62 | 45282.54 | 102.52* | 221569.58 | 73856.53 | 140.30* | 357417.20 | 59569.53 | 123.06* | 2.80 |
| Variety(V) | 2 | 18942.80 | 9471.40 | 21.44* | 36518.61 | 18259.30 | 34.69* | 55461.40 | 13865.35 | 28.64* | 3.19 |
| pH x L | 3 | 3090.02 | 1030.01 | 2.33 | 4850.56 | 1616.85 | 3.07* | 7940.58 | 1323.43 | 2.73 | 2.80 |
| L x V | 6 | 1090.83 | 181.80 | 0.41 | 588.48 | 98.08 | 0.19 | 1679.30 | 139.94 | 0.29 | 2.29 |
| pH x V | 2 | 114.81 | 57.40 | 0.13 | 61.72 | 30.86 | 0.06 | 176.52 | 44.13 | 0.09 | 3.19 |
| pHxLxV | 6 | 350.75 | 58.46 | 0.13 | 243.66 | 40.61 | 0.08 | 594.41 | 49.53 | 0.10 | 2.29 |
| Error | 48 | 21200.74 | 441.68 | | 25268.36 | 526.42 | | 46469.10 | 484.05 | | |
| TSS | 71 | 239909.95 | 3379.01 | | 380752.18 | 5362.71 | | 650751.37 | 4550.71 | | |

Appendix XXXII: Effect of pH, lime and varieties on phosphorus uptake in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 62276.85 | 62276.85 | 32.01* | 35147.40 | 35147.40 | 18.22* | 97424.25 | 48712.13 | 25.15* | 4.04 |
| Lime (L) | 3 | 105314.81 | 35104.94 | 18.05* | 69080.97 | 23026.99 | 11.94* | 174395.78 | 29065.96 | 15.00* | 2.80 |
| Variety(V) | 2 | 10486.56 | 5243.28 | 2.70 | 10818.73 | 5409.37 | 2.80 | 21305.29 | 5326.32 | 2.75 | 3.19 |
| pH x L | 3 | 4270.70 | 1423.57 | 0.73 | 3919.97 | 1306.66 | 0.68 | 8190.67 | 1365.11 | 0.70 | 2.80 |
| L x V | 6 | 611.60 | 101.93 | 0.05 | 451.28 | 75.21 | 0.04 | 1062.88 | 88.57 | 0.05 | 2.29 |
| pH x V | 2 | 90.45 | 45.22 | 0.02 | 1.64 | 0.82 | 0.00 | 92.09 | 23.02 | 0.01 | 3.19 |
| pHxLxV | 6 | 743.39 | 123.90 | 0.06 | 1120.88 | 186.81 | 0.10 | 1864.28 | 155.36 | 0.08 | 2.29 |
| Error | 48 | 93375.19 | 1945.32 | | 92598.64 | 1929.14 | | 185973.83 | 1937.23 | | |
| TSS | 71 | 277169.55 | 3903.80 | | 213139.52 | 3001.97 | | 493529.44 | 3451.25 | | |

Appendix XXXIII: Effect of pH, lime and varieties on potassium uptake in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 373648.69 | 186824.34 | 29.17* | 170276.97 | 170276.97 | 87.44* | 300542.11 | 150271.06 | 78.49* | 4.04 |
| Lime (L) | 3 | 2327520.26 | 387920.04 | 60.57* | 223336.24 | 74445.41 | 38.23* | 420854.62 | 70142.44 | 36.64* | 2.80 |
| Variety(V) | 2 | 158511.22 | 39627.80 | 6.19* | 41049.28 | 20524.64 | 10.54* | 87629.88 | 21907.47 | 11.44* | 3.19 |
| pH x L | 3 | 16698.69 | 2783.12 | 0.43 | 7943.14 | 2647.71 | 1.36 | 12140.27 | 2023.38 | 1.06 | 2.80 |
| L x V | 6 | 14816.28 | 1234.69 | 0.19 | 2778.17 | 463.03 | 0.24 | 5470.68 | 455.89 | 0.24 | 2.29 |
| pH x V | 2 | 10633.23 | 2658.31 | 0.42 | 167.60 | 83.80 | 0.04 | 434.90 | 108.73 | 0.06 | 3.19 |
| pHxLxV | 6 | 7164.21 | 597.02 | 0.09 | 908.32 | 151.39 | 0.08 | 1427.06 | 118.92 | 0.06 | 2.29 |
| Error | 48 | 614807.44 | 6404.24 | | 93475.93 | 1947.42 | | 183800.87 | 1914.59 | | |
| TSS | 71 | 3629003.48 | 25377.65 | | 539935.67 | 7604.728 | | 1020490.50 | 7136.30 | | |

* Significant at 5%

Appendix XXXIV: Effect of pH, lime and varieties on potassium uptake in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 579119.36 | 579119.36 | 57.46* | 635034.45 | 635034.45 | 64.25* | 1214153.81 | 607076.91 | 60.82* | 4.04 |
| Lime (L) | 3 | 2364449.41 | 788149.80 | 78.20* | 2527899.54 | 842633.18 | 85.26* | 4892349.0 | 815391.49 | 81.70* | 2.80 |
| Variety(V) | 2 | 110976.68 | 55488.34 | 5.51* | 175548.29 | 87774.14 | 8.88* | 286524.96 | 71631.24 | 7.18* | 3.19 |
| pH x L | 3 | 17148.79 | 5716.26 | 0.57 | 22308.60 | 7436.20 | 0.75 | 39457.39 | 6576.23 | 0.66 | 2.80 |
| L x V | 6 | 3563.48 | 593.91 | 0.06 | 2872.18 | 478.70 | 0.05 | 6435.66 | 536.30 | 0.05 | 2.29 |
| pH x V | 2 | 1385.81 | 692.90 | 0.07 | 68.69 | 34.35 | 0.00 | 1454.50 | 363.63 | 0.04 | 3.19 |
| pHxLxV | 6 | 5377.85 | 896.31 | 0.09 | 1914.97 | 319.16 | 0.03 | 7292.82 | 607.73 | 0.06 | 2.29 |
| Error | 48 | 483754.60 | 10078.22 | | 474399.39 | 9883.32 | | 958153.99 | 9980.77 | | |
| TSS | 71 | 3565775.98 | 50222.2 | | 3840046.10 | 54085.16 | | 7451779.79 | 52110.35 | | |

Appendix XXXV: Effect of pH, lime and varieties on calcium uptake in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 141534.17 | 141534.17 | 124.35* | 203476.28 | 203476.28 | 160.31* | 345010.45 | 172505.22 | 143.31* | 4.04 |
| Lime (L) | 3 | 646145.77 | 215381.92 | 189.23* | 747387.40 | 249129.13 | 196.27* | 1393533.17 | 232255.53 | 192.94* | 2.80 |
| Variety(V) | 2 | 14763.11 | 7381.55 | 6.49* | 16267.91 | 8133.95 | 6.41* | 31031.02 | 7757.75 | 6.44* | 3.19 |
| pH x L | 3 | 1669.21 | 556.40 | 0.49 | 6505.02 | 2168.34 | 1.71 | 8174.23 | 1362.37 | 1.13 | 2.80 |
| L x V | 6 | 2066.59 | 344.43 | 0.30 | 1332.85 | 222.14 | 0.18 | 3399.44 | 283.29 | 0.24 | 2.29 |
| pH x V | 2 | 5.26 | 2.63 | 0.00 | 252.13 | 126.07 | 0.10 | 257.39 | 64.35 | 0.05 | 3.19 |
| pHxLxV | 6 | 589.27 | 98.21 | 0.09 | 112.31 | 18.72 | 0.01 | 701.58 | 58.46 | 0.05 | 2.29 |
| Error | 48 | 54633.14 | 1138.19 | | 60926.39 | 1269.30 | | 115559.53 | 1203.75 | | |
| TSS | 71 | 861406.52 | 12132.49 | | 1036260.28 | 14595.22 | | 1904261.32 | 13316.51 | | |

Appendix XXXVI: Effect of pH, lime and varieties on calcium uptake in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 428687.07 | 428687.07 | 105.72* | 320089.34 | 320089.34 | 81.28* | 748776.41 | 374388.21 | 93.68* | 4.04 |
| Lime (L) | 3 | 2332050.57 | 777350.19 | 191.71* | 2206432.25 | 735477.42 | 186.76* | 4538482.8 | 756413.80 | 189.27* | 2.80 |
| Variety(V) | 2 | 9085.99 | 4542.99 | 1.12 | 19210.15 | 9605.08 | 2.44 | 28296.14 | 7074.04 | 1.77 | 3.19 |
| pH x L | 3 | 8241.87 | 2747.29 | 0.68 | 2803.58 | 934.53 | 0.24 | 11045.45 | 1840.91 | 0.46 | 2.80 |
| L x V | 6 | 3738.67 | 623.11 | 0.15 | 1414.39 | 235.73 | 0.06 | 5153.07 | 429.42 | 0.11 | 2.29 |
| pH x V | 2 | 283.30 | 141.65 | 0.03 | 480.79 | 240.40 | 0.06 | 764.09 | 191.02 | 0.05 | 3.19 |
| pHxLxV | 6 | 3364.84 | 560.81 | 0.14 | 768.88 | 128.15 | 0.03 | 4133.72 | 344.48 | 0.09 | 2.29 |
| Error | 48 | 194631.97 | 4054.83 | | 189027.59 | 3938.07 | | 383659.56 | 3996.45 | | |
| TSS | 71 | 2980084.28 | 41973.02 | | 2740226.98 | 38594.75 | | 5755133.30 | 40245.69 | | |

* Significant at 5%

Appendix XXXVII: Effect of pH, lime and varieties on boron uptake in grain

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 100467.02 | 100467.02 | 191.66* | 152206.67 | 152206.67 | 294.77* | 252673.69 | 126336.8 | 242.83* | 4.04 |
| Lime (L) | 3 | 324794.88 | 108264.96 | 206.54* | 336988.14 | 112329.38 | 217.54* | 661783.02 | 110297.1 | 212.00* | 2.80 |
| Variety(V) | 2 | 42654.17 | 21327.09 | 40.69* | 37843.06 | 18921.53 | 36.64* | 80497.23 | 20124.31 | 38.68* | 3.19 |
| pH x L | 3 | 2319.17 | 773.06 | 1.47 | 3431.28 | 1143.76 | 2.22 | 5750.45 | 958.41 | 1.84 | 2.80 |
| L x V | 6 | 3528.80 | 588.13 | 1.12 | 1020.58 | 170.10 | 0.33 | 4549.38 | 379.12 | 0.73 | 2.29 |
| pH x V | 2 | 333.65 | 166.83 | 0.32 | 673.33 | 336.66 | 0.65 | 1006.98 | 251.74 | 0.48 | 3.19 |
| pHxLxV | 6 | 1419.58 | 236.60 | 0.45 | 504.87 | 84.14 | 0.16 | 1924.45 | 160.37 | 0.31 | 2.29 |
| Error | 48 | 25160.69 | 524.18 | | 24785.01 | 516.35 | | 49945.70 | 520.27 | | |
| TSS | 71 | 500677.95 | 7051.802 | | 557452.94 | 7851.45 | | 1059743.86 | 7410.80 | | |

Appendix XXXVIII: Effect of pH, lime and varieties on boron uptake in stover

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 31314.62 | 31314.62 | 63.97* | 34037.45 | 34037.45 | 57.39* | 65352.07 | 32676.03 | 60.36* | 4.04 |
| Lime (L) | 3 | 116140.35 | 38713.45 | 79.09* | 118507.80 | 39502.60 | 66.60* | 234648.14 | 39108.02 | 72.25* | 2.80 |
| Variety(V) | 2 | 6017.30 | 3008.65 | 6.15* | 7934.59 | 3967.29 | 6.69* | 13951.89 | 3487.97 | 6.44* | 3.19 |
| pH x L | 3 | 53.04 | 17.68 | 0.04 | 115.70 | 38.57 | 0.07 | 168.74 | 28.12 | 0.05 | 2.80 |
| L x V | 6 | 120.37 | 20.06 | 0.04 | 61.81 | 10.30 | 0.02 | 182.18 | 15.18 | 0.03 | 2.29 |
| pH x V | 2 | 28.78 | 14.39 | 0.03 | 16.19 | 8.10 | 0.01 | 44.97 | 11.24 | 0.02 | 3.19 |
| pHxLxV | 6 | 135.54 | 22.59 | 0.05 | 20.51 | 3.42 | 0.01 | 156.05 | 13.00 | 0.02 | 2.29 |
| Error | 48 | 23496.43 | 489.51 | | 28469.55 | 593.12 | | 51965.97 | 541.31 | | |
| TSS | 71 | 177306.42 | 2497.274 | | 189163.59 | 2664.276 | | 373761.18 | 2613.71 | | |

Appendix XXXIX: Effect of pH, lime and varieties on pH of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 1.68 | 1.68 | 1259.44* | 1.58 | 1.58 | 1132.82* | 3.26 | 1.63 | 1194.65* | 4.04 |
| Lime (L) | 3 | 23.00 | 7.67 | 5755.71* | 21.61 | 7.20 | 5159.54* | 44.60 | 7.43 | 5450.64* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.28 | 0.00 | 0.00 | 0.24 | 0.00 | 0.00 | 0.26 | 3.19 |
| pH x L | 3 | 0.88 | 0.29 | 219.27* | 0.96 | 0.32 | 229.77* | 1.84 | 0.31 | 224.65* | 2.80 |
| L x V | 6 | 0.01 | 0.00 | 0.67 | 0.00 | 0.00 | 0.34 | 0.01 | 0.00 | 0.50 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.71 | 0.00 | 0.00 | 0.51 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.41 | 0.01 | 0.00 | 0.68 | 0.01 | 0.00 | 0.55 | 2.29 |
| Error | 48 | 0.06 | 0.00 | | 0.07 | 0.00 | | 0.13 | 0.00 | | |
| TSS | 71 | 25.63 | 0.36 | | 24.23 | 0.34 | | 49.85 | 0.35 | | |

* Significant at 5%

Appendix XL: Effect of pH, lime and varieties on electrical conductivity of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.00 | 0.004 | 1.56 | 0.00 | 0.00 | 0.80 | 0.01 | 0.00 | 1.19 | 4.04 |
| Lime (L) | 3 | 0.01 | 0.00 | 1.98 | 0.01 | 0.00 | 1.40 | 0.02 | 0.00 | 1.69 | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.60 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.36 | 3.19 |
| pH x L | 3 | 0.01 | 0.00 | 0.83 | 0.00 | 0.00 | 0.19 | 0.01 | 0.00 | 0.51 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.15 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.21 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.13 | 2.29 |
| Error | 48 | 0.11 | 0.0023 | | 0.11 | 0.00 | | 0.22 | 0.00 | | |
| TSS | 71 | 0.14 | 0.0020 | | 0.12 | 0.0017 | | 0.29 | 0.0020 | | |

Appendix XLI: Effect of pH, lime and varieties on percent base saturation of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 8.31 | 8.31 | 1.45 | 3.56 | 3.56 | 0.84 | 11.87 | 5.94 | 1.19 | 4.04 |
| Lime (L) | 3 | 1040.20 | 346.73 | 60.44* | 841.47 | 280.49 | 66.28* | 1881.67 | 313.61 | 62.91* | 2.80 |
| Variety(V) | 2 | 1.42 | 0.71 | 0.12 | 0.31 | 0.15 | 0.04 | 1.73 | 0.43 | 0.09 | 3.19 |
| pH x L | 3 | 45.93 | 15.31 | 2.67 | 67.01 | 22.34 | 5.28* | 112.94 | 18.82 | 3.78* | 2.80 |
| L x V | 6 | 1.45 | 0.24 | 0.04 | 0.24 | 0.04 | 0.01 | 1.70 | 0.14 | 0.03 | 2.29 |
| pH x V | 2 | 0.11 | 0.05 | 0.01 | 0.05 | 0.03 | 0.01 | 0.16 | 0.04 | 0.01 | 3.19 |
| pHxLxV | 6 | 1.28 | 0.21 | 0.04 | 0.14 | 0.02 | 0.01 | 1.42 | 0.12 | 0.02 | 2.29 |
| Error | 48 | 275.39 | 5.74 | | 203.15 | 4.23 | | 478.53 | 4.98 | | |
| TSS | 71 | 1374.09 | 19.35 | | 1115.93 | 15.72 | | 2499.91 | 35.21 | | |

Appendix XLII: Effect of pH, lime and varieties on organic carbon of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.00 | 0.00 | 0.47 | 0.00 | 0.00 | 0.76 | 0.00 | 0.00 | 0.61 | 4.04 |
| Lime (L) | 3 | 0.01 | 0.00 | 0.57 | 0.00 | 0.00 | 0.36 | 0.01 | 0.00 | 0.47 | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.32 | 0.00 | 0.00 | 0.25 | 3.19 |
| pH x L | 3 | 0.00 | 0.00 | 0.50 | 0.00 | 0.00 | 0.11 | 0.01 | 0.00 | 0.32 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.11 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.08 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.08 | 2.29 |
| Error | 48 | 0.15 | 0.00 | | 0.14 | 0.00 | | 0.29 | 0.00 | | |
| TSS | 71 | 0.17 | 0.0024 | | 0.15 | 0.0021 | | 0.32 | 0.0045 | | |

* Significant at 5%

Appendix XLIII: Effect of pH, lime and varieties on available nitrogen of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 148.26 | 148.26 | 1.74 | 51.44 | 51.44 | 0.58 | 199.71 | 99.85 | 1.15 | 4.04 |
| Lime (L) | 3 | 17259.93 | 5753.31 | 67.33* | 17672.00 | 5890.67 | 66.84* | 34931.93 | 5821.99 | 67.08* | 2.80 |
| Variety(V) | 2 | 37.93 | 18.97 | 0.22 | 58.67 | 29.33 | 0.33 | 96.60 | 24.15 | 0.28 | 3.19 |
| pH x L | 3 | 122.22 | 40.74 | 0.48 | 298.91 | 99.64 | 1.13 | 421.12 | 70.19 | 0.81 | 2.80 |
| L x V | 6 | 25.13 | 4.19 | 0.05 | 22.02 | 3.67 | 0.04 | 47.15 | 3.93 | 0.05 | 2.29 |
| pH x V | 2 | 0.46 | 0.23 | 0.00 | 12.95 | 6.47 | 0.07 | 13.41 | 3.35 | 0.04 | 3.19 |
| pHxLxV | 6 | 39.24 | 6.54 | 0.08 | 30.51 | 5.08 | 0.06 | 69.74 | 5.81 | 0.07 | 2.29 |
| Error | 48 | 4101.50 | 85.45 | | 4230.16 | 88.13 | | 8331.65 | 86.79 | | |
| TSS | 71 | 21734.67 | 306.12 | | 22376.65 | 315.16 | | 44142.55 | 308.69 | | |

Appendix XLIV: Effect of pH, lime and varieties on available phosphorus of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 19.46 | 19.46 | 16.82* | 22.78 | 22.78 | 8.76* | 42.24 | 21.12 | 11.25* | 4.04 |
| Lime (L) | 3 | 133.40 | 44.47 | 38.45* | 67.98 | 22.66 | 8.72* | 201.38 | 33.56 | 17.87* | 2.80 |
| Variety(V) | 2 | 0.27 | 0.14 | 0.12 | 1.11 | 0.56 | 0.21 | 1.38 | 0.35 | 0.18 | 3.19 |
| pH x L | 3 | 0.66 | 0.22 | 0.19 | 4.79 | 1.60 | 0.61 | 5.45 | 0.91 | 0.48 | 2.80 |
| L x V | 6 | 1.29 | 0.22 | 0.19 | 0.73 | 0.12 | 0.05 | 2.02 | 0.17 | 0.09 | 2.29 |
| pH x V | 2 | 0.59 | 0.30 | 0.26 | 0.01 | 0.00 | 0.00 | 0.60 | 0.15 | 0.08 | 3.19 |
| pHxLxV | 6 | 0.87 | 0.14 | 0.13 | 0.28 | 0.05 | 0.02 | 1.15 | 0.10 | 0.05 | 2.29 |
| Error | 48 | 55.51 | 1.16 | | 124.76 | 2.60 | | 180.28 | 1.88 | | |
| TSS | 71 | 212.06 | 2.99 | | 222.44 | 3.13 | | 456.84 | 3.19 | | |

Appendix XLV: Effect of pH, lime and varieties on available potassium of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 18.97 | 18.97 | 1.80 | 5.81 | 5.81 | 0.56 | 24.79 | 12.39 | 1.19 | 4.04 |
| Lime (L) | 3 | 104.24 | 34.75 | 3.31* | 262.75 | 87.58 | 8.47* | 366.99 | 61.17 | 5.87* | 2.80 |
| Variety(V) | 2 | 5.10 | 2.55 | 0.24 | 0.58 | 0.29 | 0.03 | 5.68 | 1.42 | 0.14 | 3.19 |
| pH x L | 3 | 63.18 | 21.06 | 2.00 | 10.76 | 3.59 | 0.35 | 73.94 | 12.32 | 1.18 | 2.80 |
| L x V | 6 | 10.51 | 1.75 | 0.17 | 14.71 | 2.45 | 0.24 | 25.23 | 2.10 | 0.20 | 2.29 |
| pH x V | 2 | 0.51 | 0.25 | 0.02 | 2.52 | 1.26 | 0.12 | 3.02 | 0.76 | 0.07 | 3.19 |
| pHxLxV | 6 | 7.77 | 1.29 | 0.12 | 13.28 | 2.21 | 0.21 | 21.04 | 1.75 | 0.17 | 2.29 |
| Error | 48 | 504.61 | 10.51 | | 496.45 | 10.34 | | 1001.05 | 10.43 | | |
| TSS | 71 | 714.89 | 10.07 | | 806.86 | 11.36 | | 1525.21 | 21.48 | | |

* Significant at 5%

Appendix XLVI: Effect of pH, lime and varieties on exchangeable calcium of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 1.05 | 1.05 | 8.41* | 1.03 | 1.03 | 8.06* | 2.09 | 1.04 | 8.23* | 4.04 |
| Lime (L) | 3 | 143.04 | 47.68 | 380.68* | 145.48 | 48.49 | 378.58* | 288.52 | 48.09 | 379.62* | 2.80 |
| Variety(V) | 2 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.02 | 0.01 | 0.00 | 0.01 | 3.19 |
| pH x L | 3 | 0.14 | 0.05 | 0.36 | 0.22 | 0.07 | 0.57 | 0.35 | 0.06 | 0.46 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.29 |
| Error | 48 | 6.01 | 0.13 | | 6.15 | 0.13 | | 12.16 | 0.13 | | |
| TSS | 71 | 150.25 | 2.12 | | 152.89 | 2.15 | | 303.14 | 2.12 | | |

Appendix XLVII: Effect of pH, lime and varieties on available boron of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.13 | 0.13 | 156.71* | 0.13 | 0.13 | 116.13* | 0.25 | 0.13 | 133.53* | 4.04 |
| Lime (L) | 3 | 0.01 | 0.00 | 5.73* | 0.02 | 0.01 | 5.08* | 0.03 | 0.01 | 5.36* | 2.80 |
| Variety(V) | 2 | 0.001 | 0.0006 | 0.74 | 0.003 | 0.0016 | 1.53 | 0.004 | 0.0011 | 1.19 | 3.19 |
| pH x L | 3 | 0.001 | 0.0002 | 0.29 | 0.0055 | 0.0018 | 1.71 | 0.006 | 0.0010 | 1.10 | 2.80 |
| L x V | 6 | 0.0026 | 0.00043 | 0.53 | 0.0061 | 0.0010 | 0.95 | 0.0087 | 0.00072 | 0.77 | 2.29 |
| pH x V | 2 | 0.0019 | 0.0010 | 1.18 | 0.000 | 0.0002 | 0.19 | 0.002 | 0.0006 | 0.62 | 3.19 |
| pHxLxV | 6 | 0.0004 | 0.00007 | 0.09 | 0.004 | 0.0007 | 0.64 | 0.005 | 0.0004 | 0.41 | 2.29 |
| Error | 48 | 0.0388 | 0.0008 | | 0.0517 | 0.0011 | | 0.09 | 0.0009 | | |
| TSS | 71 | 0.19 | 0.0027 | | 0.21 | 0.003 | | 0.41 | 0.0058 | | |

Appendix XLVIII: Effect of pH, lime and varieties on exchangeable hydrogen of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.26 | 0.26 | 11.26* | 0.69 | 0.69 | 19.67* | 0.95 | 0.48 | 16.30* | 4.04 |
| Lime (L) | 3 | 3.42 | 1.14 | 48.60* | 2.53 | 0.84 | 24.06* | 5.95 | 0.99 | 33.89* | 2.80 |
| Variety(V) | 2 | 0.02 | 0.01 | 0.48 | 0.00 | 0.00 | 0.06 | 0.03 | 0.01 | 0.23 | 3.19 |
| pH x L | 3 | 0.28 | 0.09 | 4.05* | 0.33 | 0.11 | 3.12* | 0.61 | 0.10 | 3.49* | 2.80 |
| L x V | 6 | 0.03 | 0.01 | 0.25 | 0.00 | 0.00 | 0.02 | 0.04 | 0.00 | 0.11 | 2.29 |
| pH x V | 2 | 0.01 | 0.01 | 0.29 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.11 | 3.19 |
| pHxLxV | 6 | 0.03 | 0.00 | 0.19 | 0.01 | 0.00 | 0.02 | 0.03 | 0.00 | 0.09 | 2.29 |
| Error | 48 | 1.13 | 0.02 | | 1.68 | 0.04 | | 2.81 | 0.03 | | |
| TSS | 71 | 5.19 | 0.073 | | 5.25 | 0.074 | | 10.46 | 0.15 | | |

* Significant at 5%

Appendix XLIX: Effect of pH, lime and varieties on exchangeable aluminium of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 0.19 | 0.19 | 19.53* | 0.27 | 0.27 | 43.53* | 0.46 | 0.23 | 28.94* | 4.04 |
| Lime (L) | 3 | 4.26 | 1.42 | 148.14* | 5.25 | 1.75 | 283.40* | 9.51 | 1.58 | 201.18* | 2.80 |
| Variety(V) | 2 | 0.02 | 0.01 | 1.05 | 0.00 | 0.00 | 0.03 | 0.02 | 0.01 | 0.65 | 3.19 |
| pH x L | 3 | 0.15 | 0.05 | 5.15* | 0.15 | 0.05 | 8.32* | 0.30 | 0.05 | 6.39* | 2.80 |
| L x V | 6 | 0.03 | 0.01 | 0.55 | 0.01 | 0.00 | 0.14 | 0.04 | 0.00 | 0.39 | 2.29 |
| pH x V | 2 | 0.01 | 0.01 | 0.53 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.33 | 3.19 |
| pHxLxV | 6 | 0.03 | 0.00 | 0.45 | 0.00 | 0.00 | 0.03 | 0.03 | 0.00 | 0.28 | 2.29 |
| Error | 48 | 0.46 | 0.01 | | 0.30 | 0.01 | | 0.76 | 0.01 | | |
| TSS | 71 | 5.14 | 0.072 | | 5.98 | 0.084 | | 11.13 | 0.16 | | |

Appendix L: Effect of pH, lime and varieties on total potential acidity of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| pH | 1 | 8.26 | 8.26 | 8.36* | 16.18 | 16.18 | 16.40* | 24.43 | 12.22 | 12.38* | 4.04 |
| Lime (L) | 3 | 182.74 | 60.91 | 61.72* | 180.99 | 60.33 | 61.17* | 363.73 | 60.62 | 61.45* | 2.80 |
| Variety(V) | 2 | 0.01 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 3.19 |
| pH x L | 3 | 1.32 | 0.44 | 0.45 | 1.52 | 0.51 | 0.51 | 2.84 | 0.47 | 0.48 | 2.80 |
| L x V | 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.29 |
| pH x V | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.19 |
| pHxLxV | 6 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.29 |
| Error | 48 | 47.37 | 0.99 | | 47.34 | 0.99 | | 94.71 | 0.99 | | |
| TSS | 71 | 239.71 | 3.38 | | 246.03 | 3.47 | | 486.71 | 3.40 | | |

Appendix LI: Effect of lime, phosphorus and boron on plant height of maize at 30 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 223.31 | 223.31 | 17.77* | 157.83 | 157.83 | 11.05* | 381.14 | 190.57 | 14.20* | 4.04 |
| Phosphorus (P) | 3 | 117.93 | 39.31 | 3.13* | 441.33 | 147.11 | 10.30* | 559.26 | 93.21 | 6.94* | 2.80 |
| Boron (B) | 2 | 217.18 | 108.59 | 8.64* | 361.38 | 180.69 | 12.66* | 578.55 | 144.64 | 10.78* | 3.19 |
| L x P | 3 | 64.72 | 21.57 | 1.72 | 45.87 | 15.29 | 1.07 | 110.59 | 18.43 | 1.37 | 2.80 |
| P x B | 6 | 20.67 | 3.45 | 0.27 | 12.45 | 2.08 | 0.15 | 33.13 | 2.76 | 0.21 | 2.29 |
| L x B | 2 | 13.59 | 6.80 | 0.54 | 4.54 | 2.27 | 0.16 | 18.13 | 4.53 | 0.34 | 3.19 |
| L x P x B | 6 | 6.06 | 1.01 | 0.08 | 10.77 | 1.80 | 0.13 | 16.83 | 1.40 | 0.10 | 2.29 |
| Error | 48 | 603.11 | 12.56 | | 685.32 | 14.28 | | 1288.43 | 13.42 | | |
| TSS | 71 | 1266.56 | 17.84 | | 1719.49 | 24.22 | | 3138.57 | 44.21 | | |

Appendix LII: Effect of lime, phosphorus and boron on plant height of maize at 60 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 8268.98 | 8268.98 | 452.73* | 7539.92 | 7539.92 | 416.98* | 15808.90 | 7904.45 | 434.95* | 4.04 |
| Phosphorus (P) | 3 | 12600.35 | 4200.12 | 229.96* | 11328.23 | 3776.08 | 208.83* | 23928.57 | 3988.10 | 219.45* | 2.80 |
| Boron (B) | 2 | 2119.37 | 1059.69 | 58.02* | 1561.93 | 780.96 | 43.19* | 3681.30 | 920.32 | 50.64* | 3.19 |
| L x P | 3 | 183.07 | 61.02 | 3.34* | 58.77 | 19.59 | 1.08 | 241.84 | 40.31 | 2.22 | 2.80 |
| P x B | 6 | 60.01 | 10.00 | 0.55 | 57.64 | 9.61 | 0.53 | 117.65 | 9.80 | 0.54 | 2.29 |
| L x B | 2 | 5.51 | 2.75 | 0.15 | 66.61 | 33.31 | 1.84 | 72.12 | 18.03 | 0.99 | 3.19 |
| L x P x B | 6 | 53.63 | 8.94 | 0.49 | 140.36 | 23.39 | 1.29 | 193.99 | 16.17 | 0.89 | 2.29 |
| Error | 48 | 876.70 | 18.26 | | 867.94 | 18.08 | | 1744.64 | 18.17 | | |
| TSS | 71 | 24167.62 | 340.39 | | 21621.39 | 304.53 | | 45958.88 | 321.39 | | |

Appendix LIII: Effect of lime, phosphorus and boron on plant height of maize at harvest

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 11917.11 | 11917.11 | 1206.37* | 11730.01 | 11730.01 | 758.77* | 23647.12 | 11823.56 | 933.28* | 4.04 |
| Phosphorus (P) | 3 | 17427.53 | 5809.18 | 588.06* | 19272.40 | 6424.13 | 415.56* | 36699.93 | 6116.66 | 482.81* | 2.80 |
| Boron (B) | 2 | 1571.78 | 785.89 | 79.56* | 938.14 | 469.07 | 30.34* | 2509.92 | 627.48 | 49.53* | 3.19 |
| L x P | 3 | 24.53 | 8.18 | 0.83 | 40.81 | 13.60 | 0.88 | 65.34 | 10.89 | 0.86 | 2.80 |
| P x B | 6 | 113.27 | 18.88 | 1.91 | 57.90 | 9.65 | 0.62 | 171.17 | 14.26 | 1.13 | 2.29 |
| L x B | 2 | 16.70 | 8.35 | 0.85 | 3.63 | 1.82 | 0.12 | 20.33 | 5.08 | 0.40 | 3.19 |
| L x P x B | 6 | 134.85 | 22.47 | 2.28 | 244.58 | 40.76 | 2.64* | 379.42 | 31.62 | 2.50* | 2.29 |
| Error | 48 | 474.17 | 9.88 | | 742.04 | 15.46 | | 1216.21 | 12.67 | | |
| TSS | 71 | 31679.94 | 446.20 | | 33029.51 | 465.20 | | 64727.72 | 452.64 | | |

Appendix LIV: Effect of lime, phosphorus and boron on number of leaves of maize at 30 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 1.39 | 1.39 | 5.56* | 1.13 | 1.13 | 4.05* | 2.51 | 1.26 | 4.76* | 4.04 |
| Phosphorus (P) | 3 | 2.56 | 0.85 | 3.41* | 2.82 | 0.94 | 3.38* | 5.38 | 0.90 | 3.39* | 2.80 |
| Boron (B) | 2 | 1.03 | 0.51 | 2.06 | 0.58 | 0.29 | 1.05 | 1.61 | 0.40 | 1.53 | 3.19 |
| L x P | 3 | 0.28 | 0.09 | 0.37 | 0.26 | 0.09 | 0.32 | 0.54 | 0.09 | 0.34 | 2.80 |
| P x B | 6 | 0.19 | 0.03 | 0.13 | 0.31 | 0.05 | 0.18 | 0.50 | 0.04 | 0.16 | 2.29 |
| L x B | 2 | 0.19 | 0.10 | 0.39 | 0.08 | 0.04 | 0.15 | 0.28 | 0.07 | 0.26 | 3.19 |
| L x P x B | 6 | 0.14 | 0.02 | 0.09 | 0.36 | 0.06 | 0.22 | 0.50 | 0.04 | 0.16 | 2.29 |
| Error | 48 | 12.00 | 0.25 | | 13.33 | 0.28 | | 25.33 | 0.26 | | |
| TSS | 71 | 17.78 | 0.25 | | 18.88 | 0.27 | | 36.83 | 0.52 | | |

* Significant at 5%

Appendix LV: Effect of lime, phosphorus and boron on number of leaves of maize at 60 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 8.68 | 8.68 | 26.04* | 8.68 | 8.68 | 31.25* | 17.36 | 8.68 | 28.41* | 4.04 |
| Phosphorus (P) | 3 | 19.49 | 6.50 | 19.49* | 12.71 | 4.24 | 15.25* | 32.19 | 5.37 | 17.56* | 2.80 |
| Boron (B) | 2 | 8.36 | 4.18 | 12.54* | 3.03 | 1.51 | 5.45* | 11.39 | 2.85 | 9.32* | 3.19 |
| L x P | 3 | 0.49 | 0.16 | 0.49 | 0.60 | 0.20 | 0.72 | 1.08 | 0.18 | 0.59 | 2.80 |
| P x B | 6 | 0.64 | 0.11 | 0.32 | 0.42 | 0.07 | 0.25 | 1.06 | 0.09 | 0.29 | 2.29 |
| L x B | 2 | 0.03 | 0.01 | 0.04 | 0.03 | 0.01 | 0.05 | 0.06 | 0.01 | 0.05 | 3.19 |
| L x P x B | 6 | 0.31 | 0.05 | 0.15 | 1.19 | 0.20 | 0.72 | 1.50 | 0.13 | 0.41 | 2.29 |
| Error | 48 | 16.00 | 0.33 | | 13.33 | 0.28 | | 29.33 | 0.31 | | |
| TSS | 71 | 53.99 | 0.76 | | 39.99 | 0.56 | | 94.00 | 1.32 | | |

Appendix LVI: Effect of lime, phosphorus and boron on number of leaves of maize at harvest

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 33.35 | 33.35 | 82.79* | 21.13 | 21.13 | 34.57* | 54.47 | 27.24 | 53.73* | 4.04 |
| Phosphorus (P) | 3 | 19.71 | 6.57 | 16.31* | 21.15 | 7.05 | 11.54* | 40.86 | 6.81 | 13.43* | 2.80 |
| Boron (B) | 2 | 9.19 | 4.60 | 11.41* | 6.78 | 3.39 | 5.55* | 15.97 | 3.99 | 7.88* | 3.19 |
| L x P | 3 | 0.26 | 0.09 | 0.22 | 0.26 | 0.09 | 0.14 | 0.53 | 0.09 | 0.17 | 2.80 |
| P x B | 6 | 0.92 | 0.15 | 0.38 | 1.22 | 0.20 | 0.33 | 2.14 | 0.18 | 0.35 | 2.29 |
| L x B | 2 | 0.53 | 0.26 | 0.66 | 0.33 | 0.17 | 0.27 | 0.86 | 0.22 | 0.42 | 3.19 |
| L x P x B | 6 | 0.69 | 0.12 | 0.29 | 0.78 | 0.13 | 0.21 | 1.47 | 0.12 | 0.24 | 2.29 |
| Error | 48 | 19.33 | 0.40 | | 29.33 | 0.61 | | 48.67 | 0.51 | | |
| TSS | 71 | 83.99 | 1.18 | | 80.99 | 1.14 | | 173.97 | 2.45 | | |

Appendix LVII: Effect of lime, phosphorus and boron on leaf area index of maize at 30 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.04 | 0.04 | 7.37* | 0.02 | 0.02 | 5.10* | 0.06 | 0.03 | 6.47* | 4.04 |
| Phosphorus (P) | 3 | 0.10 | 0.03 | 6.12* | 0.16 | 0.05 | 14.40* | 0.27 | 0.04 | 9.42* | 2.80 |
| Boron (B) | 2 | 0.01 | 0.01 | 0.96 | 0.00 | 0.00 | 0.13 | 0.01 | 0.00 | 0.63 | 3.19 |
| L x P | 3 | 0.01 | 0.00 | 0.78 | 0.01 | 0.00 | 0.86 | 0.02 | 0.00 | 0.81 | 2.80 |
| P x B | 6 | 0.01 | 0.00 | 0.20 | 0.01 | 0.00 | 0.35 | 0.01 | 0.00 | 0.26 | 2.29 |
| L x B | 2 | 0.02 | 0.01 | 1.49 | 0.00 | 0.00 | 0.33 | 0.02 | 0.00 | 1.03 | 3.19 |
| L x P x B | 6 | 0.03 | 0.00 | 0.81 | 0.00 | 0.00 | 0.11 | 0.03 | 0.00 | 0.53 | 2.29 |
| Error | 48 | 0.27 | 0.01 | | 0.18 | 0.00 | | 0.46 | 0.00 | | |
| TSS | 71 | 0.50 | 0.007 | | 0.39 | 0.0055 | | 0.92 | 0.013 | | |

* Significant at 5%

Appendix LVIII: Effect of lime, phosphorus and boron on leaf area index of maize at 60 DAS

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.05 | 0.05 | 47.57* | 0.05 | 0.05 | 35.50* | 0.10 | 0.05 | 40.45* | 4.04 |
| Phosphorus (P) | 3 | 0.03 | 0.01 | 10.57* | 0.06 | 0.02 | 13.16* | 0.09 | 0.02 | 12.10* | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.56 | 0.00 | 0.00 | 0.37 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.51 | 0.00 | 0.00 | 0.35 | 0.00 | 0.00 | 0.42 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.28 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.26 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.16 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.23 | 0.00 | 0.00 | 0.17 | 2.29 |
| Error | 48 | 0.05 | 0.00 | | 0.07 | 0.00 | | 0.12 | 0.00 | | |
| TSS | 71 | 0.14 | 0.0020 | | 0.19 | 0.0027 | | 0.35 | 0.0049 | | |

Appendix LIX: Effect of lime, phosphorus and boron on leaf area index of maize at harvest

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.01 | 0.01 | 11.08* | 0.01 | 0.01 | 11.75* | 0.01 | 0.01 | 11.47* | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 3.40* | 0.02 | 0.01 | 8.61* | 0.02 | 0.00 | 6.39* | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 2.51 | 0.00 | 0.00 | 0.41 | 0.00 | 0.00 | 1.30 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.51 | 0.00 | 0.00 | 0.91 | 0.00 | 0.00 | 0.74 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 1.18 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.64 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 2.86 | 0.00 | 0.00 | 1.68 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.73 | 0.00 | 0.00 | 0.44 | 0.00 | 0.00 | 0.56 | 2.29 |
| Error | 48 | 0.03 | 0.00 | | 0.04 | 0.00 | | 0.06 | 0.00 | | |
| TSS | 71 | 0.05 | 0.00070 | | 0.07 | 0.0010 | | 0.13 | 0.0018 | | |

Appendix LX: Effect of lime, phosphorus and boron on cob length of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 4.45 | 4.45 | 50.62* | 1.97 | 1.97 | 21.07* | 6.42 | 3.21 | 35.40* | 4.04 |
| Phosphorus (P) | 3 | 51.02 | 17.01 | 193.46* | 38.35 | 12.78 | 136.98* | 89.38 | 14.90 | 164.38* | 2.80 |
| Boron (B) | 2 | 5.14 | 2.57 | 29.21* | 3.40 | 1.70 | 18.20* | 8.53 | 2.13 | 23.54* | 3.19 |
| L x P | 3 | 0.33 | 0.11 | 1.26 | 0.24 | 0.08 | 0.86 | 0.57 | 0.10 | 1.05 | 2.80 |
| P x B | 6 | 0.91 | 0.15 | 1.72 | 1.11 | 0.18 | 1.98 | 2.02 | 0.17 | 1.86 | 2.29 |
| L x B | 2 | 0.03 | 0.01 | 0.15 | 0.03 | 0.01 | 0.15 | 0.06 | 0.01 | 0.15 | 3.19 |
| L x P x B | 6 | 0.04 | 0.01 | 0.07 | 0.18 | 0.03 | 0.31 | 0.21 | 0.02 | 0.19 | 2.29 |
| Error | 48 | 4.22 | 0.09 | | 4.48 | 0.09 | | 8.70 | 0.09 | | |
| TSS | 71 | 66.14 | 0.93 | | 49.75 | 0.7 | | 119.50 | 1.68 | | |

* Significant at 5%

Appendix LXII: Effect of lime, phosphorus and boron on cob girth of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 3.87 | 3.87 | 28.09* | 3.15 | 3.15 | 24.10* | 7.02 | 3.51 | 26.15* | 4.04 |
| Phosphorus (P) | 3 | 14.87 | 4.96 | 35.93* | 15.24 | 5.08 | 38.87* | 30.11 | 5.02 | 37.36* | 2.80 |
| Boron (B) | 2 | 1.12 | 0.56 | 4.05* | 1.33 | 0.67 | 5.11* | 2.45 | 0.61 | 4.56* | 3.19 |
| L x P | 3 | 0.22 | 0.07 | 0.54 | 0.17 | 0.06 | 0.43 | 0.39 | 0.07 | 0.49 | 2.80 |
| P x B | 6 | 0.17 | 0.03 | 0.20 | 0.29 | 0.05 | 0.37 | 0.46 | 0.04 | 0.28 | 2.29 |
| L x B | 2 | 0.04 | 0.02 | 0.16 | 0.00 | 0.00 | 0.01 | 0.05 | 0.01 | 0.09 | 3.19 |
| L x P x B | 6 | 0.05 | 0.01 | 0.06 | 0.11 | 0.02 | 0.13 | 0.15 | 0.01 | 0.09 | 2.29 |
| Error | 48 | 6.62 | 0.14 | | 6.27 | 0.13 | | 12.89 | 0.13 | | |
| TSS | 71 | 26.96 | 0.38 | | 26.57 | 0.37 | | 53.56 | 0.37 | | |

Appendix LXI: Effect of lime, phosphorus and boron on cob weight of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 5270.22 | 5270.22 | 1425.29* | 5573.92 | 5573.92 | 2294.84* | 10844.14 | 5422.07 | 1770.03* | 4.04 |
| Phosphorus (P) | 3 | 3767.48 | 1255.83 | 339.63* | 3856.47 | 1285.49 | 529.25* | 7623.95 | 1270.66 | 414.81* | 2.80 |
| Boron (B) | 2 | 218.86 | 109.43 | 29.59* | 316.80 | 158.40 | 65.22* | 535.66 | 133.92 | 43.72* | 3.19 |
| L x P | 3 | 131.83 | 43.94 | 11.88* | 68.45 | 22.82 | 9.39* | 200.27 | 33.38 | 10.90* | 2.80 |
| P x B | 6 | 21.35 | 3.56 | 0.96 | 9.33 | 1.55 | 0.64 | 30.68 | 2.56 | 0.83 | 2.29 |
| L x B | 2 | 1.50 | 0.75 | 0.20 | 1.47 | 0.73 | 0.30 | 2.97 | 0.74 | 0.24 | 3.19 |
| L x P x B | 6 | 8.05 | 1.34 | 0.36 | 11.50 | 1.92 | 0.79 | 19.55 | 1.63 | 0.53 | 2.29 |
| Error | 48 | 177.49 | 3.70 | | 116.59 | 2.43 | | 294.07 | 3.06 | | |
| TSS | 71 | 9596.78 | 135.17 | | 9954.52 | 140.20 | | 19551.49 | 136.72 | | |

Appendix LXIII: Effect of lime, phosphorus and boron on number of grains per row of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 136.13 | 136.13 | 544.50* | 174.22 | 174.22 | 545.39* | 310.35 | 155.17 | 545.00* | 4.04 |
| Phosphorus (P) | 3 | 101.71 | 33.90 | 135.61* | 152.50 | 50.83 | 159.13* | 254.21 | 42.37 | 148.80* | 2.80 |
| Boron (B) | 2 | 11.19 | 5.60 | 22.39* | 11.03 | 5.51 | 17.26* | 22.22 | 5.56 | 19.51* | 3.19 |
| L x P | 3 | 5.82 | 1.94 | 7.76* | 4.56 | 1.52 | 4.75* | 10.38 | 1.73 | 6.07* | 2.80 |
| P x B | 6 | 0.58 | 0.10 | 0.39 | 1.75 | 0.29 | 0.91 | 2.33 | 0.19 | 0.68 | 2.29 |
| L x B | 2 | 1.08 | 0.54 | 2.17 | 0.19 | 0.10 | 0.30 | 1.28 | 0.32 | 1.12 | 3.19 |
| L x P x B | 6 | 1.14 | 0.19 | 0.76 | 3.69 | 0.62 | 1.93 | 4.83 | 0.40 | 1.41 | 2.29 |
| Error | 48 | 12.00 | 0.25 | | 15.33 | 0.32 | | 27.33 | 0.28 | | |
| TSS | 71 | 269.65 | 3.80 | | 363.28 | 5.12 | | 637.99 | 4.46 | | |

* Significant at 5%

Appendix LXIV: Effect of lime, phosphorus and boron on number of rows per cob of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 45.13 | 45.13 | 58.02* | 42.01 | 42.01 | 112.04* | 87.14 | 43.57 | 75.59* | 4.04 |
| Phosphorus (P) | 3 | 4.15 | 1.38 | 1.78 | 2.38 | 0.79 | 2.11 | 6.53 | 1.09 | 1.89 | 2.80 |
| Boron (B) | 2 | 1.75 | 0.88 | 1.12 | 1.44 | 0.72 | 1.93 | 3.19 | 0.80 | 1.39 | 3.19 |
| L x P | 3 | 0.60 | 0.20 | 0.26 | 0.15 | 0.05 | 0.14 | 0.75 | 0.13 | 0.22 | 2.80 |
| P x B | 6 | 0.47 | 0.08 | 0.10 | 0.67 | 0.11 | 0.30 | 1.14 | 0.09 | 0.16 | 2.29 |
| L x B | 2 | 0.25 | 0.13 | 0.16 | 0.11 | 0.06 | 0.15 | 0.36 | 0.09 | 0.16 | 3.19 |
| L x P x B | 6 | 0.19 | 0.03 | 0.04 | 0.22 | 0.04 | 0.10 | 0.42 | 0.03 | 0.06 | 2.29 |
| Error | 48 | 37.33 | 0.78 | | 18.00 | 0.38 | | 55.33 | 0.58 | | |
| TSS | 71 | 89.88 | 1.27 | | 64.99 | 0.92 | | 155.31 | 1.09 | | |

Appendix LXV: Effect of lime, phosphorus and boron on number of grains per cob of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 42389.01 | 42389.01 | 27.68* | 51734.72 | 51734.72 | 118.16* | 94123.74 | 47061.87 | 47.80* | 4.04 |
| Phosphorus (P) | 3 | 43875.49 | 14625.16 | 9.55* | 57347.00 | 19115.67 | 43.66* | 101222.49 | 16870.41 | 17.14* | 2.80 |
| Boron (B) | 2 | 12798.86 | 6399.43 | 4.18* | 10527.08 | 5263.54 | 12.02* | 23325.94 | 5831.49 | 5.92* | 3.19 |
| L x P | 3 | 16932.93 | 5644.31 | 3.69* | 42.28 | 14.09 | 0.03 | 16975.21 | 2829.20 | 2.87* | 2.80 |
| P x B | 6 | 508.14 | 84.69 | 0.06 | 637.92 | 106.32 | 0.24 | 1146.06 | 95.50 | 0.10 | 2.29 |
| L x B | 2 | 42.36 | 21.18 | 0.01 | 340.19 | 170.10 | 0.39 | 382.56 | 95.64 | 0.10 | 3.19 |
| L x P x B | 6 | 1748.86 | 291.48 | 0.19 | 1975.47 | 329.25 | 0.75 | 3724.33 | 310.36 | 0.32 | 2.29 |
| Error | 48 | 73496.00 | 1531.17 | | 21015.33 | 437.82 | | 94511.33 | 984.49 | | |
| TSS | 71 | 191791.65 | 2701.29 | | 143620.00 | 2022.82 | | 337045.16 | 2356.96 | | |

Appendix LXVI: Effect of lime, phosphorus and boron on test weight of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 114.61 | 114.61 | 113.56* | 94.88 | 94.88 | 65.01* | 209.49 | 104.74 | 84.86* | 4.04 |
| Phosphorus (P) | 3 | 1.54 | 0.51 | 0.51 | 0.04 | 0.01 | 0.01 | 1.57 | 0.26 | 0.21 | 2.80 |
| Boron (B) | 2 | 0.36 | 0.18 | 0.18 | 0.21 | 0.11 | 0.07 | 0.58 | 0.14 | 0.12 | 3.19 |
| L x P | 3 | 4.25 | 1.42 | 1.40 | 7.71 | 2.57 | 1.76 | 11.96 | 1.99 | 1.61 | 2.80 |
| P x B | 6 | 1.13 | 0.19 | 0.19 | 2.14 | 0.36 | 0.24 | 3.27 | 0.27 | 0.22 | 2.29 |
| L x B | 2 | 0.09 | 0.04 | 0.04 | 0.25 | 0.13 | 0.09 | 0.34 | 0.09 | 0.07 | 3.19 |
| L x P x B | 6 | 0.57 | 0.09 | 0.09 | 0.27 | 0.05 | 0.03 | 0.84 | 0.07 | 0.06 | 2.29 |
| Error | 48 | 48.44 | 1.01 | | 70.05 | 1.46 | | 118.49 | 1.23 | | |
| TSS | 71 | 170.98 | 2.41 | | 175.55 | 2.47 | | 346.53 | 2.42 | | |

* Significant at 5%

Appendix LXVII: Effect of lime, phosphorus and boron on grain yield of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 4439.96 | 4439.96 | 1882.81* | 3987.25 | 3987.25 | 764.47* | 8427.21 | 4213.60 | 1112.67* | 4.04 |
| Phosphorus (P) | 3 | 2570.38 | 856.79 | 363.33* | 2375.20 | 791.73 | 151.80* | 4945.58 | 824.26 | 217.66* | 2.80 |
| Boron (B) | 2 | 470.74 | 235.37 | 99.81* | 968.01 | 484.00 | 92.80* | 1438.74 | 359.69 | 94.98* | 3.19 |
| L x P | 3 | 79.68 | 26.56 | 11.26* | 45.76 | 15.25 | 2.92* | 125.44 | 20.91 | 5.52* | 2.80 |
| P x B | 6 | 4.60 | 0.77 | 0.32 | 6.70 | 1.12 | 0.21 | 11.30 | 0.94 | 0.25 | 2.29 |
| L x B | 2 | 1.19 | 0.59 | 0.25 | 0.56 | 0.28 | 0.05 | 1.75 | 0.44 | 0.12 | 3.19 |
| L x P x B | 6 | 4.50 | 0.75 | 0.32 | 5.85 | 0.97 | 0.19 | 10.35 | 0.86 | 0.23 | 2.29 |
| Error | 48 | 113.19 | 2.36 | | 250.35 | 5.22 | | 363.55 | 3.79 | | |
| TSS | 71 | 7684.23 | 108.23 | | 7639.67 | 107.60 | | 15324.17 | 107.16 | | |

Appendix LXVIII: Effect of lime, phosphorus and boron on stover yield of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 10853.56 | 10853.56 | 303.70* | 9078.33 | 9078.33 | 393.11* | 19931.89 | 9965.94 | 338.80* | 4.04 |
| Phosphorus (P) | 3 | 5357.51 | 1785.84 | 49.97* | 6338.09 | 2112.70 | 91.48* | 11695.60 | 1949.27 | 66.27* | 2.80 |
| Boron (B) | 2 | 1393.30 | 696.65 | 19.49* | 2217.16 | 1108.58 | 48.00* | 3610.45 | 902.61 | 30.68* | 3.19 |
| L x P | 3 | 45.04 | 15.01 | 0.42 | 5.52 | 1.84 | 0.08 | 50.56 | 8.43 | 0.29 | 2.80 |
| P x B | 6 | 1.36 | 0.23 | 0.01 | 3.46 | 0.58 | 0.02 | 4.82 | 0.40 | 0.01 | 2.29 |
| L x B | 2 | 0.42 | 0.21 | 0.01 | 1.92 | 0.96 | 0.04 | 2.33 | 0.58 | 0.02 | 3.19 |
| L x P x B | 6 | 0.18 | 0.03 | 0.00 | 1.97 | 0.33 | 0.01 | 2.15 | 0.18 | 0.01 | 2.29 |
| Error | 48 | 1715.41 | 35.74 | | 1108.49 | 23.09 | | 2823.90 | 29.42 | | |
| TSS | 71 | 19366.76 | 272.77 | | 18754.95 | 264.15 | | 38123.73 | 266.60 | | |

Appendix LXIX: Effect of lime, phosphorus and boron on nitrogen content in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.77 | 0.77 | 172.89* | 0.72 | 0.72 | 188.53* | 1.48 | 0.74 | 180.12* | 4.04 |
| Phosphorus (P) | 3 | 0.13 | 0.04 | 9.53* | 0.16 | 0.05 | 13.74* | 0.28 | 0.05 | 11.47* | 2.80 |
| Boron (B) | 2 | 0.14 | 0.07 | 15.99* | 0.12 | 0.06 | 15.82* | 0.26 | 0.07 | 15.91* | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.15 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.02 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.02 | 2.29 |
| Error | 48 | 0.21 | 0.00 | | 0.18 | 0.00 | | 0.40 | 0.00 | | |
| TSS | 71 | 1.25 | 0.0176 | | 1.18 | 0.0166 | | 2.45 | 0.0171 | | |

* Significant at 5%

Appendix LXX: Effect of lime, phosphorus and boron on nitrogen content in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.34 | 0.34 | 49.76* | 0.22 | 0.22 | 36.60* | 0.56 | 0.28 | 43.57* | 4.04 |
| Phosphorus (P) | 3 | 0.07 | 0.02 | 3.57* | 0.17 | 0.06 | 9.37* | 0.24 | 0.04 | 6.30* | 2.80 |
| Boron (B) | 2 | 0.08 | 0.04 | 5.56* | 0.10 | 0.05 | 8.27* | 0.18 | 0.04 | 6.84* | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.20 | 0.01 | 0.00 | 0.15 | 2.80 |
| P x B | 6 | 0.01 | 0.00 | 0.18 | 0.00 | 0.00 | 0.07 | 0.01 | 0.00 | 0.13 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.14 | 3.19 |
| L x P x B | 6 | 0.01 | 0.00 | 0.21 | 0.00 | 0.00 | 0.03 | 0.01 | 0.00 | 0.12 | 2.29 |
| Error | 48 | 0.33 | 0.01 | | 0.29 | 0.01 | | 0.62 | 0.01 | | |
| TSS | 71 | 0.83 | 0.012 | | 0.79 | 0.011 | | 1.62 | 0.023 | | |

Appendix LXXI: Effect of lime, phosphorus and boron on phosphorus content in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.07 | 0.07 | 31.91* | 0.08 | 0.08 | 29.13* | 0.15 | 0.08 | 30.37* | 4.04 |
| Phosphorus (P) | 3 | 0.10 | 0.03 | 15.22* | 0.11 | 0.04 | 12.83* | 0.21 | 0.04 | 13.89* | 2.80 |
| Boron (B) | 2 | 0.03 | 0.02 | 6.81* | 0.05 | 0.02 | 8.58* | 0.08 | 0.02 | 7.79* | 3.19 |
| L x P | 3 | 0.01 | 0.00 | 1.28 | 0.00 | 0.00 | 0.18 | 0.01 | 0.00 | 0.67 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.24 | 0.01 | 0.00 | 0.19 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.07 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.04 | 2.29 |
| Error | 48 | 0.11 | 0.00 | | 0.14 | 0.00 | | 0.24 | 0.00 | | |
| TSS | 71 | 0.33 | 0.0046 | | 0.38 | 0.0054 | | 0.73 | 0.0051 | | |

Appendix LXXII: Effect of lime, phosphorus and boron on phosphorus content in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.02 | 0.02 | 8.36* | 0.01 | 0.01 | 5.28* | 0.02 | 0.01 | 7.27* | 4.04 |
| Phosphorus (P) | 3 | 0.02 | 0.01 | 3.34* | 0.01 | 0.00 | 3.68* | 0.03 | 0.01 | 3.46* | 2.80 |
| Boron (B) | 2 | 0.01 | 0.01 | 3.65* | 0.02 | 0.01 | 10.91* | 0.04 | 0.01 | 6.22* | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.17 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.11 | 0.00 | 0.00 | 0.24 | 0.00 | 0.00 | 0.16 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.37 | 0.00 | 0.00 | 0.15 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.22 | 0.00 | 0.00 | 0.17 | 2.29 |
| Error | 48 | 0.09 | 0.00 | | 0.05 | 0.00 | | 0.14 | 0.00 | | |
| TSS | 71 | 0.14 | 0.0020 | | 0.09 | 0.0013 | | 0.25 | 0.0017 | | |

* Significant at 5%

Appendix LXXIII: Effect of lime, phosphorus and boron on potassium content in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.06 | 0.06 | 12.96* | 0.06 | 0.06 | 10.97* | 0.12 | 0.06 | 11.92* | 4.04 |
| Phosphorus (P) | 3 | 0.06 | 0.02 | 3.83* | 0.08 | 0.03 | 4.65* | 0.13 | 0.02 | 4.26* | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.34 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.21 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.04 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.04 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 2.29 |
| Error | 48 | 0.24 | 0.00 | | 0.26 | 0.01 | | 0.50 | 0.01 | | |
| TSS | 71 | 0.36 | 0.0051 | | 0.40 | 0.0056 | | 0.80 | 0.0056 | | |

Appendix LXXIV: Effect of lime, phosphorus and boron on potassium content in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.05 | 0.05 | 15.53* | 0.06 | 0.06 | 21.71* | 0.11 | 0.06 | 18.40* | 4.04 |
| Phosphorus (P) | 3 | 0.09 | 0.03 | 8.90* | 0.11 | 0.04 | 13.16* | 0.20 | 0.03 | 10.89* | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.29 | 0.00 | 0.00 | 0.30 | 0.00 | 0.00 | 0.29 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.56 | 0.01 | 0.00 | 0.29 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.04 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.70 | 0.00 | 0.00 | 0.33 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.03 | 2.29 |
| Error | 48 | 0.16 | 0.00 | | 0.14 | 0.00 | | 0.30 | 0.00 | | |
| TSS | 71 | 0.30 | 0.0042 | | 0.33 | 0.0046 | | 0.65 | 0.0045 | | |

Appendix LXXV: Effect of lime, phosphorus and boron on calcium content in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.79 | 0.79 | 63.05* | 0.76 | 0.76 | 58.27* | 1.54 | 0.77 | 60.61* | 4.04 |
| Phosphorus (P) | 3 | 0.15 | 0.05 | 4.05* | 0.14 | 0.05 | 3.61* | 0.29 | 0.05 | 3.82* | 2.80 |
| Boron (B) | 2 | 0.01 | 0.00 | 0.30 | 0.01 | 0.00 | 0.20 | 0.01 | 0.00 | 0.25 | 3.19 |
| L x P | 3 | 0.02 | 0.01 | 0.61 | 0.02 | 0.01 | 0.41 | 0.04 | 0.01 | 0.51 | 2.80 |
| P x B | 6 | 0.01 | 0.00 | 0.07 | 0.00 | 0.00 | 0.04 | 0.01 | 0.00 | 0.05 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.08 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.04 | 2.29 |
| Error | 48 | 0.60 | 0.01 | | 0.62 | 0.01 | | 1.22 | 0.01 | | |
| TSS | 71 | 1.58 | 0.022 | | 1.55 | 0.022 | | 3.13 | 0.022 | | |

* Significant at 5%

Appendix LXXVI: Effect of lime, phosphorus and boron on calcium content in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.82 | 0.82 | 154.33* | 0.87 | 0.87 | 143.70* | 1.69 | 0.85 | 148.65* | 4.04 |
| Phosphorus (P) | 3 | 0.12 | 0.04 | 7.82* | 0.08 | 0.03 | 4.25* | 0.20 | 0.03 | 5.91* | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.28 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.20 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.08 | 0.00 | 0.00 | 0.08 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.07 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.04 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.05 | 2.29 |
| Error | 48 | 0.25 | 0.01 | | 0.29 | 0.01 | | 0.55 | 0.01 | | |
| TSS | 71 | 1.20 | 0.017 | | 1.25 | 0.018 | | 2.45 | 0.017 | | |

Appendix LXXVII: Effect of lime, phosphorus and boron on boron content in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.92 | 0.92 | 417.54* | 0.92 | 0.92 | 424.38* | 1.84 | 0.92 | 420.95* | 4.04 |
| Phosphorus (P) | 3 | 0.00 | 0.00 | 0.58 | 0.00 | 0.00 | 0.72 | 0.01 | 0.00 | 0.65 | 2.80 |
| Boron (B) | 2 | 153.53 | 76.77 | 34916.01* | 152.24 | 76.12 | 34931.43* | 305.78 | 76.44 | 34923.68* | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.14 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.08 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.17 | 0.00 | 0.00 | 0.11 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.09 | 2.29 |
| Error | 48 | 0.11 | 0.00 | | 0.10 | 0.00 | | 0.21 | 0.00 | | |
| TSS | 71 | 154.56 | 2.18 | | 153.28 | 2.16 | | 307.94 | 2.15 | | |

Appendix LXXVIII: Effect of lime, phosphorus and boron on boron content in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.72 | 0.72 | 197.58* | 0.64 | 0.64 | 225.78* | 1.36 | 0.68 | 209.88* | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 1.10 | 0.01 | 0.00 | 1.45 | 0.02 | 0.00 | 1.25 | 2.80 |
| Boron (B) | 2 | 16.10 | 8.05 | 2203.03* | 15.84 | 7.92 | 2801.54* | 31.94 | 7.99 | 2464.13* | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.10 | 0.00 | 0.00 | 0.43 | 0.00 | 0.00 | 0.24 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.19 | 0.01 | 0.00 | 0.32 | 0.01 | 0.00 | 0.25 | 2.29 |
| L x B | 2 | 0.03 | 0.02 | 4.36* | 0.04 | 0.02 | 7.68* | 0.08 | 0.02 | 5.81* | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.27 | 0.01 | 0.00 | 0.13 | 2.29 |
| Error | 48 | 0.18 | 0.00 | | 0.14 | 0.00 | | 0.31 | 0.00 | | |
| TSS | 71 | 17.05 | 0.24 | | 16.69 | 0.24 | | 33.76 | 0.24 | | |

* Significant at 5%

Appendix LXXIX: Effect of lime, phosphorus and boron on nitrogen uptake in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 1791749.74 | 1791749.74 | 950.15* | 1678643.32 | 1678643.32 | 878.71* | 3470393.06 | 1735196.53 | 914.20* | 4.04 |
| Phosphorus (P) | 3 | 602838.53 | 200946.18 | 106.56* | 623138.00 | 207712.67 | 108.73* | 1225976.53 | 204329.42 | 107.65* | 2.80 |
| Boron (B) | 2 | 240969.70 | 120484.85 | 63.89* | 336769.04 | 168384.52 | 88.14* | 577738.74 | 144434.69 | 76.10* | 3.19 |
| L x P | 3 | 18607.58 | 6202.53 | 3.29* | 9978.64 | 3326.21 | 1.74 | 28586.22 | 4764.37 | 2.51 | 2.80 |
| P x B | 6 | 1048.31 | 174.72 | 0.09 | 889.59 | 148.27 | 0.08 | 1937.91 | 161.49 | 0.09 | 2.29 |
| L x B | 2 | 2012.04 | 1006.02 | 0.53 | 4325.69 | 2162.84 | 1.13 | 6337.72 | 1584.43 | 0.83 | 3.19 |
| L x P x B | 6 | 428.52 | 71.42 | 0.04 | 521.52 | 86.92 | 0.05 | 950.04 | 79.17 | 0.04 | 2.29 |
| Error | 48 | 90516.32 | 1885.76 | | 91697.30 | 1910.36 | | 182213.62 | 1898.06 | | |
| TSS | 71 | 2748170.74 | 38706.63 | | 2745963.09 | 38675.54 | | 5505116.53 | 38497.32 | | |

Appendix LXXX: Effect of lime, phosphorus and boron on nitrogen uptake in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 1724357.59 | 1724357.59 | 230.39* | 1286207.51 | 1286207.51 | 163.06* | 3010565.10 | 1505282.55 | 195.84* | 4.04 |
| Phosphorus (P) | 3 | 478575.38 | 159525.13 | 21.31* | 639972.64 | 213324.21 | 27.04* | 1118548.02 | 186424.67 | 24.25* | 2.80 |
| Boron (B) | 2 | 291804.05 | 145902.02 | 19.49* | 401182.00 | 200591.00 | 25.43* | 692986.05 | 173246.51 | 22.54* | 3.19 |
| L x P | 3 | 25917.41 | 8639.14 | 1.15 | 11714.65 | 3904.88 | 0.50 | 37632.05 | 6272.01 | 0.82 | 2.80 |
| P x B | 6 | 6261.76 | 1043.63 | 0.14 | 7162.20 | 1193.70 | 0.15 | 13423.96 | 1118.66 | 0.15 | 2.29 |
| L x B | 2 | 5934.72 | 2967.36 | 0.40 | 17077.11 | 8538.55 | 1.08 | 23011.83 | 5752.96 | 0.75 | 3.19 |
| L x P x B | 6 | 9539.31 | 1589.88 | 0.21 | 622.22 | 103.70 | 0.01 | 10161.53 | 846.79 | 0.11 | 2.29 |
| Error | 48 | 359263.38 | 7484.65 | | 378625.76 | 7888.04 | | 737889.14 | 7686.35 | | |
| TSS | 71 | 2901653.60 | 40868.36 | | 2742564.08 | 38627.66 | | 5644272.98 | 79496.80 | | |

Appendix LXXXI: Effect of lime, phosphorus and boron on phosphorus uptake in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 211646.69 | 211646.69 | 210.14* | 222167.78 | 222167.78 | 179.72* | 433814.47 | 216907.23 | 193.38* | 4.04 |
| Phosphorus (P) | 3 | 173111.18 | 57703.73 | 57.29* | 177517.44 | 59172.48 | 47.87* | 350628.62 | 58438.10 | 52.10* | 2.80 |
| Boron (B) | 2 | 42149.68 | 21074.84 | 20.92* | 82896.85 | 41448.42 | 33.53* | 125046.52 | 31261.63 | 27.87* | 3.19 |
| L x P | 3 | 11784.01 | 3928.00 | 3.90* | 4312.09 | 1437.36 | 1.16 | 16096.09 | 2682.68 | 2.39 | 2.80 |
| P x B | 6 | 2132.74 | 355.46 | 0.35 | 3503.25 | 583.88 | 0.47 | 5635.99 | 469.67 | 0.42 | 2.29 |
| L x B | 2 | 1144.97 | 572.48 | 0.57 | 1237.28 | 618.64 | 0.50 | 2382.25 | 595.56 | 0.53 | 3.19 |
| L x P x B | 6 | 992.13 | 165.36 | 0.16 | 900.50 | 150.08 | 0.12 | 1892.63 | 157.72 | 0.14 | 2.29 |
| Error | 48 | 48344.52 | 1007.18 | | 59335.53 | 1236.16 | | 107680.05 | 1121.67 | | |
| TSS | 71 | 491305.91 | 6919.80 | | 551870.72 | 7772.83 | | 1056193.72 | 7385.97 | | |

* Significant at 5%

Appendix LXXXII: Effect of lime, phosphorus and boron on phosphorus uptake in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 81712.40 | 81712.40 | 34.22* | 55053.36 | 55053.36 | 43.26* | 136765.76 | 68382.88 | 37.37* | 4.04 |
| Phosphorus (P) | 3 | 63026.14 | 21008.71 | 8.80* | 52387.21 | 17462.40 | 13.72* | 115413.35 | 19235.56 | 10.51* | 2.80 |
| Boron (B) | 2 | 35748.19 | 17874.09 | 7.49* | 57211.63 | 28605.82 | 22.48* | 92959.82 | 23239.96 | 12.70* | 3.19 |
| L x P | 3 | 3367.24 | 1122.41 | 0.47 | 1503.07 | 501.02 | 0.39 | 4870.31 | 811.72 | 0.44 | 2.80 |
| P x B | 6 | 1861.52 | 310.25 | 0.13 | 1335.92 | 222.65 | 0.17 | 3197.44 | 266.45 | 0.15 | 2.29 |
| L x B | 2 | 756.17 | 378.09 | 0.16 | 2712.49 | 1356.25 | 1.07 | 3468.66 | 867.17 | 0.47 | 3.19 |
| L x P x B | 6 | 1603.42 | 267.24 | 0.11 | 1720.55 | 286.76 | 0.23 | 3323.97 | 277.00 | 0.15 | 2.29 |
| Error | 48 | 114604.40 | 2387.59 | | 61079.99 | 1272.50 | | 175684.39 | 1830.05 | | |
| TSS | 71 | 302679.48 | 4263.09 | | 233004.22 | 3281.75 | | 555622.79 | 3885.47 | | |

Appendix LXXXIII: Effect of lime, phosphorus and boron on potassium uptake in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 303227.08 | 303227.08 | 156.14* | 296237.00 | 296237.00 | 120.52* | 599464.08 | 299732.04 | 136.24* | 4.04 |
| Phosphorus (P) | 3 | 188188.95 | 62729.65 | 32.30* | 210758.70 | 70252.90 | 28.58* | 398947.65 | 66491.27 | 30.22* | 2.80 |
| Boron (B) | 2 | 25586.81 | 12793.40 | 6.59* | 38617.49 | 19308.74 | 7.86* | 64204.30 | 16051.07 | 7.30* | 3.19 |
| L x P | 3 | 5781.28 | 1927.09 | 0.99 | 1993.43 | 664.48 | 0.27 | 7774.71 | 1295.78 | 0.59 | 2.80 |
| P x B | 6 | 647.32 | 107.89 | 0.06 | 148.50 | 24.75 | 0.01 | 795.82 | 66.32 | 0.03 | 2.29 |
| L x B | 2 | 172.57 | 86.29 | 0.04 | 514.53 | 257.27 | 0.10 | 687.10 | 171.78 | 0.08 | 3.19 |
| L x P x B | 6 | 169.30 | 28.22 | 0.01 | 345.42 | 57.57 | 0.02 | 514.72 | 42.89 | 0.02 | 2.29 |
| Error | 48 | 93215.62 | 1941.99 | | 117979.81 | 2457.91 | | 211195.43 | 2199.95 | | |
| TSS | 71 | 616988.92 | 8689.98 | | 666594.89 | 9388.66 | | 1306805.25 | 9138.50 | | |

Appendix LXXXIV: Effect of lime, phosphorus and boron on potassium uptake in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 2060700.37 | 2060700.37 | 239.74* | 1822554.14 | 1822554.14 | 266.61* | 3883254.51 | 1941627.26 | 251.64* | 4.04 |
| Phosphorus (P) | 3 | 1347862.54 | 449287.51 | 52.27* | 1590816.47 | 530272.16 | 77.57* | 2938679.01 | 489779.83 | 63.48* | 2.80 |
| Boron (B) | 2 | 214677.35 | 107338.67 | 12.49* | 304021.57 | 152010.78 | 22.24* | 518698.92 | 129674.73 | 16.81* | 3.19 |
| L x P | 3 | 19512.89 | 6504.30 | 0.76 | 13762.85 | 4587.62 | 0.67 | 33275.75 | 5545.96 | 0.72 | 2.80 |
| P x B | 6 | 1186.91 | 197.82 | 0.02 | 3122.89 | 520.48 | 0.08 | 4309.80 | 359.15 | 0.05 | 2.29 |
| L x B | 2 | 501.21 | 250.61 | 0.03 | 9516.46 | 4758.23 | 0.70 | 10017.67 | 2504.42 | 0.32 | 3.19 |
| L x P x B | 6 | 465.92 | 77.65 | 0.01 | 2713.01 | 452.17 | 0.07 | 3178.93 | 264.91 | 0.03 | 2.29 |
| Error | 48 | 412589.48 | 8595.61 | | 328126.25 | 6835.96 | | 740715.73 | 7715.79 | | |
| TSS | 71 | 4057496.68 | 57147.84 | | 4074633.64 | 57389.21 | | 8154990.75 | 57027.91 | | |

* Significant at 5%

Appendix LXXXV: Effect of lime, phosphorus and boron on calcium uptake in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 867459.62 | 867459.62 | 139.24* | 802965.51 | 802965.51 | 120.41* | 1670425.13 | 835212.56 | 129.51* | 4.04 |
| Phosphorus (P) | 3 | 241000.63 | 80333.54 | 12.89* | 217455.14 | 72485.05 | 10.87* | 458455.77 | 76409.29 | 11.85* | 2.80 |
| Boron (B) | 2 | 1714.78 | 857.39 | 0.14 | 10317.46 | 5158.73 | 0.77 | 12032.24 | 3008.06 | 0.47 | 3.19 |
| L x P | 3 | 35415.57 | 11805.19 | 1.89 | 24004.70 | 8001.57 | 1.20 | 59420.26 | 9903.38 | 1.54 | 2.80 |
| P x B | 6 | 2416.92 | 402.82 | 0.06 | 1505.79 | 250.97 | 0.04 | 3922.71 | 326.89 | 0.05 | 2.29 |
| L x B | 2 | 1635.91 | 817.95 | 0.13 | 715.01 | 357.51 | 0.05 | 2350.92 | 587.73 | 0.09 | 3.19 |
| L x P x B | 6 | 1927.02 | 321.17 | 0.05 | 1092.38 | 182.06 | 0.03 | 3019.40 | 251.62 | 0.04 | 2.29 |
| Error | 48 | 299032.54 | 6229.84 | | 320081.98 | 6668.37 | | 619114.52 | 6449.11 | | |
| TSS | 71 | 1450602.99 | 20431.03 | | 1378137.97 | 19410.39 | | 2831528.44 | 19800.90 | | |

Appendix LXXXVI: Effect of lime, phosphorus and boron on calcium uptake in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 2290242.29 | 2290242.29 | 288.65* | 2273554.22 | 2273554.22 | 328.64* | 4563796.51 | 2281898.25 | 307.28* | 4.04 |
| Phosphorus (P) | 3 | 503545.02 | 167848.34 | 21.15* | 401366.29 | 133788.76 | 19.34* | 904911.31 | 150818.55 | 20.31* | 2.80 |
| Boron (B) | 2 | 17809.43 | 8904.71 | 1.12 | 39052.49 | 19526.25 | 2.82 | 56861.92 | 14215.48 | 1.91 | 3.19 |
| L x P | 3 | 20578.82 | 6859.61 | 0.86 | 7132.14 | 2377.38 | 0.34 | 27710.96 | 4618.49 | 0.62 | 2.80 |
| P x B | 6 | 2286.97 | 381.16 | 0.05 | 3061.32 | 510.22 | 0.07 | 5348.29 | 445.69 | 0.06 | 2.29 |
| L x B | 2 | 3561.46 | 1780.73 | 0.22 | 5349.45 | 2674.73 | 0.39 | 8910.91 | 2227.73 | 0.30 | 3.19 |
| L x P x B | 6 | 1168.46 | 194.74 | 0.02 | 3816.46 | 636.08 | 0.09 | 4984.92 | 415.41 | 0.06 | 2.29 |
| Error | 48 | 380853.01 | 7934.44 | | 332064.23 | 6918.00 | | 712917.24 | 7426.22 | | |
| TSS | 71 | 3220045.45 | 45352.75 | | 3065396.61 | 43174.60 | | 6285769.0 | 43956.43 | | |

Appendix LXXXVII: Effect of lime, phosphorus and boron on boron uptake in grain of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 628750.29 | 628750.29 | 2170.35* | 578161.93 | 578161.93 | 1009.21* | 1206912.22 | 603456.11 | 1399.18* | 4.04 |
| Phosphorus (P) | 3 | 305461.68 | 101820.56 | 351.47* | 283972.06 | 94657.35 | 165.23* | 589433.74 | 98238.96 | 227.78* | 2.80 |
| Boron (B) | 2 | 1166180.58 | 583090.29 | 2012.73* | 1392789.42 | 696394.71 | 1215.59* | 2558970.00 | 639742.50 | 1483.31* | 3.19 |
| L x P | 3 | 10051.76 | 3350.59 | 11.57* | 5184.62 | 1728.21 | 3.02* | 15236.39 | 2539.40 | 5.89* | 2.80 |
| P x B | 6 | 5153.00 | 858.83 | 2.96* | 5418.02 | 903.00 | 1.58 | 10571.01 | 880.92 | 2.04 | 2.29 |
| L x B | 2 | 8089.11 | 4044.55 | 13.96* | 9959.18 | 4979.59 | 8.69* | 18048.29 | 4512.07 | 10.46* | 3.19 |
| L x P x B | 6 | 1089.20 | 181.53 | 0.63 | 901.03 | 150.17 | 0.26 | 1990.23 | 165.85 | 0.38 | 2.29 |
| Error | 48 | 13905.62 | 289.70 | | 27498.53 | 572.89 | | 41404.15 | 431.29 | | |
| TSS | 71 | 2138681.25 | 30122.27 | | 2303884.79 | 32449.08 | | 4443892.40 | 31076.17 | | |

* Significant at 5%

Appendix LXXXVIII: Effect of lime, phosphorus and boron on boron uptake in stover of maize

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 247011.95 | 247011.95 | 427.55* | 211495.99 | 211495.99 | 608.50* | 458507.94 | 229253.97 | 495.52* | 4.04 |
| Phosphorus (P) | 3 | 85271.58 | 28423.86 | 49.20* | 101774.50 | 33924.83 | 97.61* | 187046.08 | 31174.35 | 67.38* | 2.80 |
| Boron (B) | 2 | 334895.70 | 167447.85 | 289.83* | 385713.52 | 192856.76 | 554.87* | 720609.23 | 180152.31 | 389.39* | 3.19 |
| L x P | 3 | 1201.30 | 400.43 | 0.69 | 63.23 | 21.08 | 0.06 | 1264.53 | 210.76 | 0.46 | 2.80 |
| P x B | 6 | 1364.30 | 227.38 | 0.39 | 2101.61 | 350.27 | 1.01 | 3465.91 | 288.83 | 0.62 | 2.29 |
| L x B | 2 | 5572.14 | 2786.07 | 4.82* | 5796.28 | 2898.14 | 8.34* | 11368.42 | 2842.10 | 6.14* | 3.19 |
| L x P x B | 6 | 13.83 | 2.31 | 0.00 | 47.72 | 7.95 | 0.02 | 61.55 | 5.13 | 0.01 | 2.29 |
| Error | 48 | 27731.43 | 577.74 | | 16683.36 | 347.57 | | 44414.79 | 462.65 | | |
| TSS | 71 | 703062.24 | 9902.29 | | 723676.22 | 10192.62 | | 1426976.23 | 9978.85 | | |

Appendix LXXXIX: Effect of lime, phosphorus and boron on pH of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 3.43 | 3.43 | 162.66* | 4.37 | 4.37 | 276.47* | 7.80 | 3.90 | 211.44* | 4.04 |
| Phosphorus (P) | 3 | 0.08 | 0.03 | 1.33 | 0.05 | 0.02 | 1.10 | 0.14 | 0.02 | 1.23 | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.04 | 3.19 |
| L x P | 3 | 0.01 | 0.00 | 0.15 | 0.02 | 0.01 | 0.36 | 0.03 | 0.00 | 0.24 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.07 | 0.01 | 0.00 | 0.03 | 2.29 |
| L x B | 2 | 0.01 | 0.00 | 0.17 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.10 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.06 | 0.01 | 0.00 | 0.04 | 2.29 |
| Error | 48 | 1.01 | 0.02 | | 0.76 | 0.02 | | 1.77 | 0.02 | | |
| TSS | 71 | 4.54 | 0.064 | | 5.21 | 0.073 | | 9.76 | 0.068 | | |

Appendix XC: Effect of lime, phosphorus and boron on electrical conductivity of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.01 | 0.01 | 3.30 | 0.00 | 0.00 | 1.07 | 0.01 | 0.01 | 2.09 | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 1.33 | 0.00 | 0.00 | 0.36 | 0.01 | 0.00 | 0.80 | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.12 | 0.00 | 0.00 | 0.15 | 3.19 |
| L x P | 3 | 0.01 | 0.00 | 0.97 | 0.00 | 0.00 | 0.29 | 0.01 | 0.00 | 0.60 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.34 | 0.01 | 0.00 | 0.50 | 0.01 | 0.00 | 0.42 | 2.29 |
| L x B | 2 | 0.01 | 0.00 | 1.54 | 0.00 | 0.00 | 0.42 | 0.01 | 0.00 | 0.93 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.29 | 0.00 | 0.00 | 0.07 | 0.01 | 0.00 | 0.17 | 2.29 |
| Error | 48 | 0.11 | 0.00 | | 0.13 | 0.00 | | 0.24 | 0.00 | | |
| TSS | 71 | 0.15 | 0.0021 | | 0.15 | 0.0021 | | 0.30 | 0.0042 | | |

* Significant at 5%

Appendix XCI: Effect of lime, phosphorus and boron on percent base saturation of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 441.34 | 441.34 | 140.81* | 449.25 | 449.25 | 137.45* | 890.59 | 445.30 | 139.10* | 4.04 |
| Phosphorus (P) | 3 | 2.01 | 0.67 | 0.21 | 2.44 | 0.81 | 0.25 | 4.45 | 0.74 | 0.23 | 2.80 |
| Boron (B) | 2 | 0.03 | 0.02 | 0.01 | 0.04 | 0.02 | 0.01 | 0.08 | 0.02 | 0.01 | 3.19 |
| L x P | 3 | 0.36 | 0.12 | 0.04 | 0.26 | 0.09 | 0.03 | 0.63 | 0.10 | 0.03 | 2.80 |
| P x B | 6 | 0.28 | 0.05 | 0.01 | 0.32 | 0.05 | 0.02 | 0.60 | 0.05 | 0.02 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.00 | 0.05 | 0.03 | 0.01 | 0.05 | 0.01 | 0.00 | 3.19 |
| L x P x B | 6 | 0.08 | 0.01 | 0.00 | 0.24 | 0.04 | 0.01 | 0.32 | 0.03 | 0.01 | 2.29 |
| Error | 48 | 150.45 | 3.13 | | 156.89 | 3.27 | | 307.33 | 3.20 | | |
| TSS | 71 | 594.56 | 8.37 | | 609.49 | 8.58 | | 1220.42 | 17.19 | | |

Appendix XCII: Effect of lime, phosphorus and boron on organic carbon of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.00 | 0.00 | 0.24 | 0.00 | 0.00 | 0.20 | 0.00 | 0.00 | 0.22 | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 0.30 | 0.01 | 0.00 | 0.20 | 0.01 | 0.00 | 0.25 | 2.80 |
| Boron (B) | 2 | 0.01 | 0.00 | 0.36 | 0.00 | 0.00 | 0.01 | 0.01 | 0.00 | 0.18 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.01 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.01 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.02 | 2.29 |
| Error | 48 | 0.46 | 0.01 | | 0.50 | 0.01 | | 0.95 | 0.01 | | |
| TSS | 71 | 0.48 | 0.0068 | | 0.51 | 0.0072 | | 1.00 | 0.014 | | |

Appendix XCIII: Effect of lime, phosphorus and boron on soil available nitrogen of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 1829.62 | 1829.62 | 533.05* | 1504.35 | 1504.35 | 740.40* | 3333.97 | 1666.99 | 610.16* | 4.04 |
| Phosphorus (P) | 3 | 17.07 | 5.69 | 1.66 | 12.49 | 4.16 | 2.05 | 29.56 | 4.93 | 1.80 | 2.80 |
| Boron (B) | 2 | 4.46 | 2.23 | 0.65 | 7.40 | 3.70 | 1.82 | 11.85 | 2.96 | 1.08 | 3.19 |
| L x P | 3 | 20.11 | 6.70 | 1.95 | 4.60 | 1.53 | 0.75 | 24.71 | 4.12 | 1.51 | 2.80 |
| P x B | 6 | 11.61 | 1.93 | 0.56 | 2.00 | 0.33 | 0.16 | 13.61 | 1.13 | 0.42 | 2.29 |
| L x B | 2 | 0.31 | 0.16 | 0.05 | 0.56 | 0.28 | 0.14 | 0.87 | 0.22 | 0.08 | 3.19 |
| L x P x B | 6 | 8.89 | 1.48 | 0.43 | 2.16 | 0.36 | 0.18 | 11.05 | 0.92 | 0.34 | 2.29 |
| Error | 48 | 164.75 | 3.43 | | 97.53 | 2.03 | | 262.28 | 2.73 | | |
| TSS | 71 | 2056.82 | 28.97 | | 1631.08 | 22.97 | | 3707.44 | 25.93 | | |

* Significant at 5%

Appendix XCIV: Effect of lime, phosphorus and boron on soil available phosphorus of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 47.26 | 47.26 | 62.19* | 76.18 | 76.18 | 58.40* | 123.43 | 61.72 | 59.79* | 4.04 |
| Phosphorus (P) | 3 | 56.25 | 18.75 | 24.68* | 63.18 | 21.06 | 16.14* | 119.43 | 19.90 | 19.28* | 2.80 |
| Boron (B) | 2 | 0.21 | 0.10 | 0.14 | 0.93 | 0.46 | 0.36 | 1.14 | 0.28 | 0.28 | 3.19 |
| L x P | 3 | 3.51 | 1.17 | 1.54 | 1.25 | 0.42 | 0.32 | 4.76 | 0.79 | 0.77 | 2.80 |
| P x B | 6 | 2.14 | 0.36 | 0.47 | 0.55 | 0.09 | 0.07 | 2.69 | 0.22 | 0.22 | 2.29 |
| L x B | 2 | 0.04 | 0.02 | 0.03 | 0.10 | 0.05 | 0.04 | 0.14 | 0.03 | 0.03 | 3.19 |
| L x P x B | 6 | 1.32 | 0.22 | 0.29 | 1.00 | 0.17 | 0.13 | 2.32 | 0.19 | 0.19 | 2.29 |
| Error | 48 | 36.47 | 0.76 | | 62.62 | 1.30 | | 99.09 | 1.03 | | |
| TSS | 71 | 147.20 | 2.07 | | 205.81 | 2.90 | | 353.01 | 2.47 | | |

Appendix XCV: Effect of lime, phosphorus and boron on soil available potassium of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 21.59 | 21.59 | 10.63* | 46.29 | 46.29 | 16.91* | 67.88 | 33.94 | 14.23* | 4.04 |
| Phosphorus (P) | 3 | 2.27 | 0.76 | 0.37 | 5.37 | 1.79 | 0.65 | 7.63 | 1.27 | 0.53 | 2.80 |
| Boron (B) | 2 | 2.25 | 1.12 | 0.55 | 2.93 | 1.46 | 0.53 | 5.17 | 1.29 | 0.54 | 3.19 |
| L x P | 3 | 13.84 | 4.61 | 2.27 | 13.27 | 4.42 | 1.62 | 27.11 | 4.52 | 1.90 | 2.80 |
| P x B | 6 | 14.30 | 2.38 | 1.17 | 12.37 | 2.06 | 0.75 | 26.67 | 2.22 | 0.93 | 2.29 |
| L x B | 2 | 0.89 | 0.45 | 0.22 | 9.59 | 4.80 | 1.75 | 10.49 | 2.62 | 1.10 | 3.19 |
| L x P x B | 6 | 4.99 | 0.83 | 0.41 | 13.27 | 2.21 | 0.81 | 18.26 | 1.52 | 0.64 | 2.29 |
| Error | 48 | 97.50 | 2.03 | | 131.42 | 2.74 | | 228.92 | 2.38 | | |
| TSS | 71 | 157.64 | 2.22 | | 234.50 | 3.30 | | 397.82 | 5.60 | | |

Appendix XCVI: Effect of lime, phosphorus and boron on soil exchangeable calcium of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 25.32 | 25.32 | 3162.69* | 26.15 | 26.15 | 4373.27* | 51.47 | 25.74 | 3680.22* | 4.04 |
| Phosphorus (P) | 3 | 13.36 | 4.45 | 556.21* | 13.12 | 4.37 | 731.61* | 26.48 | 4.41 | 631.19* | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.07 | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 | 0.08 | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.34 | 0.01 | 0.00 | 0.15 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.06 | 0.00 | 0.00 | 0.03 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.13 | 0.00 | 0.00 | 0.06 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.17 | 0.01 | 0.00 | 0.08 | 2.29 |
| Error | 48 | 0.38 | 0.01 | | 0.29 | 0.01 | | 0.67 | 0.01 | | |
| TSS | 71 | 39.07 | 0.55 | | 39.58 | 0.56 | | 78.68 | 0.55 | | |

* Significant at 5%

Appendix XCVII: Effect of lime, phosphorus and boron on soil available boron of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.05 | 0.05 | 5.97* | 0.03 | 0.03 | 4.54* | 0.08 | 0.04 | 5.36* | 4.04 |
| Phosphorus (P) | 3 | 0.00 | 0.00 | 0.05 | 0.01 | 0.00 | 0.26 | 0.01 | 0.00 | 0.14 | 2.80 |
| Boron (B) | 2 | 0.17 | 0.09 | 10.04* | 0.10 | 0.05 | 7.93* | 0.27 | 0.07 | 9.14* | 3.19 |
| L x P | 3 | 0.00 | 0.00 | 0.15 | 0.00 | 0.00 | 0.06 | 0.01 | 0.00 | 0.11 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.08 | 0.01 | 0.00 | 0.25 | 0.01 | 0.00 | 0.15 | 2.29 |
| L x B | 2 | 0.03 | 0.01 | 1.70 | 0.01 | 0.00 | 0.53 | 0.04 | 0.01 | 1.20 | 3.19 |
| L x P x B | 6 | 0.07 | 0.01 | 1.40 | 0.02 | 0.00 | 0.52 | 0.09 | 0.01 | 1.02 | 2.29 |
| Error | 48 | 0.41 | 0.01 | | 0.31 | 0.01 | | 0.72 | 0.01 | | |
| TSS | 71 | 0.75 | 0.011 | | 0.48 | 0.0068 | | 1.26 | 0.018 | | |

Appendix XCVIII: Effect of lime, phosphorus and boron on soil exchangeable hydrogen of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 3.56 | 3.56 | 671.70* | 1.35 | 1.35 | 529.81* | 4.91 | 2.46 | 625.62* | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 0.72 | 0.01 | 0.00 | 0.68 | 0.02 | 0.00 | 0.71 | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.18 | 0.00 | 0.00 | 0.07 | 3.19 |
| L x P | 3 | 0.03 | 0.01 | 1.78 | 0.01 | 0.00 | 1.84 | 0.04 | 0.01 | 1.80 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.19 | 0.00 | 0.00 | 0.08 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.21 | 0.00 | 0.00 | 0.34 | 0.00 | 0.00 | 0.25 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.14 | 0.00 | 0.00 | 0.07 | 2.29 |
| Error | 48 | 0.25 | 0.01 | | 0.12 | 0.00 | | 0.38 | 0.00 | | |
| TSS | 71 | 3.86 | 0.054 | | 1.50 | 0.021 | | 5.36 | 0.075 | | |

Appendix XCIX: Effect of lime, phosphorus and boron on soil exchangeable aluminium of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 0.17 | 0.17 | 42.58* | 0.30 | 0.30 | 109.59* | 0.47 | 0.23 | 70.45* | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 0.55 | 0.00 | 0.00 | 0.27 | 0.01 | 0.00 | 0.43 | 2.80 |
| Boron (B) | 2 | 0.00 | 0.00 | 0.46 | 0.00 | 0.00 | 0.73 | 0.01 | 0.00 | 0.57 | 3.19 |
| L x P | 3 | 0.02 | 0.01 | 1.91 | 0.02 | 0.01 | 1.84 | 0.04 | 0.01 | 1.88 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.03 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.03 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.03 | 2.29 |
| Error | 48 | 0.19 | 0.00 | | 0.13 | 0.00 | | 0.32 | 0.00 | | |
| TSS | 71 | 0.39 | 0.0055 | | 0.46 | 0.0065 | | 0.85 | 0.012 | | |

* Significant at 5%

Appendix C: Effect of lime, phosphorus and boron on total potential acidity of post-harvest soil

| SOV | DF | 2016 | | | 2017 | | | Pooled | | | F tab |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SS | MSS | F cal | SS | MSS | F cal | SS | MSS | F cal | |
| Lime (L) | 1 | 52.14 | 52.14 | 5618.10* | 49.78 | 49.78 | 9520.36* | 101.92 | 50.96 | 7024.44* | 4.04 |
| Phosphorus (P) | 3 | 0.01 | 0.00 | 0.51 | 0.02 | 0.01 | 1.20 | 0.03 | 0.01 | 0.76 | 2.80 |
| Boron (B) | 2 | 0.01 | 0.00 | 0.36 | 0.01 | 0.00 | 0.68 | 0.01 | 0.00 | 0.47 | 3.19 |
| L x P | 3 | 0.02 | 0.01 | 0.85 | 0.02 | 0.01 | 1.20 | 0.04 | 0.01 | 0.97 | 2.80 |
| P x B | 6 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.04 | 0.00 | 0.00 | 0.02 | 2.29 |
| L x B | 2 | 0.00 | 0.00 | 0.01 | 0.00 | 0.00 | 0.16 | 0.00 | 0.00 | 0.06 | 3.19 |
| L x P x B | 6 | 0.00 | 0.00 | 0.02 | 0.00 | 0.00 | 0.03 | 0.00 | 0.00 | 0.03 | 2.29 |
| Error | 48 | 0.45 | 0.01 | | 0.25 | 0.01 | | 0.70 | 0.01 | | |
| TSS | 71 | 52.63 | 0.74 | | 50.08 | 0.71 | | 102.81 | 0.72 | | |

* Significant at 5%