GROWTH AND YIELD OF GROUNDNUT VARIETIES AS AFFECTED BY DIFFERENT LEVELS OF CALCIUM AND APPLICATION TIME

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DHAKA-1207

June, 2015

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REGISTRATION NO. 09-03498

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

MASTER OF SCIENCE (MS)

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2015

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CERTIFICATE

*This is to certify that the thesis entitled "**GROWTH AND YIELD OF GROUNDNUT VARIETIES AS AFFECTED BY DIFFERENT LEVELS OF CALCIUM AND APPLICATION TIME**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **TAHMINA AKTER RINA,** Registration. No. **09-03498** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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ACKNOWLEDGEMENT

All praises to the almighty **Allah** for his gracious kindness and infinite mercy in all the endeavors the author to let her successfully complete the research work and the thesis leading to Master of Science.

The author would like to express her heartiest respect, deep sense of gratitude and sincere, profound appreciation to her supervisor, **Prof. Dr. Md. Fazlul Karim**, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis. Likewise grateful appreciation is conveyed to Co-supervisor, **Prof. Dr. H. M. M. Tariq Hossain**, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for his constant encouragement, cordial suggestions, constructive criticisms and valuable advice to conduct the research work as well as preparation of the thesis.

The author would like to express her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their scholarly suggestions, constructive criticisms, support, encouragement and sympathetic consideration during the course of studies and for providing unforgettable help at the time of preparing the thesis.

The author appreciates the assistance rendered by the stuffs of Agronomy Department and all labors and stuff of Sher-e-Bangla Agricultural University farm, for their valuable and sincere help in carrying out the research work.

The author wishes to extend her special thanks to Jibon, Rabbi, Habib, Mahmud and other friends and all well wishers for their help during experimentation, active encouragement and inspiration to complete this study.

Finally the author is very glad to express her gratefulness and deepest appreciation to her family members and other relatives for their great sacrifices, endless prayers, blessings and support to reach her at this level of higher education.

The Author

GROWTH AND YIELD OF GROUNDNUT VARIETIES AS AFFECTED BY DIFFERENT LEVELS OF CALCIUM AND APPLICATION TIME

ABSTRACT

A field experiment was conducted at the research field of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from September, 2014 to January, 2015 with a view to study the growth and yield of groundnut varieties as affected by different levels of calcium and application time. The experiment was carried out in split plot design considering three varieties *i.e*. V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1(Maijchaur badam) in the main plot and five levels of Ca (calcium) viz. T_1= NPKCa as basal, T_2= NPK as basal + 100 kg Ca ha^1 at flower initiation (45 DAS), T_3= NPK as basal + 200 kg Ca ha^{-1} at flower initiation (45 DAS), T_4= NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS) and T_5= NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS) in the sub plot replicated three times. BARI Chinabadam-8 gave highest pod yield (1.75 t ha^{-1}) which was 18.24% and 2.34% higher than the Dhaka-1 (1.48 t ha^{-1}) and BINA Chinabadam-4 (1.71 t ha^{-1}), respectively. Among the Ca levels, NPK + 100 kg Ca ha^{-1} at flower initiation (45 DAS) scored the highest pod yield (2.03 t ha^{-1}) which was 49.26%, 43.97%, 27.67% and 20.12% higher than Ca levels NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS), NPKCa as basal, NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS) and NPK as basal + 200 kg Ca ha^{-1} at flower initiation (45 DAS), respectively. BARI Chinabadam-8 in combination with NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) produced the highest pod yield (2.30 t ha^{-1}) which was 86.99 % higher than treatment combination Dhaka-1 with NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS) (1.23 t ha^{-1}). The yield was attributed due to maximum pods $plant^{-1}$ followed by seeds pod^{-1} and 100 seeds weight. Results revealed that application of 100 kg Ca ha^{-1} at the time of flower initiation along with basal NPK could be the best for groundnut production irrespective of varietal difference.

LIST OF CONTENTS

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF CONTENTS (contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (contd.)

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BADC	=	Bangladesh Agricultural Development Corporation
LAI	=	Leaf area index
ppm	=	Parts per million
et al.	=	And others
N	=	Nitrogen
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash
G	=	Gypsum
DAS	=	Days after sowing
ha^{-1}	=	Per hectare
kg	=	Kilogram
q	=	Quintal
µg	=	Micro gram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
HI	=	Harvest Index
No.	=	Number
Wt.	=	Weight
LSD	=	Least Significant Difference
^{0}C	=	Degree Celsius
NS	=	Non significant
cm	=	Centimeter
mm	=	Millimeter
Max	=	Maximum
Min	=	Minimum
%	=	Percent
cv.	=	Cultivar
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of coefficient of variance
Hr	=	Hour
T	=	Ton
viz.	=	Videlicet (namely)

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is an annual field crop under the sub-family Papilionaceae of the family Fabacaae. It is also known as peanut, monkeynut and eartnut. It is popularly known as Chinabadam in Bangladesh. It is one of the principal economic crops of the world and ranks l3th position among the food crops (Reddy and Kaul, 1986). There are many oil crops grown in Bangladesh. Of them, mustard and sesame ranks first and second positions, respectively while groundnut is the third, both in area and production. Groundnut being a multipurpose crop, it can help reduce the edible oil, food and fodder shortage in the country. Groundnut is mainly valued for its quality edible oil (48-50%) which is higher in comparison to other oil seeds grown in Bangladesh. Groundnut contains 48-52% oil, 25-30% protein and 20% carbohydrate together with very rich in vitamin B and E. This means that it can help alleviate the acute shortages of oil and protein needs of the country. The aerial plant parts of groundnut are used as fodder. Again its oil cake that contains 45-56% protein could be the best cattle feed of all, besides being used as manure. Being a legume crop, it fixes atmospheric nitrogen in the soil through its nodule bacteria (*Rhizobium*) and helps maintain sustainable soil fertility (Lee *et al.*, 1998). Its ability to grow vigorously in diverse environments, especially in N-deficient soils, is particularly advantageous in subsistence agriculture. It is also better adapted to environmental stresses as well as tolerant to soil fertility problems.

There are three botanical types of cultivated groundnut in the world: Virginia, Spanish and Valencia. In Bangladesh Spanish types are mostly grown by the necessity of the growing conditions. It is a photoinsensitive crop and allows cultivation throughout the year. Despite its insensitivity, it is grown mainly in *Rabi* season in ‘charlands’ due to high land scarcity in *Kharif* season. In Bangladesh, groundnut is cultivated in almost 32000 ha of land with annual production 54000 ton (FAOSTAT, 2013).

Groundnut cultivation is concentrated in ‘char’ areas of Kishorganj, Noakhali, Sherpur and Kurigram districts during the Rabi season and its Kharif cultivation is limited for seed purposes in high land areas of Dhaka, Comilla, Rajshahi and Kushtia districts. Its yield (1.60 t ha^{-1}) in Bangladesh is very low (FAOSTAT, 2013) compared to very high average yields obtained in Mozambique (2.60 t ha^{-1}), Israel (2.86 t ha^{-1}) and U.S.A. (2.60 t ha^{-1}) (Agasimani *et al.* 1986). This poor yield is attributed to a wide variety of factors. Of them, non-availability of suitable high yielding stable varieties and lack of proper management practices are most important. Productivity of groundnut can be raised manifold through both improved varieties and management practices (Reddy and Kaul. 1986).

Groundnut is characterized by aerial flowers and sub-terranean fruits. Most of the flowers produced in this crop finally fail to develop pods with only 10-33% develop into harvestable pods (Rahman and Mia 1978; Patil *et al.* 1984; Reddy *et al.* 1990). Mature pods are mostly developed from the first basal flowers which are often closer to the ground have competitive advantages over the later (Emery, 1963 and Hartzook, 1967). Moreover, within the available varieties, old or recently evolved one has a specific growth period within which maximum number of effective flowers those result more mature pods ultimately lead to higher yield. Therefore, an insight study into the flowering pattern of the crop life that ultimately leads to more mature pods and final yield appears utmost necessity for following efficient selection of desired varieties. Pod yield in groundnut is controlled pulygenically, has background influence on its component characters with individual pod number and weight being the most important ones.

Groundnut seed development is unique from other plants. Once flowers are pollinated, a peg is formed which moves downward as geotropic movement and then moves horizontally called dia-geotropic movement. Calcium is the most critical element in growth and development of groundnut pegs, pods and seeds and is the main limiting factor of groundnut production in many parts of the world (Safarzadeh Vishkaee, 1999). The essentiality of calcium for the fruitification of groundnut has been amply established by a number of workers. For groundnut about 1 m eq. exchangeable Ca $100g^{-1}$ of soil in the root zone and three times this much in the pod formation zone are considered as threshold levels. So, it is very important that adequate levels of calcium should be present in the top 10 cm of soil, or pegging zone, (Sumner *et al*., 1988) because this is where developing pods must acquire calcium. Calcium enters the seed by diffusing directly from soil into the hull, where it is channeled to the funiculus.

Calcium deficiency leads to high percentage of aborted seeds (empty pods) and improperly filled pods (Ntare *et al*., 2008). It also leads to shriveled fruit, including darkened plumules and production of pods without seed (Singh and Oswalt, 1995). Presence of enough calcium content in the soil leads to prevent of black hallow and cracked pods, decreases of aflatoxin production and consequently decreases decayed pod of groundnut.

Different scientists observed that calcium in groundnut bush is approximately motionless and its concentration in any parts of the plant depends on when that part is forming and growing, because calcium is absorbed through roots of groundnut and then transmitted to the aerial parts of the plant but is not transmitted from aerial parts towards economic parts (pod + seed). So the calcium in the soil must be adequate around the growing pod (Norman *et al*., 2005; Smart, 1994; Ramachandrappa and Kulkarni, 1992; Slak and Morrill, 1972). Although, calcium is transmitted as inactive transition from aerial parts to fruits as a result of transpiration, but in groundnut which is a plant with underground pods, especially the transition of calcium from xylem to pods is difficult, because pods are growing underground and there are no stomata on pods. In other words, pods don't perform transpiration; therefore, they don't have calcium through transpiration flow (Safarzadeh Vishkaee, 2004; Agasimani *et al*., 1992). Understanding these phenomena, different scientists observed increased pods and seed yields of groundnut when they applied calcium during reproductive stages which ensured pods and seeds to uptake calcium for their proper development and yield (Ntare *et al*., 2008; Norman *et al*., 2005; Rao and Shaktawat, 2005; Ursal *et al*., 1994). A few works on time application of calcium management in groundnut were done in Bangladesh. In view of this fact it is thought that the present groundnut yield could be improved with inclusion of HYV of groundnut fertilized with optimum amount of calcium during its flowering stage. Hence a detailed study was under taken with the following objectives:

- To observe the response of HYV groundnut by applying calcium at their reproductive stages.
- To determine the time and dose of calcium for pod and seed development of groundnut.
- To study the combined effect of variety and calcium application on the growth and yield of groundnut.

Chapter II

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Most of the farmer in Bangladesh cultivate groundnut following the conventional procedure. A few research works have been conducted in our country regarding split application of Ca for production of groundnut. The research findings in this regard are scanty. Some of the pertinent works on these have been reviewed in this chapter.

2.1 Crop growth characters

2.1.1 Plant height

Habib (2014) conducted an experiment in rabi season on calcium management towards peg and pod development of groundnut and found that at harvest, the longest plant height (39.95 cm) was recorded from treatment NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS). The lowest plant height (30.21 cm) was found from 400 kg Ca ha^{-1} at flower initiation (45 DAS) which was statistically similar with treatments NPKCa as basal (Control) (31.14 cm) and NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS) (33.14 cm).

Yadav *et al*. (2014) conducted a research work at the research farm of Udai Pratap Autonomous College, Varanasi adjoining in the Department of Agriculture Chemistry and Soil Science during *kharif* season of 2009 to study the effect of gypsum on growth and yield of groundnut (*Arachis hypogaea* L.) and found that highest plant height recorded with T_2 (NPK =25:50:20 kg ha^{-1} + gypsum @ 200 kg ha^{-1}) (23.16 cm) followed by T_1 (NPK =25:50:20 kg ha^{-1} + gypsum @ 100 kg ha^{-1}) (22.5 cm), T_3 (NPK = 25:50:20 kg ha^{-1} + gypsum @ 300 kg ha^{-1}) (21.83 cm) and T_4 (NPK = 25:50:20 kg ha^{-1} + gypsum @ 400 kg ha^{-1}) (20.5 cm). T_0 (no fertilizer and gypsum) recorded minimum plant height (19.41 cm) and overall effect of treatments was statistically significant. T_2 was found to be significant superior over control.

An experiment was conducted by Kabir *et al*. (2013) on the growth and yield of groundnut with phosphorus, calcium and boron and reported that the highest plant height (59.68cm) was obtained from Ca_2 (165 kg Ca ha^{-1}) and the lowest one (47.18 cm) was found at control (0 kg Ca ha^{-1}). They also reported that the highest plant height (64.5 cm) was obtained at the highest level of fertilizers combination ($P_{2\times}$ Ca_1 $\times B_2$= 50 ka P×110 kg Ca ×2.5 kg B) and the lowest (44.5 cm) one was found at control (0 kg ha^{-1}).

Rahman (2006) conducted two experiments in the year 1997-98 and 1998-99 to determine the effect of calcium and *Bradyrhizobium* inoculation of the growth, yield and quality of groundnut and reported that the fertilizer element calcium significantly influenced plant height in 1997-98 and 1998- 99. In the first year the longest plants were obtained from the treatment 150 kg ha^{-1} Ca while the shortest plan from the control plot. In the second year similar trend was also showed by calcium application. He also found that the interaction of calcium and *Bradyrhizobium* fertilization was significant in 1997-98 but insignificant in 1998-99. In both the year, the longest plant (53.47 and 53.07 cm, respectively) were produced in the treatment of 50 kg ha^{-1} Ca with inoculation and the shortest plant was produced (43.77 and 41.67 cm, respectively) in control.

2.1.2 Leaves plant^{-1}

An experiment was conducted by Habib (2014) in rabi season on calcium management towards peg and pod development of groundnut and found that different levels of calcium had significant effect on leaves plant^{-1} at 50, 150 DAS and harvest and the rest of the sampling date had no significance effect. Total leaves plant^{-1} increased up to 150 DAS and then decreased at harvest among all the calcium levels except NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) and NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS) treatments. It was observed that at 50 DAS, the highest leaves plant^{-1} (17.96) was found in NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS) which was statistically similar (17.30) with NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS). At harvest, maximum leaves plant^{-1} (87.35) was recorded from treatment NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) which was statistically similar with NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS) and the lowest leaves plant^{-1} (69.33) was recorded from NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS).

2.1.3 Dry matter content plant^{-1}

Habib (2014) conducted an experiment in rabi season on calcium management towards peg and pod development of groundnut and found that above ground dry matter (AGDM) increased exponentially with time and the increasing trend was slow at initial growth stage and rapid from 70 to 110 DAS and again became steady up to harvest. AGDM was significantly affected by different level of Ca treatments at 90, 110, 130, 150 DAS and harvest. Treatment NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) scored the highest AGDM (5.78, 14.07, 16.66, 17.22 and 18.02 g plant^{-1} at 90, 110, 130, 150 DAS and harvest, respectively).

An experiment was conducted by Kabir *et al*. (2013) to investigated the effect of phosphorus, calcium and boron on the growth and yield of groundnut and reported that the highest dry matter (31.1 g) was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest dry matter content (28.44) from control treatment Ca_0 (0 kg Ca ha^{-1}). They also found that the highest dry matter (33.0 g) was recorded with $P_2 \times Ca_1 \times B_2$ (50 kg ha^{-1} TSP×110 kg ha^{-1} gypsum × 2.5 kg ha^{-1} Borax) at 100 DAS and the lowest one (25.90 g) was found at control $P_0 \times Ca_0 \times B_0$ (no fertilizers).

2.1.4 Crop growth rate (CGR)

Kabir *et al*. (2013) conducted an experiment to investigate the effect of phosphorus, calcium and boron on the growth and yield of groundnut and reported that the highest CGR (20.39 g m^{-2}d^{-1}) was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest CGR (18.70 g m^{-2}d^{-1}) from control treatment Ca_0 (0 kg Ca ha^{-1}). They also found that the highest CGR (22.22 g m^{-}

$^{2}d^{-1}$) was recorded with $P_2 \times Ca_1 \times B_2$(50 kg ha^{-1} TSP×110 kg ha^{-1} gypsum × 2.5 kg ha^{-1} Borax) at 100 DAS and the lowest one (16.89 g $m^{-2}d^{-1}$) was found at control $P_0 \times Ca_0 \times B_0$ (no fertilizers).

2.2 Yield contributing characters

2.2.1 Branches plant^{-1}

An experiment was conducted by Habib (2014) in rabi season on calcium management towards peg and pod development of groundnut and found that different levels of calcium significantly influenced branches plant^{-1} at 30, 50, 90, 150 DAS and at harvest. Treatment NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) achieved the highest branches plant^{-1} (3.48, 10.15 and 9.11 at 50 and 150 DAS and harvest, respectively) and the treatment NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS) scored the lowest branches plant^{-1} (2.49, 7.30 and 6.48 at 50 and 150 DAS and at harvest, respectively).

Yadav *et al.* (2014) conducted an experiment at the research farm of Udai Pratap Autonomous College, Varanasi adjoining in the Department of Agriculture Chemistry and Soil Science during *kharif* season of 2009 to determine the gypsum effect on growth and yield of groundnut and found that highest branches plant^{-1} was recorded with T_2 (NPK = 25:50:20 kg ha^{-1} + gypsum @ 200 kg ha^{-1}) (9.8) and minimum in T_0 (no fertilizers and gypsum) (7.25).

An experiment was conducted by Kabir *et al*. (2013) to investigate the phosphorus, calcium and boron performance on the growth and yield of groundnut and reported that the highest branches plant^{-1} (7.22) was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest one (6.44) from control treatment Ca_0 (0 kg Ca ha^{-1}). They also reported that the highest branches plant^{-1} (8.0) was obtained from the treatments combination of $P_2 \times Ca_1 \times B_1$,

$P_2 \times Ca_1 \times B_2$, and $P_2 \times Ca_2 \times B_2$ and the lowest one (5.33) from control treatment combination ($P_0 \times Ca_0 \times B_0$).

Kamara *et al*. (2011) conducted a research work to find out the effect of calcium and phosphorus fertilizer on the growth and yield of groundnut and reported that calcium application had a positive effect on branches plant^{-1}. The highest branches plant^{-1} (9.50) was obtained in the treatment with 200 kg Ca ha^{-1} and the lowest branches plant^{-1} (8.33) was obtained in the control treatment.

Research conducted by Rahman (2006) in the year 1997-98 and 1998-99 to determine the effect of calcium and *Bradyrhizobium* inoculation of the growth, yield and quality of groundnut and reported that calcium fertilization influenced the number of branches per plant significantly in 1997-98 and 1998-99. In 1997-98, the highest number of branches was produced with 150 kg ha^{-1} Ca treatment. Other doses of calcium produced identical number of branches with the highest one. Control plot produced significantly poorer number of branches per plant compared to calcium treated plot. In 1998-99 similar trend also found from the experiment.

2.2.2 Pods plant^{-1}

An experiment was conducted by Habib (2014) in rabi season on calcium management towards peg and pod development of groundnut and found that the varietal variation had no significant effect on pods plant^{-1} over time except at 150 DAS. The highest pods plant^{-1} (15.47) was recorded from the Dhaka-1 at 150 DAS which was statistically at par with BARI Chinabadam-8 while the lowest pods plant^{-1} (13.30) was obtained from BARI Chinabadam-9.

Kabir *et al*. (2013) studied the effect of phosphorus, calcium and boron on the growth and yield of groundnut and reported that the highest pods plant^{-1} (18.47) was obtained from the treatment Ca_1 (110 kg Ca ha^{-1}) and the lowest one (16.44) was recorded from control treatment Ca_0 (0 kg Ca ha^{-1}).

Bagarama *et al*. (2012) studied the effect of gypsum and NPK fertilizer on groundnut performance in Western Tanzania and reported that the application of gypsum material and NPK significantly reduced the number of unfilled groundnut pods compared to the control treatment. The lowest number of unfilled pods 25 plants^{-1} (93) was found in treatment T_4 (groundnut + 400 kg ha^{-1} gypsum) soil mineral, while the control treatment T_1 (sole groundnuts) had the highest number unfilled pods per 25 plants^{-1} (202).

Research conducted by Kamara *et al*. (2011) to investigate the effect of calcium and phosphorus fertilizer on the growth and yield of groundnut and reported that calcium application had a positive effect on the filled pods plant^{-1}. The highest number of filled pods was obtained in the treatment with 100 kg Ca ha^{-1} in the major season and was 33.5% more than the unfertilized treatment. Increasing the rate of calcium from 100 kg ha^{-1} to 200 kg ha^{-1} did not bring significant increase in number of filled pods. The ratio of filled to unfilled pods was 3.8:1 in the major season and 0.7:1 in the minor season.

Pathak (2010) conduct a research work to investigate the effect of calcium on peanut pod and seed development under field conditions and reported that a higher percentage of asynchronized mature (24.27 %) and very mature (12.91 %) fruits were obtained than in the gypsum treated condition which had 16.57 % mature and 8.34 % very mature fruits, respectively. Georgia Green had a lower percentage of asynchronized mature (17.71 %) and very matures (8.60%) fruits than C-99R.

Rahman (2006) investigated the effect of calcium and *Bradyrhizobium* inoculation of the growth, yield and quality of groundnut and reported that calcium had a positive effect on the mature pods plant^{-1} and affected significantly in 1997-98 and 1998-99. The highest mature pods plant^{-1} was obtained in the treatment of 150 kg Ca ha^{-1} in 1997-98 and the other treatments varied significantly. In 1998-99, the highest mature pods plant^{-1} was obtained in the treatment of 150 kg Ca ha^{-1} that produced identical number with treatment 100 kg Ca ha^{-1} and 200 kg Ca ha^{-1}. The lowest number pods plant^{-1}

was obtained in the treatment of 0 kg Ca ha^{-1}. He also reported that the mature pods $plant^{-1}$ interacted significantly by calcium and *Bradyrhizobium* in 1997-98 only. In 1997-98, the highest mature pods $plant^{-1}$ was produced with 100 kg Ca ha^{-1} with inoculation and the lowest matured pods $plant^{-1}$ was produced in control.

Blamey and Chapman (1982) found that liming increased the percentage of mature pods.

Hall (1975) studied the effect of phosphorus, potassium, and calcium on peanuts at Mauke (Cook Islands) and reported that the highest pods $plot^{-1}$(520) was given by treatment P + Ca where as the lowest pods $plot^{-1}$ (47) given by control treatment which show identity with k treatment.

2.2.3 Seeds pod^{-1}

Habib (2014) conducted an experiment in rabi season on calcium management towards peg and pod development of groundnut and found significant variation was observed on kernels pod^{-1} due to different calcium levels treatments. Among the calcium levels, the highest kernels pod^{-1} (1.72) was recorded from NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS). The lowest kernels pod^{-1} (1.58) was recorded from NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS) treatment.

Study conducted by Pathak (2010) to find out the effect of calcium on peanut pod and seed development under field conditions and reported that for two-segmented pods, there was a higher percentage of two seeds (84.2 % versus 78.1%) when gypsum was applied. He also reported that cultivars also differed in the seeds pod^{-1}. Georgia Green had a higher percentage of two-segmented pods filled with two seeds (85.0 %) than C-99R (77.3 %).

Sorensen and Butts (2008) studied a research work to determine potentiality of pod yield and mineral concentration of four peanut cultivars following gypsum application with subsurface drip irrigation and he found that the cultivars O2C (71%) gave the highest total sound mature kernel where as the NCV cultivar gave the lowest (60 %) total sound mature kernel.

2.2.4 100 seeds weight

An experiment was conducted by Habib (2014) in rabi season on calcium management towards peg and pod development of groundnut and found that the effect of calcium level showed significant variation in 1000 kernel weight. NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) gave the highest 1000 kernel weight (565.6 g) which was statistically similar with NPK as basal + 200 kg Ca ha^{-1} at flower initiation (45 DAS). The lowest 1000 kernel weight (503.7 g) was found from NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS).

Rahman (2006) worked on the effect of calcium and *Bradyrhizobium* inoculation of the growth, yield and quality of groundnut and reported that 100 seed weight of groundnut varied significantly with calcium application. The heaviest seed in 1979-98 was produced with 150 kg Ca ha^{-1}, which produced at par weight with 100 kg Ca ha^{-1}. Other treatments produced significantly poorer weighed seed and were identical with the control and the lightest seed was obtained in control. In 1998-99, a similar result was also obtained excepting that only 50 kg Ca $ha^{-1}$and control produced identical results.

Gashti *et al.* (2012) conducted an experiment to determine the effect of potassium and calcium application on yield, yield components and qualitative characteristics of peanut in Guilan province, Iran. He observed that the highest 100 kernels weight obtained in 90 kg ha^{-1} of calcium that had considerable difference than the others.

Blamey and Chapman (1982) reported that liming increased 100-kernel mass of groundnut.

2.3 Yields

2.3.1 Pod yield

Yadav *et al.* (2014) studied the effect of gypsum on growth and yield of groundnut and found that highest fresh weight of pod was recorded under treatment T_2 (NPK A =25:50:20 kg ha^{-1} + gypsum @ 200 kg ha^{-1}) (37.88 q ha^{-1}) and minimum with treatment T_0 (no fertilizer and gypsum) (9.35 q ha^{-1}). They also reported that maximum yield was recorded with treatment T_2 (NPK =25:50:20 kg ha^{-1} + gypsum @ 200 kg ha^{-1}) (26.10 q ha^{-1}) followed by T_4 (NPK =25:50:20 kg ha^{-1} + gypsum @ 400 kg ha^{-1}) (18.15 q ha^{-1}) and T_3(NPK =25:50:20 kg ha^{-1} + gypsum @ 300 kg ha^{-1}) (17.05 q ha^{-1}) and T_1 (NPK =25:50:20 kg ha^{-1} + gypsum @ 100 kg ha^{-1}) (13.40 q ha^{-1}). Minimum yield was recorded with treatment T_0 (no fertilizer and gypsum) (7.55 q ha^{-1}).

Study conducted by Hassan and Mahmoud (2014) to investigate the effect of different sources of calcium, organic and inorganic nitrogen on sandy soil, peanut yield and components and found that the values of pod dry weights was increased from 630.0 to 4800.0 kg fed^{-1} as mean values in the control treatment for the label zeolite at different calcium resources, respectively. They also reported that the values of pod dry weight were increased from 630.0 to 3444.0 kg fed^{-1} for the organic compost at different calcium resources.

Thilakarathna *et al.* (2014) conducted an experiment to investigate the influence of gypsum application on yield and visual quality of groundnut grown in maspotha in kurunegala district of Sri Lanka was and observed that treatment T_4 (250 kg ha^{-1} of gypsum) showed the highest (1297.67 g) fresh weight $plot^{-1}$ and the lowest (937.67 g) fresh weight $plot^{-1}$ gave the control (0 kg ha^{-1} of gypsum). They also reported that treatment T_4 (250 kg ha^{-1} of gypsum) showed the highest (865.11 g) dry weight $plot^{-1}$ and the lowest (618.00 g) dry weight $plot^{-1}$ gave the control (0 kg ha^{-1} of gypsum).

An experiment was conducted by Habib (2014) in rabi season on calcium management towards peg and pod development of groundnut and found that the pod yield exerted significant variation among the different levels of calcium. Result revealed that the highest pod yield (2.27 t ha^{-1}) was recorded from treatment NPK as basal + 100 kg Ca ha^{-1} at flower initiation, 45 DAS and the lowest yield (1.47 t ha^{-1}) was obtained from treatment NPK as basal + 400 kg Ca ha^{-1} at flower initiation, 45 DAS which showed statistical identity with NPKCa as basal producing 1.50 (t ha^{-1}). The treatment NPK as basal + 100 kg Ca ha^{-1} at flower initiation, 45 DAS gave 54.42% higher pod yield than the treatment NPK as basal + 400 kg Ca ha^{-1} at flower initiation, 45 DAS.

Kabir *et al*. (2013) conducted an experiment to investigate effect of phosphorus, calcium and boron on the growth and yield of groundnut and reported that the highest (2.67 t ha^{-1}) pod yield was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest one (2.19 t ha^{-1}) was recorded from control treatment Ca_0 (0 kg Ca ha^{-1}).

Gashti *et al*. (2012) studied the effect of potassium and calcium application on yield, yield components and qualitative characteristics of peanut in Guilan province, Iran. He observed that the highest yield of pod (5650 kg h^{-1}) obtained in 90 kg ha^{-1} of calcium and the lowest pod yield obtained from the control treatment (0 kg calcium).

Kamara *et al*. (2011) conducted an experiment to find out the effect of calcium and phosphorus fertilizer on the growth and yield of groundnut. They reported that calcium application significantly influenced pod yields. Application of 100 kg Ca ha^{-1} resulted in highest (3076 ka ha^{-1}) pod yield where as control give the lowest one.

Study conducted by Sorensen and Butts (2008) to determine potentiality of pod yield and mineral concentration of four peanut cultivars following gypsum application with subsurface drip irrigation and they found that the cultivars GG gave the highest pod yield (3440 kg ha^{-1}) where as the O2C cultivar gave the lowest pod yield (2909 kg ha^{-1}).

Rahman (2006) conducted two experiments in the year 1997-98 and 1998-99 to investigate the effect of calcium and *Bradyrhizobium* inoculation of the growth, yield and quality of groundnut and reported that calcium had a distinct and significant effect of the yield of groundnut. In 1997- 98, the highest yield was obtained with the treatment 150 kg Ca $ha^{-1}$and other treatments produced significantly poorer yield but 50 kg Ca $ha^{-1}$and control produced identical yield. In 1998-99, similar results were also obtained and the highest yield was obtained with 150 kg Ca $ha^{-1}$and other treatments produced significantly poorer yield and the lowest yield was obtained in control.

Rao and Shaktawat (2005) determined the response of organic manure, phosphorus and gypsum on nutrient uptake in groundnut and they found that the highest pod yield (18.1 q ha^{-1}) was recorded from treatment (250 kg ha^{-1}gypsum, at flowering and half at sowing + half at 35DAS) and the lowest pod yield (16.6 q ha^{-1}) was recorded from the control treatment.

Study conducted by Sarkar (2002) and observed that furrow application each 2 to 4 q ha^{-1} of calcium carbonate and gypsum to the acid soil of Jharkhand increased pod yield of groundnut to the tune of 47.6% and 17.3 % in Maharashtra and 57.9% in Orissa.

Wenxin *et al*. (2001) conducted a research work to investigate the response of calcium and boron on the growth, yield and quality of peanut and the results showed that the application of Ca fertilizer increased yield of peanut. They also reported that combined application of Ca and B also increased yield of peanut and Ca fertilizer was the main effect.

Research work conducted by Gascho *et al*. (1993) to investigate the calcium source and time of application for runner and virginia peanuts and they reported that calcite-PPI increased yield by 899 kg ha^{-1} and PPI dolomite increased yield by 1218 kg ha^{-1} compared to no Ca application.

Blamey and Chapman (1982) reported that liming significantly increased pod yield by 105% and decreased the incidence of pops.

Hall (1975) studied the effect of phosphorus, potassium, and calcium on peanuts at Mauke (cook islands) and reported that the highest pod yield (3.83 kg plot^{-1}) was given by treatment P + Ca where as the lowest (0.53 kg plot^{-1}) given by control treatment.

2.3.2 Stover yield

An experiment was conducted by Yadav *et al.* (2014) to study the response of gypsum on growth and yield of groundnut. Maximum straw yield (37.97 q ha^{-1}) was recorded under treatment T_2 (NPK =25:50:20 kg ha^{-1} + gypsum @ 200 kg ha^{-1}) and minimum (10.19 q ha^{-1}) with treatment T_0 (no fertilizer and gypsum.

Hassan and Mahmoud (2014) conducted an experiment to determine the effect of different sources of calcium, organic and inorganic nitrogen on sandy soil, peanut yield and components and found that the values of stover dry weights was increased from 593.0 to 1250.0 kg fed^{-1} as mean values in the control treatment for the label zeolite at different calcium resources, respectively. They also reported that the values of stover dry weight were increased from 593.0 to 782.0 kg fed^{-1} for the organic compost at different calcium resources. The lowest value of stover was obtained from plants received phospho-gypsum + ammonium nitrate. The highest value was recorded for plants that received gypsum + label zeolite and gypsum + compost.

An experiment was conducted by Habib (2014) in rabi season on calcium management towards peg and pod development of groundnut and found that the significant variation of stover yield was received due to different levels of calcium. Highest stover yield (3.57 t ha^{-1}) was recorded from NPK as basal + 100 kg Ca ha^{-1} at flower initiation, 45 DAS and the lowest stover yield (2.77 t ha^{-1}) was recorded from NPKCa as basal (Control) treatment which was statistically similar with NPK as basal + 400 kg Ca ha^{-1} at flower initiation, 45 DAS producing 2.81 t ha^{-1}.

Kabir *et al*. (2013) conducted an experiment to investigate effect of phosphorus, calcium and boron on the growth and yield of groundnut and reported that the highest stover yield (7.81 t ha^{-1}) was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest one (7.19 t ha^{-1}) was recorded from control treatment Ca_0 (0 kg Ca ha^{-1}).

Rao and Shaktawat (2005) conducted a research work to study the response of organic manure, phosphorus and gypsum on nutrient uptake in groundnut and they found that the highest stover yield (31.6 q ha^{-1}) was recorded from treatment (250 kg ha^{-1}) gypsum, at flowering and half at sowing + half at 35DAS) and the lowest stover yield (30.5 q ha^{-1}) was recorded from the control treatment.

Blamey and Chapman (1982) reported that liming significantly increased the stover yield by 73 %.

2.3.3 Biological yield

Habib (2014) conducted an experiment in rabi season on calcium management towards peg and pod development of groundnut and found that the different levels of calcium had significant effect on biological yield. It was observed that the highest biological yield (5.84 t ha^{-1}) was found in NPK as basal + 100 kg Ca ha^{-1} at flower initiation, 45 DAS and the lowest biological yield (4.27 t ha^{-1}) was recorded found from NPKCa as basal (Control) which was statistically similar with NPK as basal + 400 kg Ca ha^{-1} at flower initiation, 45 DAS (4.28 t ha^{-1}).

An experiment conducted by Kabir *et al.* (2013) to determine the response of phosphorus, calcium and boron on the growth and yield of groundnut and found that the highest biological yield (10.48 t ha^{-1}) was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest biological yield (9.38 t ha^{-1}) was recorded from control treatment Ca_0 (0 kg Ca ha^{-1}).

2.3.4 Harvest Index

Habib (2014) conducted an experiment in rabi season on calcium management towards peg and pod development of groundnut and found that the significant variation was observed in harvest index due to the effect of calcium levels. The highest harvest index (40.42 %) was found due to the effect of NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS) (Ca_2). NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS) gave the lowest harvest index (32.00%).

Study conducted by Kabir *et al*. (2013) conducted to investigate the influence of phosphorus, calcium and boron on the growth and yield of groundnut and result revealed that the highest (26.02%) HI (harvest index) was obtained from the treatment Ca_2 (165 kg Ca ha^{-1}) and the lowest HI (23.38 %) was recorded from control treatment Ca_0 (0 kg Ca ha^{-1}).

Rahman (2006) conducted two researches work in the year 1997-98 and 1998-99 to investigate the response of calcium and *Bradyrhizobium* inoculation of the growth, yield and quality of groundnut and reported that the highest harvest index was found in the treatment 150 kg Ca ha^{-1} and the lowest was obtained in control, which produced identical results with lower doses of calcium (50 kg ha^{-1}). In 1998-99, 150 kg Ca ha^{-1} produced the highest harvest index that was at par with 100 kg Ca ha^{-1} and control. The lower doses of calcium produced similar results that were obtained in 1997-98.

Calcium is very much crucial for pod formation of groundnut. It may be concluded that after a long study of different literatures, 100-130 kg Ca ha^{-1} could be effective for increasing growth, yield and yield attributes of groundnut.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was undertaken at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from September, 2014 to January, 2015 to come across the proper management of calcium aiming at the potential development of peg and pod of groundnut. This chapter deals with a brief description on experimental site, climate, soil and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses.

3.1 Site Description

3.1.1 Geographical Location

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

3.1.2 Agro-Ecological Region

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

3.1.3 Climate

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. Meteorological data related to the temperature, relative humidity and rainfall during the experiment period were collected from mini weather station, Sher-e-bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-II.

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, shallow red brown terrace soils under Tejgaon series. Soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranges from 5.7-6.0 and had organic carbon 0.86% and 1.19 % before sowing and after harvest, respectively. The experimental area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.2 Materials

(a) Seeds- BARI Chinabadam-8 was collected from Bangladesh Agricultural Research Institute (BARI); BINA Chinabadam-4 was collected from Bangladesh Institute of Nuclear Agriculture (BINA) and Dhaka-1 was collected from Bangladesh Agricultural Development Corporation (BADC).

(b) Fertilizers- Urea, TSP, MoP and gypsum were used as sources of N, P, K and Ca, respectively.

3.3 Description of the variety

3.3.1 BARI Chinabadam-8

BRRI Chinabadam-8 is a high yielding variety of groundnut was developed by the Oil Seed Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. The pedigree line (ICGV-94322) of the variety was suitable with Bangladesh climatic condition and crossed with some released varieties in deferent steps for experimentation, after that the variety was released in 2006 by the authorization National Seed Board. It takes about 140-150 days to mature in *rabi* season and 125-140 days during kharif season. It attains a plant height of 35-42 cm at maturity. Leaf color deep green, it contains 20-25 nuts per plant with cluster, the shells are smooth and whitish in color and soft in nature, seeds are reddish brown in color. Medium 100 seeds weight of about 55-60 g with a shelling percentage is about 65-70%. The cultivar gives a pod yield of 2.3-2.5 t ha^{-1} of unshelled nuts. This is a Spanish class variety. This is one of the best varieties so far released by BARI.

3.3.2 BINA Chinabadam-4

BINA Chinabadam-4 is also a high yielding variety of groundnut was developed by the Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh-2202, Bangladesh. The variety was released in 2008 by the authorization of National Seed Board. It takes about 140-150 days to mature in *rabi* season and 100-120 days during *kharif* season. Pod and kernels are medium bold sized. It can tolerate *Cercospora* leaf spot, collar root and rust diseases and also performs better under drought and saline conditions. The cultivar gives a pod yield of maximum 3.5 t ha^{-1}, average 2.6 t ha^{-1}. This is one of the best varieties so far released by BINA.

3.3.3 Dhaka-1 (Maijchaur badam)

Dhaka-1 (Maijchaur badam) is a popular variety of groundnut was developed by the Oil Seed Research Center, Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh. The variety was released in 1976. It takes about 140-150 days to mature in rabi season and 130-140 days during khrif season. It attains a plant height of 30-35 cm at maturity. Leaf color light green, it contains 25-30 nuts $plant^{-1}$, the nuts are round, medium in size, and seeds are light brown in color. Medium 100 seeds weight is about 32-35 g with a shelling percentage is about 72-75%. The cultivar gives a pod yield of 1.8-2 t ha^{-1} of unshelled nuts.

3.4 Layout of the experiment

The experiment was laid in a split-plot design with three replications having varieties in the main plots and levels of calcium in the sub-plots. There were 15 treatment combinations. The total numbers of unit plots were 45. The size of unit plot was 3.8 m × 1.8 m. Row to row and plant to plant distances were 30 cm and 15 cm, respectively. Distances between plot to plot and replication to replication were 1m and 1.5 m, respectively.

3.5 Treatments under investigation

There were two factors in the experiment as varieties and different level of calcium managements as mentioned below:

Factors: The experiment comprised of two factors namely three groundnut varieties and five levels of Ca fertilizers

A. Factor-1:Variety (03):

a) $V_{1} =$ BARI Chinabadam-8

b) $V_{2} =$ BINA Chinabadam-4

c) $V_{3} =$ Dhaka-1 (Maijchaur badam)

B. Factor-2:Different level of Ca management (05):

a) T_1= NPKCa as basal (Control)

b) T_2= NPK as basal + 100 kg Ca ha^{-1} at flower initiation (45 DAS)

c) T_3= NPK as basal + 200 kg Ca ha^{-1} at flower initiation (45 DAS)

d) T_4= NPK as basal + 300 kg Ca ha^{-1} at flower initiation (45 DAS)

e) T_5=NPK as basal + 400 kg Ca ha^{-1} at flower initiation (45 DAS)

3.6 Treatment combination: fifteen treatment combinations

V_1T_1	V_2T_1	V_3T_1
V_1T_2	V_2T_2	V_3T_2
V_1T_3	V_2T_3	V_3T_3
V_1T_4	V_2T_4	V_3T_4
V_1T_5	V_2T_5	V_3T_5

3.7 Detail of experimental preparation

3.7.1 Land preparation

The plot selected for the experiment was opened in the first week of September, 2014 with a power tiller and was exposed to the sun for a week, after one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed from the experimental field.

3.7.2 Collection and preparation of initial soil sample

The initial soil samples were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different location covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves etc. were picked up and removed. Then the samples were air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis and subsequently analyzed from Soil Resources Development Institute (SRDI), Farmgate, Dhaka- 1215.

3.7.3 Fertilization

The recommended chemical fertilizer dose used for groundnut varieties was 13.8-35.9-49.8 kg ha^{-1} of N, P and K, respectively as common for all treatments. Gypsum was used as the source of Ca fertilizer following treatment variables. Fertilization (basal dose) was completed on 11 September, 2014. Half of urea along with other fertilizers as per treatment were applied during final land preparation as basal dose except gypsum and thoroughly mixed with soil. The rest half urea was applied at 45 days after sowing (DAS) when flowers were initiated by side dressing as per treatment. Gypsum was applied following treatment variables.

3.7.4 Seed sowing

Seeds of the 3 varieties of groundnut (BARI Chinabadam-8, BINA Chinabadam-4 and Dhaka-1) were sown at the rate of 100 kg ha^{-1} (unshelled groundnut) on 12 September, 2014. Before sowing seeds germination percentage data were recorded 87%, 94% and 90% for BARI Chinabadam-8, BINA Chinabadam-4 and Dhaka-1, respectively. The groundnuts were first unshelled and treated with Bavistin 250 WP @ 2 g kg^{-1} seed, then sown in lines maintaining a line to line distance of 30 cm and seed to seed distance of 15 cm having 2 seeds $hole^{-1}$ in the well prepared plot.

3.8 Intercultural operations

3.8.1 Irrigation and drainage

Pre-sowing irrigation was given to ensure the maximum germination percentage. Generally for upland soil 2 irrigations are required but considering the experiment field soil condition several time irrigations was given. Irrigations were given depending on the soil moisture content after soil moisture testing by hand. Before harvesting a last irrigation was given for convenience harvesting. During experimental period, there was heavy rainfall for several times. So it was essential to remove the excess water from the field.

3.8.2 Gap filling, thinning, weeding and Mulching

Gap filling and thinning were done at 20 and 23 DAS, respectively to maintain the uniformity of plant population. The crop was infested with some weeds during the early stage of crop establishment. Two hand weeding were done for every technique. After irrigation the soil surface became crusty, so there needed several mulching operation done manually to break down the hard soil crust.

3.8.3 Earthing up

Earthing up was done lightly on 22 October, 2014 which was 40 days after sowing. It was done to encourage pegging and potential pod development.

3.8.4 Plant protection measures

Bavistin 250 WP was directly applied in the row to control ant. Insecticides Admire 200 SL @ 1 ml liter^{-1} water and Ripcord 10 EC @ 1 ml litre^{-1} water were mixed and then sprayed on the leaves two times by knapsack sprayer to control jessed to protect the crop. To control foot and root rot of groundnut Bavastin 250 WP @ 1 g liter^{-1} water was sprayed to protect the crop plants.

3.8.5 Harvesting and post harvest operation

There is a thumb rule that the crop should be harvested when about 75% of the pods became mature at 110 DAS. After observing some maturity indices such as leaf became yellow, spots on the leaf, pod became hard and tough and dark tannin discoloration inside the shell crops were harvested. The Samples were collected the area of 2 m^2 of each plot avoiding the border plants. During harvest the pod contained 35% moisture. The harvested crops were tied into bundles and carried to the threshing floor. Then the pods were separated from the plants .The separated pod and the stover were sun dried by spreading those on the threshing floor. The seeds were separated from the pod and dried in the sun for 3 to 5 consecutive days for achieving safe moisture (8%) of seed.

3.9 Data collection

Experimental data were recorded from 20 DAS and continued until harvest at an interval of 20 days. Dry weights of plant were collected by destructive sampling 5 plants at different dates from the inner rows leaving border rows. The followings data were recorded during the experiment.

Crop growth characters

- Plant height (cm)
- Leaves plant^{-1}(no.)
- Dry matter weight plant^{-1}(g)
- Crop growth rate (CGR) (g m^{-2} d^{-1})
- Relative growth rate (RGR) (mg g^{-1} d^{-1})

Yield contributing characters

- Branches plant^{-1}(no.)
- Pods plant^{-1} (no.)
- Seeds pod^{-1} (no.)
- 100 seeds weight (g)

Yields

- Pod yield (t ha^{-1})
- Stover yield (t ha^{-1})
- Biological yield (t ha^{-1})
- Harvest Index (%)

3.10 Detailed Procedures of Recording Data

3.10.1 Crop growth characters

3.10.1.1 Plant height (cm)

Five plants were selected randomly from the inner row of each plot .The height of the plants were measured from the ground level to the tip of the plant at 20, 40, 60, 80, and 100 DAS. The mean value of plant height was recorded in cm.

3.10.1.2 Leaves plant^{-1}

Five plants were selected randomly from the inner row of each plot. Leaves plant^{-1} was counted from each plant sample and then averaged at 20, 40, 60, 80, and 100 DAS.

3.10.1.3 Dry matter weight plant^{-1} (g)

Five plants were collected randomly from each plot at 20, 40, 60, 80, and 100 DAS. Then the sample plant put into envelop and placed in oven maintaining 70^0 C for 72 hours for oven dry until attained a constant level and the mean of dry matter weight plant^{-1} was determined.

3.10.1.4 Crop Growth Rate (CGR)

The crop growth rate values at different growth stages were calculated using the following formula (Brown, 1994).

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

Where,

W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

GA= Ground area (m^2)

3.10.1.5 Relative Growth Rate (RGR)

The relative growth rate (RGR) values at different growth stages were calculated using the following formula (Brown, 1994).

$$RGR = \frac{Log_e W_2 - Log_e W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ d}^{-1}$$

Where,

W_1= Total dry matter production at previous sampling date

W_2= Total dry matter production at current sampling date

T_1= Date of previous sampling

T_2= Date of current sampling

Log_e= Natural logarithm

3.10.2 Yield contributing characters

3.10.2.1 Branches plant^{-1} (no.)

The branches plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of branches of all sampled plants then the average data were recorded.

3.10.2.2 Pods plant^{-1} (no.)

The pods plant^{-1} was counted from five randomly sampled plants. It was done by counting total number of pegs of all sampled plants then the average data were recorded.

3.10.2.3 Kernels pod^{-1} (no.)

Randomly 20 groundnuts were taken to determine seeds pod^{-1}. It was done by counting total number of seeds and divided by total number of sampled nuts.

3.10.2.4 1000 kernels weight (g)

From the seed stock of each plot 1000 seeds were counted and the weight was measured by an electrical balance. It was recorded in gram (g).

3.10.3 Yields

3.10.3.1 Pod yield (t ha^{-1})

Pod yield was calculated from unshelled, cleaned and well dried grains collected from the central 2 m^2 area of all 4 inner rows of the each plot (leaving two boarder rows) and expressed as t ha^{-1} on 8 % moisture basis.

3.10.3.2 Stover yield (t ha^{-1})

Stover yield was determined from the central 2 m^2 area of 4 inner rows of the each plot. After threshing, the sub sample was oven dried to a constant weight and finally converted to t ha^{-1}.

3.10.3.3 Biological yield (t ha^{-1})

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

Biological yield = Grain yield + Stover yield

3.10.3.4 Harvest Index (%)

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

Harvest Index (%) = $\frac{E \quad y \quad l\!\cdot (t\,h\ -1)}{B \quad y \quad (t\,h\ -1)} \times 100$

3.11 Statistical analysis of data

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program MSTAT-C and then mean difference were adjusted by Least Significance difference (LSD) test at 5% level of significance (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

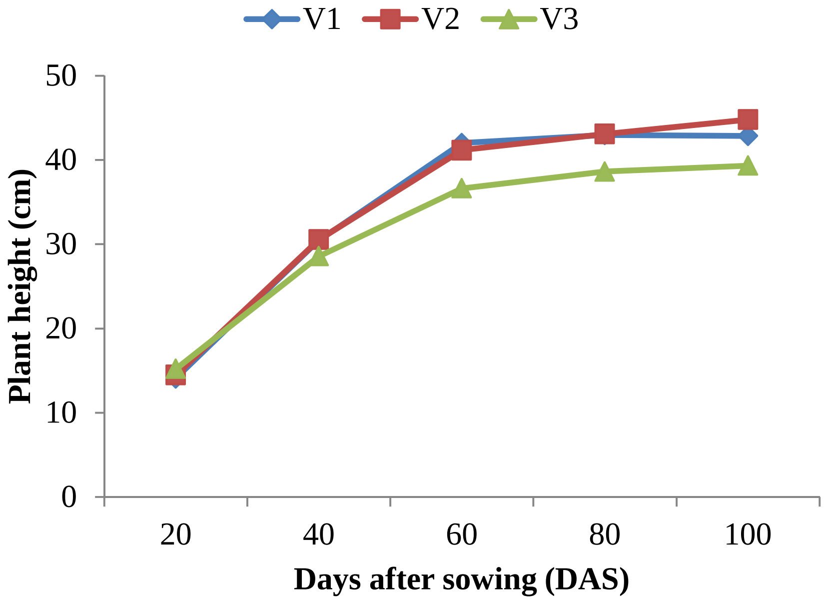
RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of calcium fertilizer management on the growth, development and yield of three groundnut varieties, cv. BARI Chinabadam-8, BINA Chinabadam-4 and Dhaka-1. Data on different growth, yield contributing characters and yield of groundnuts were recorded. The results have been presented and discussed with the help of graphs and tables and possible interpretations given under the following headings:

4.1 Plant height (cm)

4.1.1 Effect of variety

Plant height rapidly increased from 20 DAS to 60 DAS thereafter a slower rate of increase in plant height was recorded up to 80 DAS; after that a slower rate of decrease in plant height was recorded up to 100 DAS. The results showed that the effect of varietal variations on plant height was significant at 40, 80 and 100 DAS (Fig. 1). The highest plant height (30.56, 43.09 and 44.80 cm at 40, 80 and 100 DAS, respectively) was found from BINA Chinabadam-4 (V_2) which was statistically similar with BARI Chinabadam-8 (V_1) at 40 and 80 DAS. The lowest plant height (28.57, 38.62 and 39.33 cm at 40, 80 and 100 DAS, respectively) was found from Dhaka-1 (V_3). Variation of plant height might be due to the genetic variation among the varieties.

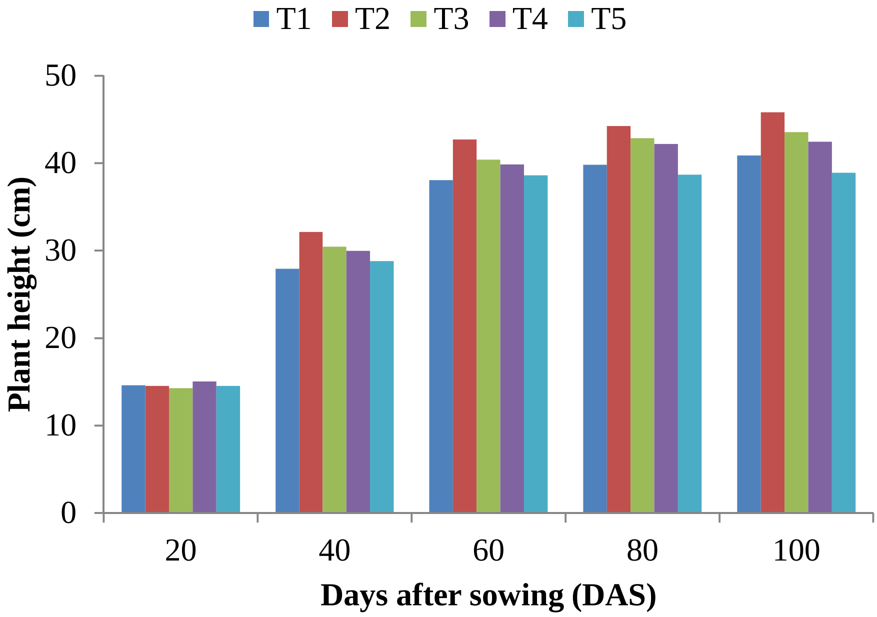


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 1. Effect of different varieties on plant height of groundnut at different days after sowing (LSD $_{(0.05)}$ = 1.71, 1.28, 5.66, 2.61 and 1.56 at 20, 40, 60, 80 and 100 DAS, respectively)

4.1.2 Effect of different application of calcium

Statistically significant variation was recorded for different application of calcium (Ca) treatments at 40 to 100 DAS (Fig. 2). The highest plant height (32.15, 42.70, 44.26 and 45.83 cm at 40, 60, 80 and 100 DAS, respectively) was found from T_2 which was statistically similar with T_3 at 40, 60, 80 and 100 DAS; T_4 at 60 and 80 DAS. The lowest plant height (27.92 and 38.06 cm at 40 and 60 DAS, respectively) was found from T_1 which was statistically similar with T_4 and T_5; (38.68 and 38.90 cm at 80 and 100 DAS, respectively) was found from T_5 which was statistically similar with T_1. The result might be due to the fact that calcium enhances the vegetative growth of groundnut plants, Rahman (2006). Similar results have been reported by Habib (2014); Kabir *et al*. (2013); Kalaiyarasan *et al*. (2003); Sharma and Yadav (1997).



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 2. Effect of calcium application on plant height of groundnut at different days after sowing (LSD $_{(0.05)}$ = 1.09, 2.08, 2.85, 3.29 and 2.95 at 20, 40, 60, 80 and 100 DAS, respectively)

4.1.3 Combined effect of variety and application of calcium

Combination of variety and level of calcium showed significant variation for plant height throughout the growing season (Table 1). At 20 DAS, highest plant height (15.61 cm) was recorded from the combination of V_3T_4 which was statistically identical with all the combinations except V_1T_5 and V_2T_3, whereas the lowest plant height (13.35 cm) was obtained from V_2T_3 which was statistically similar with all the combinations except V_3T_3, V_3T_4 and V_3T_5. At 40 and 60 DAS, highest plant height (33.12 and 45.59 cm, respectively) was recorded from the combination of V_1T_2 which was statistically identical with V_1T_3, V_1T_4, V_2T_2, V_2T_3, V_2T_4, V_2T_5 and V_3T_2 at 40 DAS; V_1T_3, V_1T_4, V_1T_5, V_2T_2, V_2T_3, V_2T_4 and V_2T_5 at 60 DAS; whereas the lowest plant height (26.47 cm at 40 DAS) was obtained from V_3T_1 which was statistically similar with V_1T_1, V_1T_5, V_2T_1, V_2T_5, V_3T_3, V_3T_4 and V_3T_5; (34.13 cm at 60 DAS) was obtained from V_3T_5 which was statistically similar with V_2T_1, V_3T_1, V_3T_3 and V_3T_4. At 80 and 100 DAS, highest plant height (46.31 and 48.28 cm, respectively) was recorded from the combination of V_2T_2 which was statistically identical with V_1T_1, V_1T_2, V_1T_3, V_1T_4, V_2T_1, V_2T_3, V_2T_4 and V_3T_2 at 80 DAS; V_1T_2, V_1T_3, V_2T_1, V_2T_3 and V_2T_4 at 100 DAS; whereas the lowest plant height (35.73 and 36.43 cm at 80 and 100 DAS, respectively) was obtained from V_3T_5 which was statistically similar with V_1T_1, V_1T_5, V_2T_5, V_3T_1, V_3T_2, V_3T_3 and V_3T_4 at 80 DAS; V_1T_1, V_1T_5, V_2T_5, V_3T_1, V_3T_3 and V_3T_4 at 100 DAS.

Table 1. Combined effect of different varieties and calcium application on plant height of groundnut at different days after sowing

Treatment combination	Plant height (cm) at different days after sowing (DAS)				
	20	40	60	80	100
V_1T_1	14.07 a-c	28.49 cd	40.02 b-d	41.40 a-d	41.37 c-f
V_1T_2	14.29 a-c	33.12 a	45.59 a	45.03 ab	46.79 ab
V_1T_3	13.94 a-c	31.00 a-c	42.09 ab	44.37 ab	43.99 a-d
V_1T_4	14.75 a-c	30.40 a-c	41.51 a-c	43.48 ab	42.45 b-e
V_1T_5	13.41 bc	29.27 b-d	40.83 a-c	40.59 b-d	39.65 d-f
V_2T_1	14.82 a-c	28.80 cd	38.39 b-e	41.47 a-c	43.33 a-d
V_2T_2	14.57 a-c	32.47 ab	43.04 ab	46.31 a	48.28 a
V_2T_3	13.35 c	31.17 a-c	42.06 ab	44.81 ab	46.64 ab
V_2T_4	14.74 a-c	30.80 a-c	41.45 a-c	43.15 ab	45.16 a-c
V_2T_5	14.96 a-c	29.57 a-d	40.90 a-c	39.71 b-d	40.61 c-f
V_3T_1	14.97 a-c	26.47 d	35.77 de	36.55 cd	37.98 ef
V_3T_2	14.73 a-c	30.87 a-c	39.48 b-d	41.43 a-d	42.43 b-e
V_3T_3	15.51 a	29.20 b-d	37.09 c-e	39.45 b-d	40.03 d-f
V_3T_4	15.61 a	28.73 cd	36.64 c-e	39.95 b-d	39.77 d-f
V_3T_5	15.25 ab	27.60 cd	34.13 e	35.73 d	36.43 f
LSD $_{(0.05)}$	1.90	3.61	4.94	5.70	5.11
CV (%)	7.71	7.17	7.34	8.14	7.16

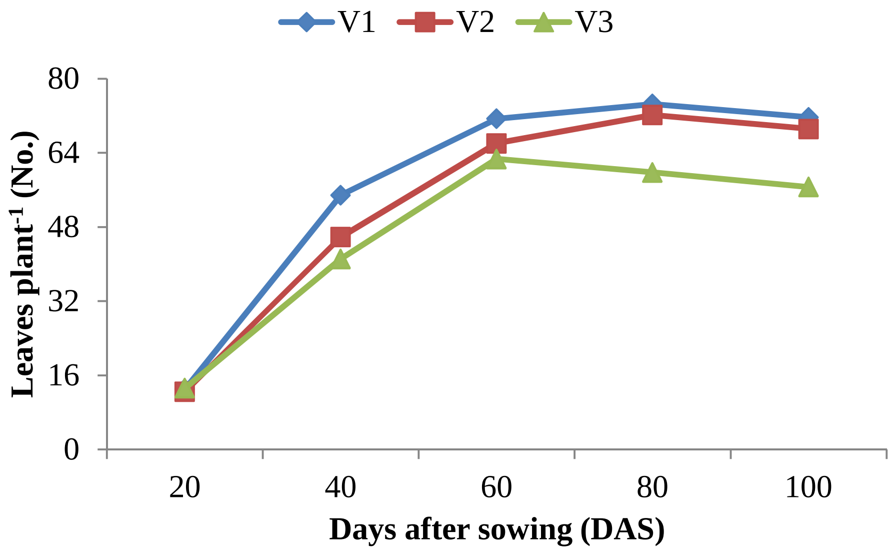
V_1= BARI Chinabadam-8,
V_2= BINA Chinabadam-4 and
V_3= Dhaka-1

T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

4.2 Leaves plant^{-1}

4.2.1 Effect of variety

Total leaves plant^{-1} rapidly increased up to 60 DAS and then slowly increased up to 80 DAS; thereafter slowly decreased up to 100 DAS among all the varieties. There was a significant difference among the varieties on leaves plant^{-1} at 20, 40, 60, 80 and 100 DAS (Fig. 3). The highest number of leaves plant^{-1} (13.23 at 20 DAS) was recorded from V_3 which was statistically similar with V_1; (54.87, 71.37, 74.53 and 71.67 at 40, 60, 80 and 100 DAS, respectively) was recorded from V_1 which was statistically similar with V_2 at 80 and 100 DAS. On the other hand, the lowest number of leaves plant^{-1} (12.50 at 20 DAS) was recorded from V_2; (41.13, 62.67, 59.79 and 56.65 at 40, 60, 80 and 100 DAS, respectively) was recorded from V_3. Number of leaves plant^{-1} might be varied due to the genetic variation among the varieties.

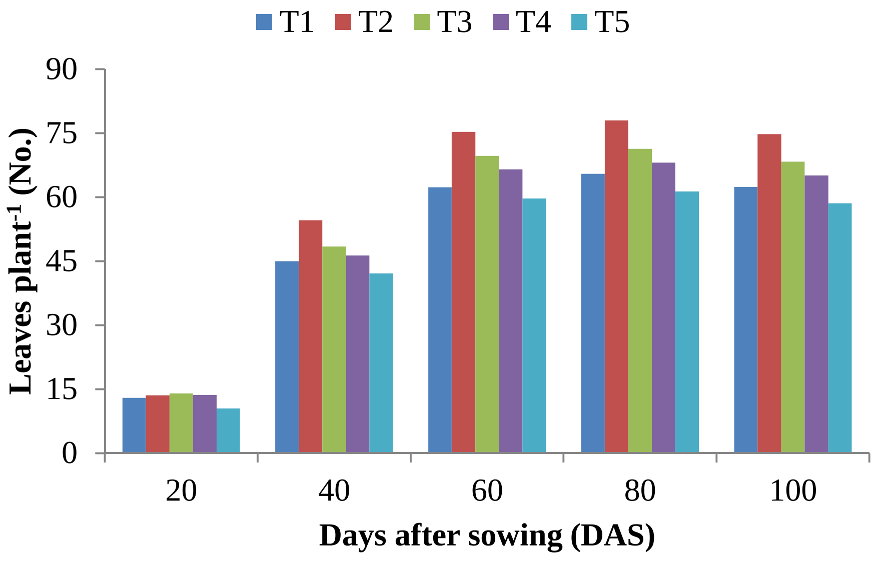


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 3. Effect of different varieties on leaves plant^{-1} of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.38, 3.54, 3.14, 7.56 and 9.00 at 20, 40, 60, 80 and 100 DAS, respectively)

4.2.2 Effect of different application of calcium

Significant variations were observed on leaves $plant^{-1}$ due to different application of calcium throughout the growing season (Fig. 4). Total leaves $plant^{-1}$ increased up to 80 DAS and then decreased up to 100 DAS among all the calcium application. The highest number of leaves $plant^{-1}$ (14.03 at 20 DAS) was found in T_3 which was statistically similar with all calcium application except T_5 and the lowest leaves $plant^{-1}$ (10.44) found from T_5. At 40, 60, 80 and 100 DAS, the highest number of leaves $plant^{-1}$ (54.56, 75.28, 77.98 and 74.77, respectively) was recorded from T_2 which was statistically similar with T_3 at 60, 80 and 100 DAS; whereas the lowest number of leaves $plant^{-1}$ (42.11, 59.72, 61.33 and 58.56, respectively) was recorded from T_5 which was statistically similar with T_1 and T_4 at 40, 60 and 80 DAS. The results agreed with the findings of Safarzadeh (2004) who stated that gypsum increased foliage yield by its application at rate of 150 kg ha^{-1}.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 4. Effect of calcium application on leaves $plant^{-1}$ of groundnut at different days after sowing (LSD $_{(0.05)}$ = 1.55, 5.25, 7.21, 7.05 and 6.49 at 20, 40, 60, 80 and 100 DAS, respectively)

4.2.3 Combined effect of variety and different application of calcium

Combined effect of variety and different application of calcium exerted significant variation on leaves plant^{-1} throughout the growing period (Table 2). The result revealed that, the highest leaves plant^{-1} (17.83 at 20 DAS) was observed from V_2T_3 which was statistically similar with V_3T_2; (67.00, 82.50, 83.50 and 80.53 at 40, 60, 80 and 100 DAS, respectively) were observed from V_1T_2 which were statistically similar with V_1T_3 and V_2T_2 at 60 DAS; V_1T_3, V_1T_4, V_2T_2, V_2T_3 and V_2T_4 at 80 and 100 DAS; whereas the lowest leaves plant^{-1} (9.00 at 20 DAS) was observed from V_2T_5 which was statistically similar with V_1T_3, V_2T_2 and V_3T_5; (35.67, 55.83, 51.17 and 48.50 at 40, 60, 80 and 100 DAS, respectively) were observed from V_3T_5 which were statistically similar with V_2T_1, V_2T_5, V_3T_1 and V_3T_4 at 40 DAS; V_1T_5, V_2T_1, V_2T_4, V_2T_5, V_3T_1, V_3T_2, V_3T_3 and V_3T_4 at 60 DAS; V_3T_1, V_3T_3 and V_3T_4 at 80 and 100 DAS.

Table 2. Combined effect of different varieties and calcium application on leaves plant^{-1} of groundnut at different days after sowing

Treatment combination	Leaves plant^{-1} (No.) at different days after sowing (DAS)				
	20	40	60	80	100
V_1T_1	12.33 cd	51.33 bc	68.33 b-d	70.50 b-e	67.83 b-d
V_1T_2	14.00 b-d	67.00 a	82.50 a	83.50 a	80.53 a
V_1T_3	11.43 d-f	52.67 b	72.17 a-c	77.00 a-c	74.63 ab
V_1T_4	14.33 bc	53.00 b	69.67 b-d	74.17 a-d	70.50 a-c
V_1T_5	13.00 b-d	50.33 bc	64.17 b-e	67.50 b-f	64.83 b-e
V_2T_1	12.00 c-e	43.33 c-f	61.00 c-e	70.50 b-e	67.00 b-d
V_2T_2	11.50 d-f	50.67 bc	75.17 ab	78.50 ab	75.17 ab
V_2T_3	17.83 a	47.00 b-e	69.83 b-d	75.00 a-c	71.67 a-c
V_2T_4	12.17 cd	48.00 b-d	65.17 b-e	71.67 a-d	69.67 a-d
V_2T_5	9.000 f	40.33 d-f	59.17 de	65.33 c-f	62.33 c-f
V_3T_1	14.50 bc	40.33 d-f	57.67 de	55.33 fg	52.33 fg
V_3T_2	15.17 ab	46.00 b-e	68.17 b-e	71.93 a-d	68.60 b-d
V_3T_3	12.83 b-d	45.67 b-e	67.00 b-e	62.00 d-g	58.67 d-g
V_3T_4	14.33 bc	38.00 ef	64.67 b-e	58.50 e-g	55.17 e-g
V_3T_5	9.333 ef	35.67 f	55.83 e	51.17 g	48.50 g
LSD $_{(0.05)}$	2.69	9.09	12.49	12.21	11.24
CV (%)	12.34	11.4	11.11	10.53	10.13

V_1= BARI Chinabadam-8,
V_2= BINA Chinabadam-4 and
V_3= Dhaka-1

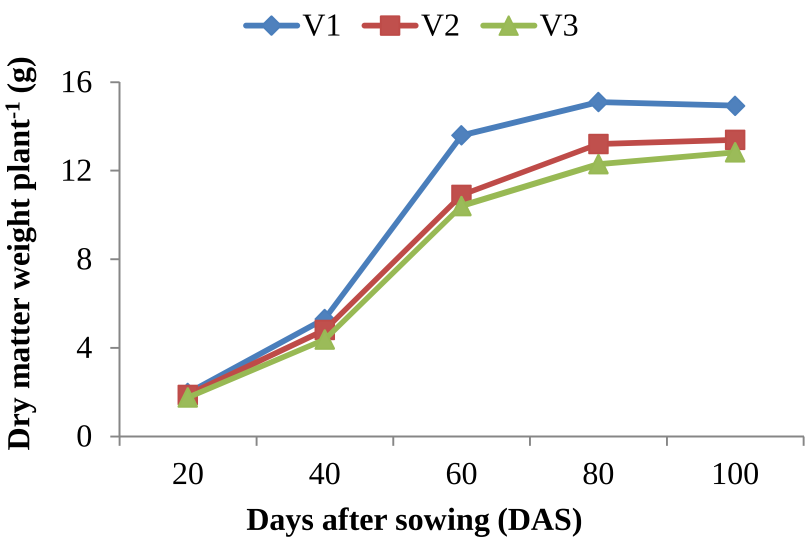
T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

4.3 Above ground dry matter weight plant^{-1} (g)

Irrespective of varietal and calcium application differences, the above ground dry matter (AGDM) production was very slow up to 40 DAS there after it was picked at 60 DAS then slowly reduced up to 100 DAS which was a typical trend of dry matter production.

4.3.1 Effect of variety

Significant variation of dry matter weight plant^{-1} was found due to varietal variation throughout the growing period (Fig.5). The highest dry matter weight plant^{-1} (1.97, 5.31, 13.60, 15.10 and 14.94 g at 20, 40, 60, 80 and 100 DAS, respectively) was recorded from V_1 which was statistically similar with V_2 at 20, 40 and 100 DAS. On the other hand, the lowest dry matter weight plant^{-1} (1.76, 4.38, 10.41, 12.30 and 12.83 g at 20, 40, 60, 80 and 100 DAS, respectively) was recorded from V_3 which was statistically similar with V_2 at 40, 60, 80 and 100 DAS.

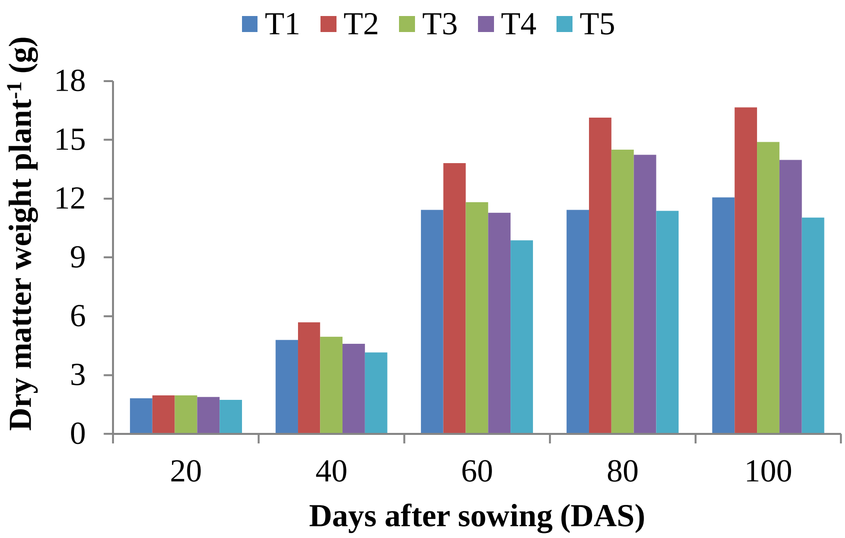


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 5. Effect of different varieties on dry matter weight plant^{-1} of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.10, 0.56, 1.22, 1.72 and 1.77 at 20, 40, 60, 80 and 100 DAS, respectively)

4.3.2 Effect of different application of calcium

Dry matter weight plant^{-1} was significantly affected by different level of calcium throughout the growing period (Fig. 6). Dry matter weight plant^{-1} increased rapidly from 20 to 60 DAS and then slowly increased up to 100 DAS. The highest dry matter weight plant^{-1} (1.97 g at 20 DAS) was found in T_3 which was statistically similar with all other calcium application except T_5 and the lowest dry matter weight plant^{-1} (1.73) found from T_5 which was statistically similar with T_1 and T_4. At 40, 60, 80 and 100 DAS, the highest dry matter weight plant^{-1} (5.69, 13.81, 16.14 and 16.65 g, respectively) was recorded from T_2 whereas the lowest dry matter weight plant^{-1} (4.153, 9.88, 11.38 and 11.03 g, respectively) was recorded from T_5 which was statistically similar with T_4 at 40 DAS; T_1 at 80 and 100 DAS. Habib (2014) and Meena *et al.* (2007) reported that lack of calcium in the root zone resulted in a significant decrease in top growth. Moreover excess Ca reduce the uptake of P and K which are essential elements for plant growth thus ultimately reduction of plant growth and low dry matter production.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 6. Effect of calcium application on dry matter weight plant^{-1} of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.20, 0.43, 1.23, 0.89 and 1.10 at 20, 40, 60, 80 and 100 DAS, respectively)

4.3.3 Combined effect of variety and different application of calcium

Dry matter weight differed significantly for variation of the treatment combinations throughout the growing period (Table 3). The result revealed that, the highest dry matter weight plant^{-1} (2.28 g at 20 DAS) was observed from V_1T_4

which was statistically similar with V_1T_1, V_2T_2, V_2T_3, V_2T_5, V_3T_2 and V_3T_3; (6.07, 15.21, 18.05 and 17.41 g at 40, 60, 80 and 100 DAS, respectively) were observed from V_1T_2 which were statistically similar with V_1T_1, V_2T_2 and V_3T_2 at 40 DAS; V_1T_1, V_1T_4 and V_2T_2 at 60 DAS; V_1T_3, V_2T_2 and V_3T_2 at 100 DAS; whereas the lowest dry matter weight plant^{-1} (1.52, 3.12, 7.50 and 9.30 g at 20, 40, 60 and 100 DAS, respectively) was observed from V_3T_5 which was statistically similar with V_1T_2, V_1T_3, V_1T_5, V_2T_1, V_2T_4, V_3T_1 and V_3T_4 at 20 DAS; V_2T_1, V_2T_5 and V_3T_4 at 60 DAS; V_2T_5 and V_3T_1 at 100 DAS; (9.87 g at 80 DAS) was observed from V_3T_1 which was statistically similar with V_2T_1, V_2T_5 and V_3T_5.

Table 3. Combined effect of different varieties and calcium application on dry matter weight plant^{-1} of groundnut at different days after sowing

Treatment combination	Dry matter weight plant^{-1} (g) at different days after sowing (DAS)				
	20	40	60	80	100
V_1T_1	2.20 ab	5.40 a-c	13.94 ab	13.31 ef	13.68 e-g
V_1T_2	1.73 d-f	6.07 a	15.21 a	18.05 a	17.41 a
V_1T_3	1.86 b-f	5.25 b-d	12.80 b-e	15.19 b-d	15.64 a-d
V_1T_4	2.28 a	4.95 b-e	13.38 a-c	15.94 bc	15.29 b-e
V_1T_5	1.75 c-f	4.90 b-f	12.67 b-e	13.00 f	12.67 g-i
V_2T_1	1.57 f	4.76 c-f	9.50 fg	11.10 g	11.69 hi
V_2T_2	2.07 a-d	5.62 ab	13.19 a-d	16.33 b	15.96 a-c
V_2T_3	2.10 a-c	4.70 c-f	11.22 d-f	14.76 c-e	14.38 c-g
V_2T_4	1.74 d-f	4.53 d-f	11.18 d-f	13.27 ef	13.81 d-g
V_2T_5	1.93 a-e	4.44 ef	9.47 fg	10.58 g	11.13 h-j
V_3T_1	1.67 ef	4.20 f	10.87 ef	9.87 g	10.80 ij
V_3T_2	2.08 a-d	5.40 a-c	13.03 b-d	14.03 d-f	16.56 ab
V_3T_3	1.93 a-e	4.91 b-f	11.41 c-f	13.55 ef	14.64 c-f
V_3T_4	1.61 ef	4.27 ef	9.270 fg	13.47 ef	12.84 f-h
V_3T_5	1.52 f	3.12 g	7.497 g	10.55 g	9.297 j
LSD $_{(0.05)}$	0.35	0.75	2.14	1.53	1.90
CV (%)	11.24	9.24	10.9	6.72	8.21

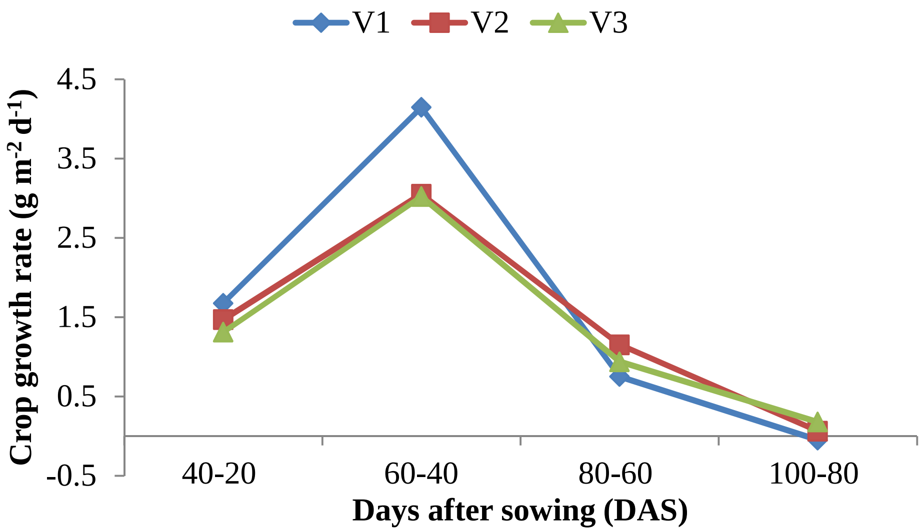
V_1= BARI Chinabadam-8,
V_2= BINA Chinabadam-4 and
V_3= Dhaka-1

T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

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

4.4.1 Effect of variety

Crop growth rate is a measure of the increase in size, mass or crops over a period of time. Significant variation on Crop growth rate (CGR) was found due to varietal variation at 40-20, 60-40, 80-60 and 100-80 DAS (Fig. 7). The maximum CGR (1.67 and 4.14 g m^{-2} d^{-1} at 40-20 and 60-40 DAS, respectively) was recorded from V_1; (1.15 g m^{-2} d^{-1} at 80-60 DAS) was recorded from V_2; (0.17 g m^{-2} d^{-1} at 100-80 DAS) was recorded from V_3; whereas the minimum CGR (1.31 and 3.01 g m^{-2} d^{-1} at 40-20 and 60-40 DAS, respectively) was recorded from V_3; (0.75 g m^{-2} d^{-1} at 80-60 DAS) was recorded from V_1; (-0.05 g m^{-2} d^{-1} at 100-80 DAS) was recorded from V_1 which shown identity with V_2 at 40-20 and 60-40 DAS.

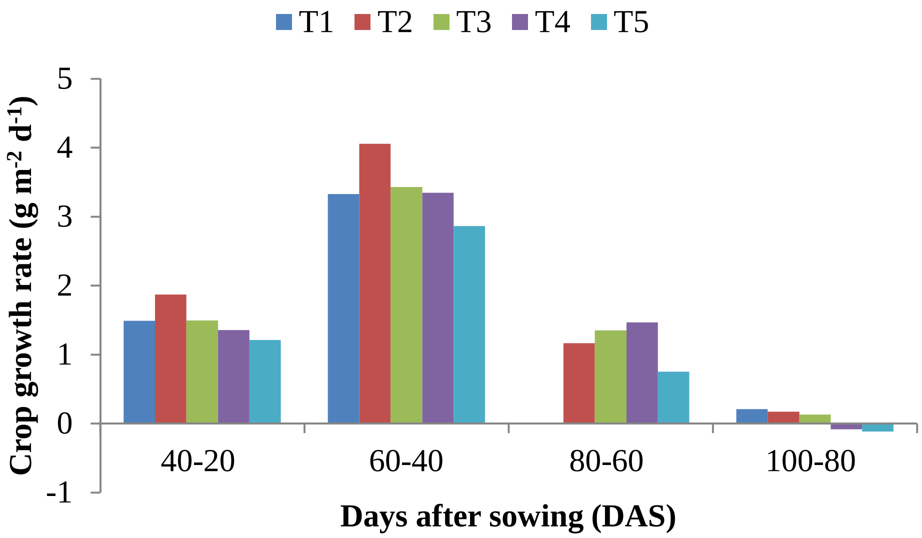


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 7. Effect of different varieties on crop growth rate of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.18, 0.22, 0.15 and 0.06 at 40-20, 60-40, 80-60 and 100-80 DAS, respectively)

4.4.2 Effect of different application of calcium

CRG increased slowly at the early growth stage and reached pick at 60-40 DAS and slowly declined for most of the treatments, even negative score was recorded on some treatments up to 100 DAS. Crop growth rate showed significant variation among the different calcium application at 40-20, 60-40, 80-60 and 100-80 DAS (Fig. 8). The maximum CGR (1.87 and 4.06 g m^{-2} d^{-1} at 40-20 and 60-40 DAS, respectively) was recorded from T_2; (1.47 g m^{-2} d^{-1} at 80-60 DAS) was recorded from T_4; (0.21 g m^{-2} d^{-1} at 100-80 DAS) was recorded from T_1 which was statistically similar with T_2; whereas the minimum CGR (1.36 and -0.09 g m^{-2} d^{-1} at 40-20 and 100-80 DAS, respectively) was recorded from T_4; (2.86 and 0.75 g m^{-2} d^{-1} at 60-40 and 80-60 DAS, respectively) was recorded from T_5. Similar results have been reported by Habib (2014) and Kabir *et al*. (2013).



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 8. Effect of calcium application on crop growth rate of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.13, 0.35, 0.09 and 0.04 at 40-20, 60-40, 80-60 and 100-80, respectively)

4.4.3 Combined effect of variety and different application of calcium

CGR Showed significant difference among different variety and calcium application combinations (Table 4). The highest CGR (2.17 and 4.57 g m^{-2} d^{-1} at 40-20 and 60-40 DAS, respectively) were observed from the combined effect of V_1T_2 which were statistically identical with V_1T_1 and V_1T_4 at 60-40 DAS; (2.07 g m^{-2} d^{-1} at 80-60 DAS) was recorded from V_3T_4; (0.84 g m^{-2} d^{-1} at 100-80 DAS) was recorded from V_3T_2; whereas the minimum CGR (0.80 and

2.19 g m^{-2} d^{-1} at 40-20 and 60-40 DAS, respectively) was recorded from V_3T_5 which was statistically similar with V_2T_1, V_2T_5 and V_3T_4 at 60-40 DAS; (-0.49 g m^{-2} d^{-1} at 80-60 DAS) was recorded from V_3T_1; (-0.42 g m^{-2} d^{-1} at 100-80 DAS) was recorded from V_3T_5.

Table 4. Combined effect of different varieties and calcium application on crop growth rate of groundnut at different days after sowing

Treatment combination	Crop growth rate (g m^{-2} d^{-1}) at different days after sowing (DAS)			
	40-20	60-40	80-60	100-80
V_1T_1	1.60 b-d	4.27 ab	-0.32 j	0.13 c
V_1T_2	2.17 a	4.57 a	1.42 cd	-0.21 e
V_1T_3	1.69 bc	3.78 b-d	1.20 ef	0.15 c
V_1T_4	1.34 ef	4.21 ab	1.28 de	-0.21 e
V_1T_5	1.58 b-d	3.89 bc	0.17 i	-0.11 d
V_2T_1	1.60 b-d	2.37 e	0.80 g	0.20 c
V_2T_2	1.78 b	3.78 bcd	1.57 c	-0.12 d
V_2T_3	1.31 ef	3.26 d	1.77 b	-0.12 d
V_2T_4	1.40 d-f	3.32 cd	1.05 f	0.18 c
V_2T_5	1.26 f	2.52 e	0.56 h	0.18 c
V_3T_1	1.27 f	3.34 cd	-0.50 k	0.31 b
V_3T_2	1.66 bc	3.82 b-d	0.50 h	0.84 a
V_3T_3	1.49 c-e	3.25 d	1.08 f	0.36 b
V_3T_4	1.33 ef	2.50 e	2.07 a	-0.21 e
V_3T_5	0.80 g	2.19 e	1.53 c	-0.42 f
$LSD_{(0.05)}$	0.22	0.61	0.16	0.08
CV (%)	8.72	10.6	10.03	69.84

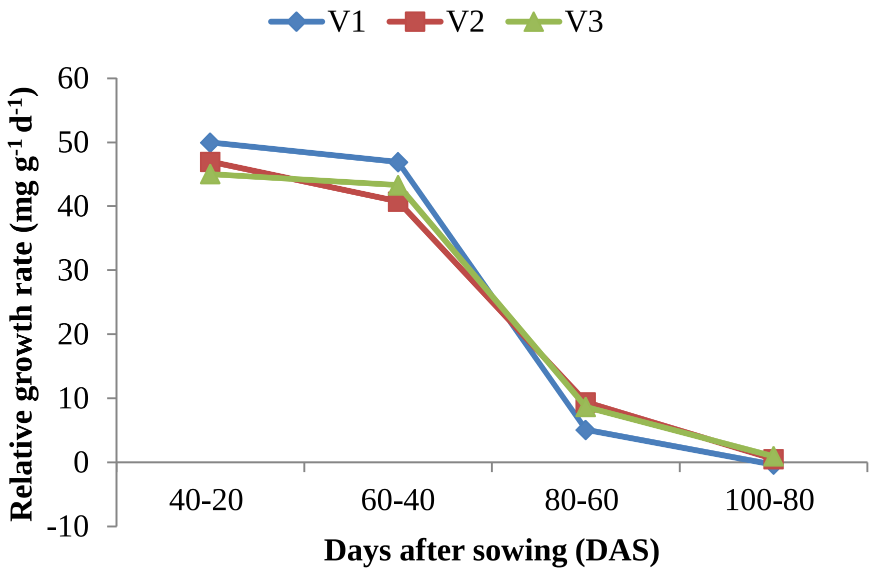
V_1= BARI Chinabadam-8,
V_2= BINA Chinabadam-4 and
V_3= Dhaka-1

T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

4.5 Relative growth rate (RGR)

4.5.1 Effect of variety

Relative growth rate is the increase of materials per unit of plant materials per unit of time. RGR of groundnut plant was varied significantly due to variety shown in Figure 9. It was revealed that the highest RGR (49.97, 46.91, 9.40 and 0.96 mg $g^{-1}d^{-1}$ at 40-20, 60-40, 80-60 and 100-80 DAS, respectively) was observed from variety V_1, V_1, V_2 and V_3, respectively which was statistically similar with V_2 at 40-20 DAS; V_3 at 60-40 DAS and 80-60 DAS. Whereas the lowest RGR (45.05, 40.76, 5.08 and -0.34 mg $g^{-1}d^{-1}$ at 40-20, 60-40, 80-60 and 100-80 DAS, respectively) were measured from variety $V_{3,}$ V_2, V_1 and V_1, respectively which was statistically similar with V_2 at 40-20 DAS; V_3 at 60-40 DAS.

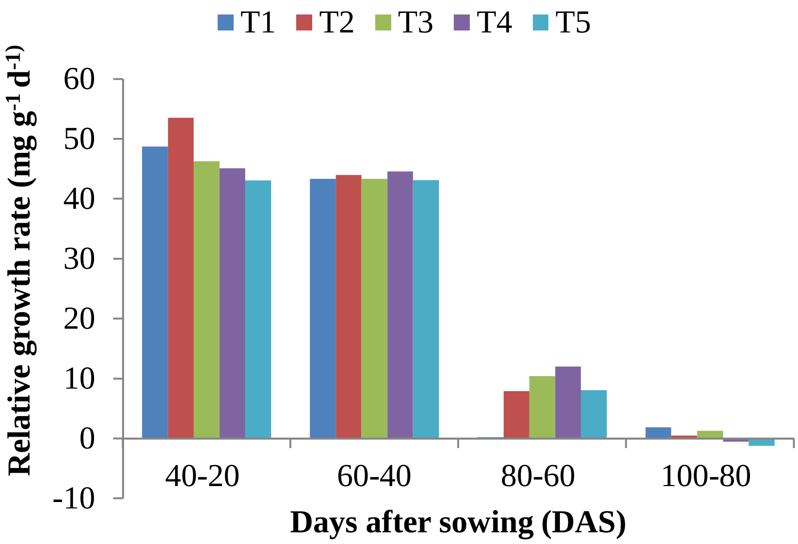


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 9. Effect of different varieties on relative growth rate of groundnut at different days after sowing (LSD $_{(0.05)}$ = 4.00, 4.74, 1.46 and 0.07 at 40-20, 60-40, 80-60 and 100-80 DAS, respectively)

4.5.2 Effect of different application of calcium

Relative growth rate was also significantly affected by different application of calcium over time (Fig. 10). Result showed that the highest RGR (53.51, 44.58, 11.99 and 1.88 mg g^{-1} d^{-1} at 40-20, 60-40, 80-60 and 100-80 DAS, respectively) were gained from treatments T_1, T_4, T_4 and T_1, respectively which was statistically similar with all other treatments at 60-40 DAS. Whereas the lowest RGR (43.05, 43.13, 0.23 and -1.23 mg $g^{-1}d^{-1}$ at 40-20, 60-40, 80-60 and 100-80 DAS, respectively) were attained from T_5, T_5, T_1 and T_5, respectively which was statistically similar with T_3 and T_4 at 40-20 DAS; similar with all other treatments at 60-40 DAS.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 10. Effect of calcium application on relative growth rate of groundnut at different days after sowing (LSD $_{(0.05)}$ = 4.40, 4.95, 0.96 and 0.04 at 40-20, 60-40, 80-60 and 100-80 DAS, respectively)

4.5.3 Combined effect of variety and different application of calcium

RGR Showed significant difference among different variety and calcium application combinations (Table 5). The highest RGR (62.64, 49.64, 18.61 and 3.85 mg g^{-1} d^{-1} at 40-20, 60-40, 80-60 and 100-80 DAS, respectively) were gained from the combined effect of V_1T_2, V_1T_4, V_3T_4 and V_3T_3, respectively which was statistically similar with V_2T_1 at 40-20 DAS; all other combinations except V_2T_1, V_2T_5 and V_3T_4 at 60-40 DAS. Whereas the lowest RGR (35.77, 34.83, -4.75 and -4.10 mg g^{-1} d^{-1} at 40-20, 60-40, 80-60 and 100-80 DAS, respectively) were attained from the combinations of V_3T_5, V_2T_1, V_3T_1 and V_3T_5, respectively which was statistically similar with V_1T_4, V_2T_3 and V_2T_5 at 40-20 DAS; V_2T_2, V_2T_3, V_2T_5, V_3T_3 and V_3T_4 at 60-40 DAS.

Table 5. Combined effect of different varieties and calcium application on relative growth rate of groundnut at different days after sowing

Treatment combination	Relative growth rate (mg g^{-1} d^{-1}) at different days after sowing (DAS)			
	40-20	60-40	80-60	100-80
V_1T_1	44.84 c-f	47.49 a	-2.38 h	0.96 f
V_1T_2	62.64 a	45.77 a-c	8.82 d	-1.29 i
V_1T_3	51.83 bc	44.43 a-c	8.76 d	0.92 f
V_1T_4	38.95 fg	49.64 a	8.67 d	-1.35 i
V_1T_5	51.56 bc	47.24 ab	1.54 g	-0.95 h
V_2T_1	55.30 ab	34.83 d	7.82 d	1.63 d
V_2T_2	50.06 bc	42.27 a-d	10.9 c	-0.79 g
V_2T_3	40.20 e-g	43.38 a-d	14.00 b	-0.88 h
V_2T_4	47.47 c-e	45.34 a-c	8.68 d	1.34 e
V_2T_5	41.83 d-g	38.00 cd	5.59 e	1.37 e
V_3T_1	45.99 c-f	47.60 a	-4.75 i	3.06 c
V_3T_2	47.82 b-e	43.89 a-c	3.88 f	3.55 b
V_3T_3	46.83 c-e	42.14 a-d	8.55 d	3.85 a
V_3T_4	48.85 b-d	38.76 b-d	18.61 a	-1.54 j
V_3T_5	35.77 g	44.15 a-c	16.98 a	-4.10 k
$LSD_{(0.05)}$	7.63	8.58	1.67	0.08
CV (%)	9.56	11.66	12.84	12.07

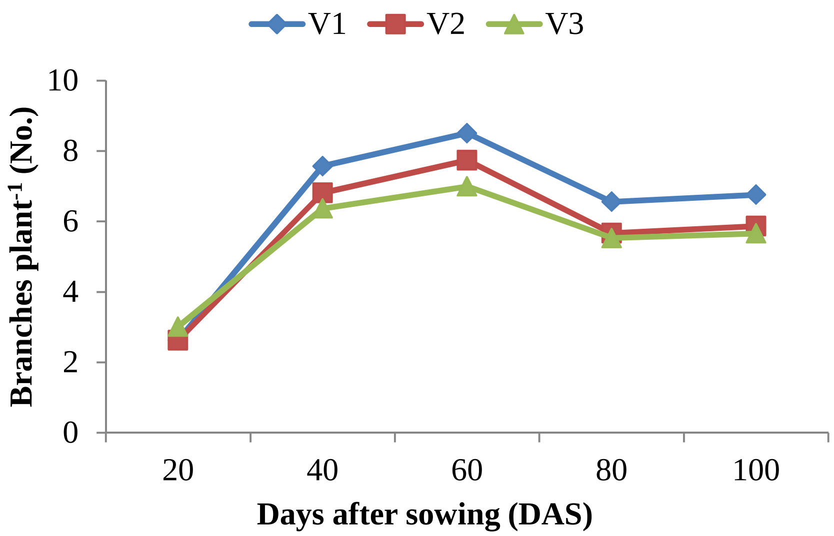
V_1= BARI Chinabadam-8,
V_2= BINA Chinabadam-4 and
V_3= Dhaka-1

T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK AS BASAL as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

4.6 Branches plant^{-1} (no.)

4.6.1 Effect of variety

Significant variation of branches plant^{-1} was found due to varietal variation throughout the growing period (Fig. 11). The highest number of branches plant^{-1} (3.01 at 20 DAS) was recorded from V_3; (7.57, 8.51, 6.56 and 6.76 at 40, 60, 80 and 100 DAS, respectively) was recorded from V_1 which was statistically similar with V_2 at 60 DAS. On the other hand, the lowest number of branches plant^{-1} (2.63 at 20 DAS) was recorded from V_1 and V_2; (6.37, 6.99, 5.53 and 5.66 at 40, 60, 80 and 100 DAS, respectively) was recorded from V_3 which was statistically similar with V_2 at 60, 80 and 100 DAS.

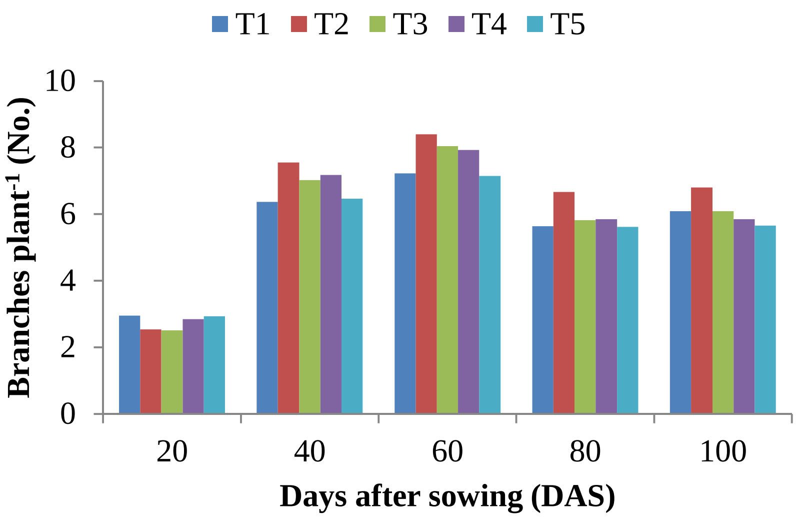


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 11. Effect of different varieties on branches plant^{-1} of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.16, 0.28, 1.37, 0.57 and 0.50 at 20, 40, 60, 80 and 100 DAS, respectively)

4.6.2 Effect of different application of calcium

Different application of calcium significantly influenced branches plant^{-1} throughout the growing period (Fig. 12). The highest number of branches plant^{-1} (2.96 at 20 DAS) was found in T_1 which was statistically similar with T_4 and T_5 and the lowest branches plant^{-1} (2.51) found from T_3 which was statistically similar with T_2. At 40, 60, 80 and 100 DAS, the highest number of branches plant^{-1} (7.56, 8.40, 6.67 and 6.80, respectively) was recorded from T_2 which was statistically similar with T_3 and T_4 at 40 and 60 DAS; whereas the lowest number of branches plant^{-1} (6.37 at 40 DAS) was recorded from T_1 which was statistically similar with T_3 and T_4; (7.14, 5.62 and 5.66 at 60, 80 and 100 DAS, respectively) was recorded from T_5 which was statistically similar with T_1 and T_4 at 60 DAS; all calcium application except T_2 at 80 and 100 DAS. The results agreed with the findings of Habib (2014); Salke *et al.* (2010); Rahman (2006) and Sharma and Yaday (1997) who observed that the application of calcium increased branches.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 12. Effect of calcium application on branches plant^{-1} of groundnut at different days after sowing (LSD $_{(0.05)}$ = 0.32, 0.72, 0.79, 0.58 and 0.64 at 20, 40, 60, 80 and 100 DAS, respectively)

4.6.3 Combined effect of variety and different application of calcium

Combination between variety and different application of calcium exerted significant effect on the branches plant^{-1} throughout the growing period (Table 6). The result revealed that, the highest branches plant^{-1} (3.53 at 20 DAS) was observed from V_3T_5 which was statistically similar with V_1T_1, V_2T_1 and V_3T_4; (8.40, 9.07, 7.33 and 7.53 at 40, 60, 80 and 100 DAS, respectively) were observed from V_1T_2 which were statistically similar with V_1T_3, V_1T_4 and V_2T_2 at 40 and 80 DAS; all other combinations except V_2T_1, V_2T_5, V_3T_1, V_3T_3, V_3T_4 and V_3T_5 at 60 DAS; V_1T_1, V_1T_3 and V_2T_2 at 100 DAS; whereas the lowest branches plant^{-1} (2.07 at 20 DAS) was observed from V_2T_3 which was statistically similar with V_1T_2, V_1T_5 and V_2T_4; (5.83 and 5.17 at 40 and 80 DAS, respectively) were observed from V_3T_1 which were statistically similar with all other combinations except V_1T_2, V_1T_3, V_1T_4 and V_2T_2 at 40 and 80 DAS; (6.13 and 5.17 at 60 and 100 DAS, respectively) were observed from V_3T_5 which were statistically similar with V_2T_1, V_2T_5, V_3T_1, V_3T_3 and V_3T_4 at 60 DAS; V_2T_1, V_2T_3, V_2T_4, V_2T_5, V_3T_1, V_3T_2, V_3T_3 and V_3T_4 at 100 DAS.

Table 6. Combined effect of different varieties and calcium application on branches plant^{-1} of groundnut at different days after sowing

Treatment combination	Branches plant^{-1} (No.) at different days after sowing (DAS)				
	20	40	60	80	100
V_1T_1	3.00 a-d	7.07 b-d	8.01 a-d	6.27 b-e	6.87 ab
V_1T_2	2.27 ef	8.40 a	9.07 a	7.33 a	7.53 a
V_1T_3	2.67 c-e	7.73 ab	8.60 ab	6.47 a-d	6.80 ab
V_1T_4	2.73 c-e	7.73 ab	8.47 a-c	6.60 a-c	6.33 bc
V_1T_5	2.47 d-f	6.93 b-d	8.40 a-c	6.13 b-f	6.27 bc
V_2T_1	3.13 a-c	6.20 cd	7.13 c-f	5.47 d-f	5.93 b-d
V_2T_2	2.67 c-e	7.33 a-c	8.40 a-c	6.80 ab	6.87 ab
V_2T_3	2.07 f	7.00 b-d	8.27 a-d	5.40 ef	5.67 cd
V_2T_4	2.47 d-f	6.93 b-d	8.00 a-d	5.40 ef	5.33 cd
V_2T_5	2.80 b-e	6.60 b-d	6.90 def	5.27 ef	5.53 cd
V_3T_1	2.73 c-e	5.83 d	6.53 ef	5.17 f	5.47 cd
V_3T_2	2.67 c-e	6.93 b-d	7.73 a-e	5.87 b-f	6.00 b-d
V_3T_3	2.80 b-e	6.33 cd	7.27 b-f	5.60 c-f	5.80 b-d
V_3T_4	3.33 ab	6.87 b-d	7.31 b-f	5.53 d-f	5.87 b-d
V_3T_5	3.53 a	5.87 d	6.13 f	5.47 d-f	5.17 d
LSD $_{(0.05)}$	0.56	1.25	1.37	1.01	1.10
CV (%)	11.96	10.71	10.49	10.11	10.7

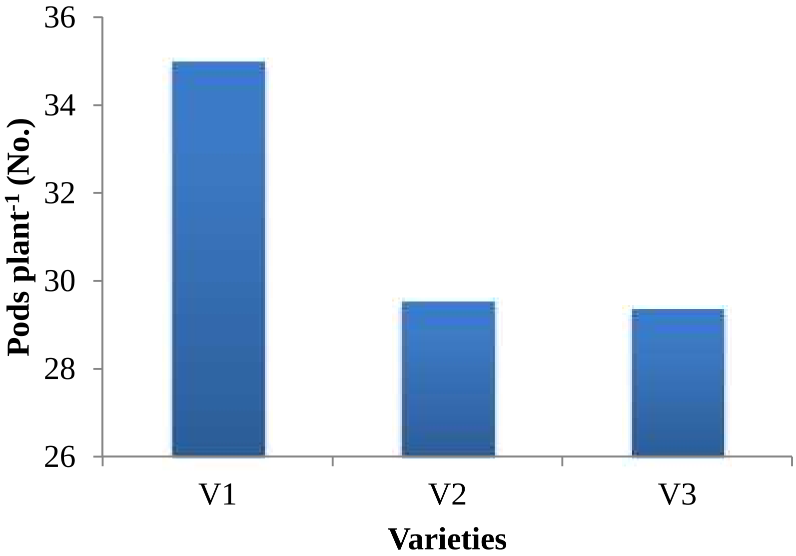
V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

4.7 Pods plant^{-1} (no.)

4.7.1 Effect of variety

Significant variation on pods plant^{-1} was found due to varietal variation (Fig. 13). The highest pods plant^{-1} (34.99) was recorded from V_1 while the lowest pods plant^{-1} (29.35) was obtained from V_3 which was statistically similar with V_2. BARI Chinabadam-8 (V_1) gave 19.22% higher pods plant^{-1} over the Dhaka-1 (V_3). The results agreed with the findings of Pathak (2010) but Habib (2014) reported that Dhaka-1 gave the highest (15.47) pods plant^{-1} which was statistically similar with BARI Chinabadam-8.



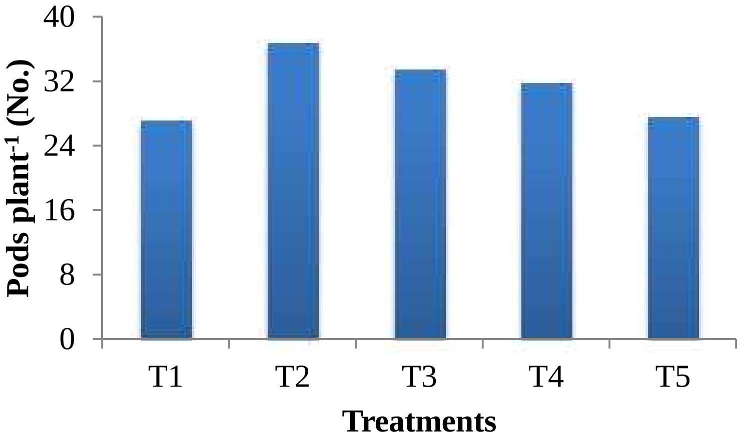
V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 13. Effect of different varieties on pods plant^{-1} of groundnut (LSD $_{(0.05)}$ = 3.11)

4.7.2 Effect of different application of calcium

Different application of calcium had significant effect on pods plant^{-1} (Fig. 14). The highest pods plant^{-1} (36.70) was recorded from T_2 while the lowest pods plant^{-1} (27.07) was obtained from T_1 which was statistically similar with T_5. T_2 gave 35.57% higher pods plant^{-1} over treatment T_1. The indeterminate nature of peanut could play a role in calcium availability to pods set later in the season. Boote (1982) showed that peanut has exponential growth in fruit load from 49-

89 days after planting (DAP) and later it slows. Kvien *et al*. (1988) showed that the peak time for calcium absorption by the developing pod is up to 60 days after the gynophores (pegs) enters the soil. Hence the initial fruit load receives all maternal assimilates and enough calcium to progress toward maturity. Kamara *et al*. (2011) also reported that the highest filled pods were obtained in the treatment with 100 kg Ca ha^{-1}. Increasing the rate of calcium from 100 kg ha^{-1} to 200 kg ha^{-1} did not bring significant increase in filled pods plant^{-1}. Hall, (1975) investigated that calcium markedly improved the filling of the pods. The only element having a yield effect on its own was calcium, yields being at least doubled by its use. Only a fraction of the total pegs in any case developed into fruit. The lack of calcium in the pegging area resulted in the pegs forming very few fruit. The fact that calcium was supplied to the roots all the time it was withheld from the pegs apparently indicates that this element cannot be taken up through the roots and translocated to the developing fruit sufficiently to supply the needs in that region. Thus applying 100 ka ha^{-1} Ca at 45 days after sowing was most effective for fruit development. Similar findings were reported by (Kabir *et al*., 2013).



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 14. Effect of calcium application on pods plant^{-1} of groundnut (LSD $_{(0.05)}$ = 3.02)

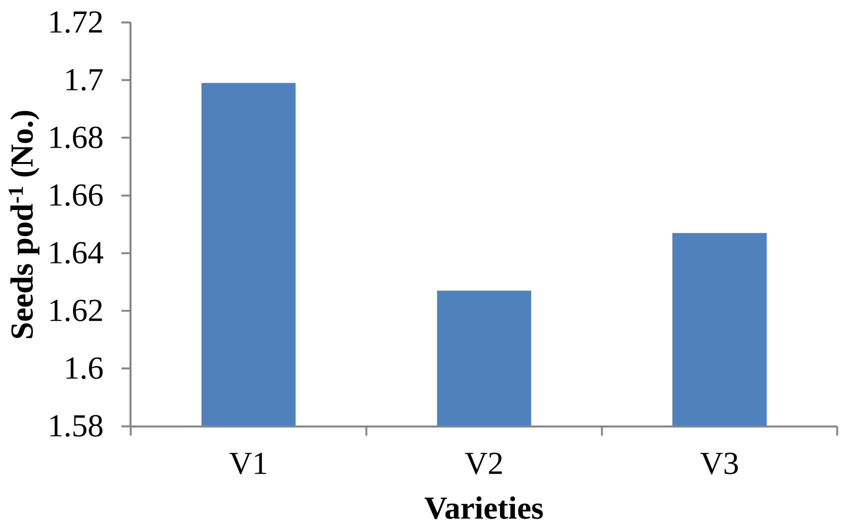
4.7.3 Combined effect of variety and different application of calcium

Combined effect of variety and different application of calcium significantly influenced pods plant^{-1} (Table 7). The highest pods plant^{-1} (39.20) was obtained from the combined effect of V_1T_2 which was statistically similar with V_1T_3, V_1T_4, V_2T_2 and V_3T_2. The lowest pods plant^{-1} (24.02) was found from the combined effect of V_3T_5 which was statistically similar with V_2T_1, V_2T_4, V_2T_5 and V_3T_1.

4.8 Seeds pod^{-1} (no.)

4.8.1 Effect of variety

Non-significant variation was found on seeds pod^{-1} due to varietal variations in groundnut (Fig. 15). The highest (1.70) and lowest (1.63) seeds pod^{-1} was gained from V_1 and V_2, respectively.

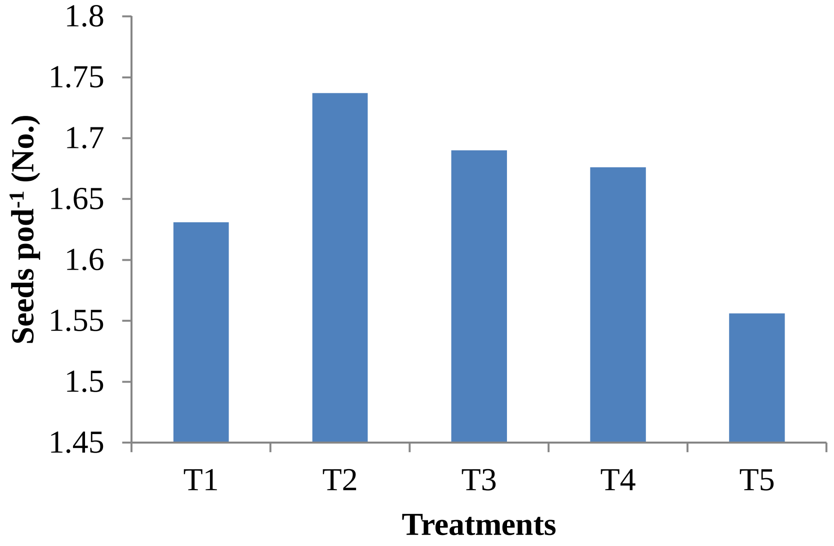


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 15. Effect of different varieties on seeds pod^{-1} of groundnut (LSD $_{(0.05)}$ = 0.12)

4.8.2 Effect of different application of calcium

Significant variation was observed on seeds pod^{-1} due to different calcium application on groundnut (Fig. 16). Among the calcium application, the highest seeds pod^{-1} (1.74) was recorded from T_2 which was statistically similar with all other treatments except T_5. The lowest seeds pod^{-1} (1.56) was recorded from T_5 which was statistically similar with T_1. It is possible that calcium may exert an early effect on peanut reproduction by increasing the successful fertilization of the distal ovule, thereby increasing the two-segmented pods carrying two seeds. Additionally, distal ovules can abort even if properly fertilized due to the competition of nutrients Habib (2014) and (Teixeira *et al*., 2006).



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 16. Effect of calcium application on seeds pod^{-1} of groundnut (LSD $_{(0.05)}$ = 0.12)

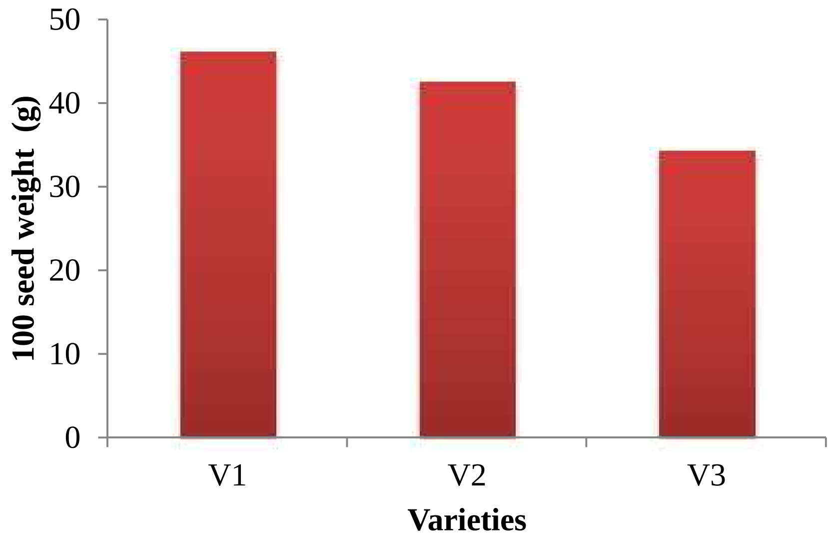
4.8.3 Combined effect of variety and different application of calcium

Combined effect of variety and different application of calcium responded differently in terms of seeds pod^{-1} (Table 7). The highest (1.76) seeds pod^{-1} was obtained from the combined effect of V_1T_2 which was statistically similar with all other treatments except V_2T_5 and V_3T_5. The lowest seeds pod^{-1} (1.51) was obtained from the combined effect of V_2T_5 which was statistically similar with all other treatments except V_1T_2, V_1T_3 and V_2T_2.

4.9 100 seed weight (g)

4.9.1 Effect of variety

The 100 seed weight showed significant variation among the different varieties (Fig. 17). The highest 100 seed weight (46.13 g) was found in V_1 and the lowest 100 seed weight (34.27 g) was obtained from V_3.

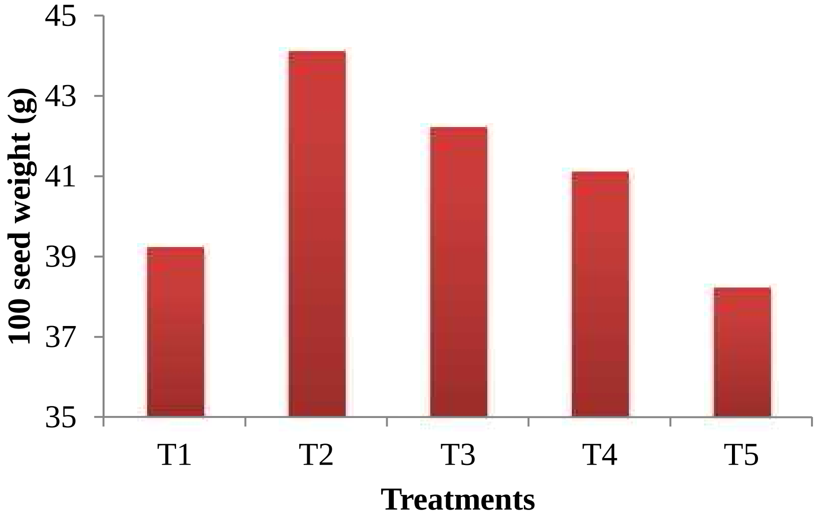


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 17. Effect of different varieties on 100 seed weight of groundnut (LSD $_{(0.05)}$ = 2.87)

4.9.2 Effect of different application of calcium

Effect of calcium level showed significant variation in 100 seed weight of groundnut (Fig. 18). The highest 100 seed weight (44.11 g) was found in T_2 which was statistically similar with T_3 and T_4. The lowest 100 seed weight (38.22 g) was found from T_5 which was statistically similar with T_1 and T_4. The results agreed with the findings of Das and Garnayak (1995) who stated that Ca enhanced the seed weight. Safarzadeh (2004), Sumner (1995) and Smart (1994) also reported that applying of calcium from gypsum has led to the big seeds. It is likely that as peanut size increases more calcium is absorbed thus increased seed size and ultimately getting the highest 100 seeds weight.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 18. Effect of calcium application on 100 seed weight of groundnut (LSD $_{(0.05)}$ = 3.05)

4.9.3 Combined effect of variety and different application of calcium

Combined effect of variety and different application of calcium responded differently in respect of 100 seed weight on groundnut (Table 7). The highest 100 seed weight (50.33 g) was found from the combined effect of V_1T_2 which was statistically similar with V_1T_3 and V_1T_4. The lowest 100 seed weight (31.33 g) was found with the combined effect of V_3T_5 which was statistically similar with V_3T_1, V_3T_3 and V_3T_4.

Table 7. Combined effect of different varieties and calcium application on pods plant^{-1}, Seeds pod^{-1} and 100 seed weight of groundnut

Treatment combination	Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	100 seed weight (g)
V_1T_1	29.44 de	1.68 a-c	43.67 b-d
V_1T_2	39.20 a	1.76 a	50.33 a
V_1T_3	38.49 a	1.73 ab	48.00 ab
V_1T_4	36.64 a	1.70 a-c	46.67 a-c
V_1T_5	31.18 b-d	1.63 a-c	42.00 c-e
V_2T_1	25.54 ef	1.56 a-c	41.33 de
V_2T_2	35.02 a-c	1.74 a	44.67 b-d
V_2T_3	30.61 c-e	1.68 a-c	43.33 b-d
V_2T_4	29.10 d-f	1.65 a-c	42.00 c-e
V_2T_5	27.39 d-f	1.510 c	41.33 de
V_3T_1	26.23 d-f	1.653 a-c	32.67 fg
V_3T_2	35.86 ab	1.703 a-c	37.33 ef
V_3T_3	31.13 b-d	1.663 a-c	35.33 fg
V_3T_4	29.50 de	1.683 a-c	34.67 fg
V_3T_5	24.02 f	1.530 bc	31.33 g
LSD $_{(0.05)}$	5.24	0.21	5.28
CV (%)	9.93	7.31	7.64

V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

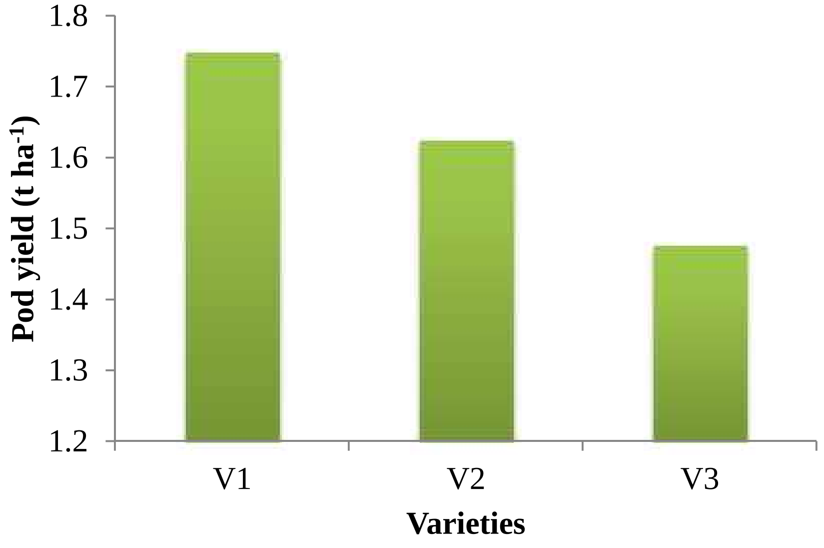
T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

4.10 Pod yield (t ha^{-1})

4.10.1 Effect of variety

Pod yield showed significant difference among the varieties shown in Figure 19. The highest pod yield (1.75 t ha^{-1}) was recorded by BARI Chinabadam-8 (V_1) which was statistically different from others. The lowest pod yield (1.48 t ha^{-1}) was obtained from Dhaka-1 (V_3) which was also statistically different from others. 18.24% higher pod yield was given by the BARI Chinabadam-8 (V_1) over the Dhaka-1 (V_3). This result was similar with Habib (2014) and

Kamara (2011) who found that variety had significant effect on pod yield. Furthermore the pod yield was attributed due to pods plant^{-1}, seeds pod^{-1} and 1000 seed weight.

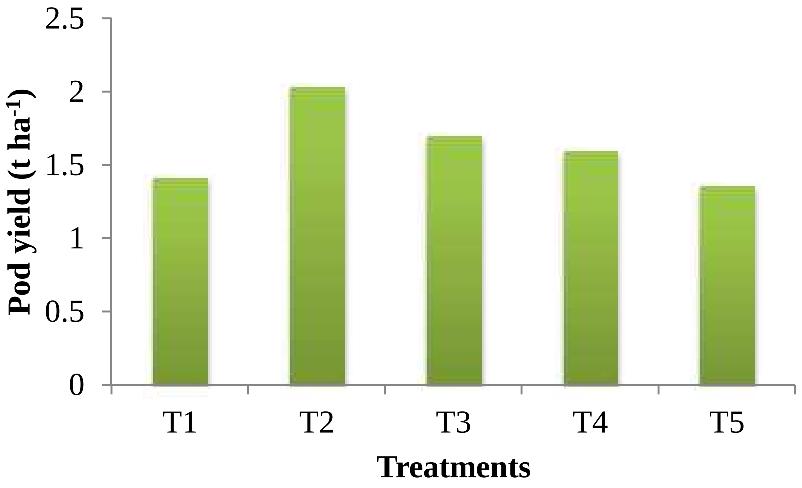


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 19. Effect of different varieties on pod yield of groundnut (LSD $_{(0.05)}$ = 0.12)

4.10.2 Effect of different application of calcium

Pod yield exerted significant variation among the different application of calcium on groundnut (Fig. 20). Result revealed that the highest pod yield (2.03 t ha^{-1}) was recorded from treatment T_2, whereas the lowest yield (1.36 t ha^{-1}) was obtained from treatment T_5 which showed statistical identity with T_1. The treatment T_2 gave 49.26% higher pod yield than the treatment T_5. The other remaining treatments gave the intermediate pod yield. Similar findings were reported by Thilakarathna *et al.* (2014), Kabir *et al.* (2013), Kamara (2011), Rao and Shaktawat (2005), Safarzadeh (2004), Zhang and Zao (1995), Mathur (1994), Gajanan *et al.*(1991), Hall (1975) and Smith (1954) who state that application of Ca at the time of flowering increased the pod yield. It's thought that increasing of the mature pods number in each bush and also increasing of pod weight in this rate of calcium to be major factors that were effective on pod yield in peanut. It probably seems due to the positive effect of gypsum on chemical properties of soil especially around the growing pods. Thus, all of these factors could directly or indirectly cause to increase of plant growth rate (PGR), nutrients absorption from the soil and finally led to increase of pod yield. Wiatrak *et al*. (2006) indicated that under strip-till management systems gypsum application may help to increase peanut yields with high potential yield by increasing Ca availability in the fruiting zone. Application of Ca content fertilizer increased nutrients availability to the crop during the growing season which leads to greater utilization of assimilates into the pods and ultimately increased the yield (Kabir *et al*., 2013). The ameliorating effect of Ca on Al and Mn toxicity and the increase in available N, P, and Mo could also have contributed to the yield increase (Quaggio *et al*. (2004). The high yields obtained from the 100kg Ca ha^{-1} have been due to increased cation exchange and pH of the soil which elicited positive effects on the productivity of the groundnut (Murata, 2003). Opposite results also observed by Wiatrak *et al*. (2006), Grichar *et al*. (2004), Jordan *et al*. (2000), Adams *et al*. (1993), Adams and Hartzog, (1991), Weiss (1983) and Walker and Keisling (1978) who stated that pod yield is not necessarily increased as levels of calcium increase more over high amount of Ca may reduces production, applying 110 kg Ca ha^{-1} and 165 kg Ca ha^{-1} did not lead to significant difference in pod yield, indicating that 110 kg Ca ha^{-1} was enough for the particular soil.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 20. Effect of calcium application on pod yield of groundnut (LSD $_{(0.05)}$ = 0.12)

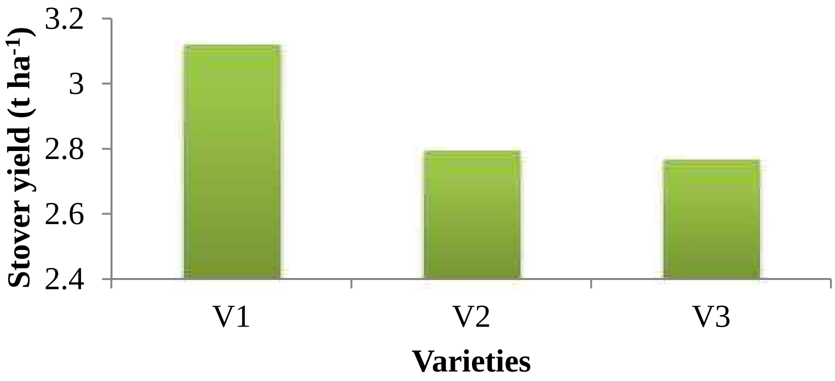
4.10.3 Combined effect of variety and different application of calcium

Combined effect of variety and different application of calcium responded differently in case of pod yield of groundnut (Table 8). The highest pod yield (2.30 t ha^{-1}) was recorded from V_1T_2 combination. The lowest pod yield (1.23 t ha^{-1}) was recorded from V_3T_5 combination which was statistically similar with V_2T_1, V_2T_5 and V_3T_1. The combined effect of V_1T_2 gave 86.99% higher pod yield over the combined effect of V_3T_5. Similar results were also Habib (2014) and Kabir *et al.* (2013) who reported that 100 kg Ca ha^{-1} in combination with BARI Chinabadam-7 at the time of flowering resulted in the best yield of groundnut.

4.11 Stover yield (t ha^{-1})

4.11.1 Effect of variety

Significant differences were observed in stover yield due to varietal variations (Fig. 21). The highest stover yield (3.12 t ha^{-1}) was obtained from V_1 and the lowest stover yield (2.77 t ha^{-1}) was obtained from V_3 which was statistically similar with V_2.

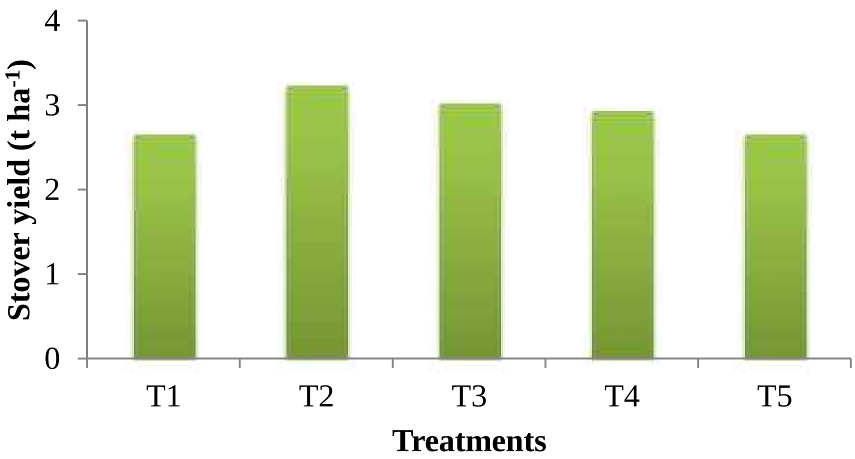


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 21. Effect of different varieties on stover yield of groundnut (LSD $_{(0.05)}$ = 0.26)

4.11.2 Effect of different application of calcium

Significant variation of stover yield was received due to different application of calcium (Fig. 22). Highest stover yield (3.23 t ha^{-1}) was recorded from T_2 which was statistically similar with T_3 and the lowest stover yield (2.65 t ha^{-1}) was recorded from T_1 and T_5 both treatment. This result was in agreement with the findings of Kabir *et al*. (2013) and Mandal *et al.* (2005).



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 22. Effect of calcium application on stover yield of groundnut (LSD $_{(0.05)}$ = 0.27)

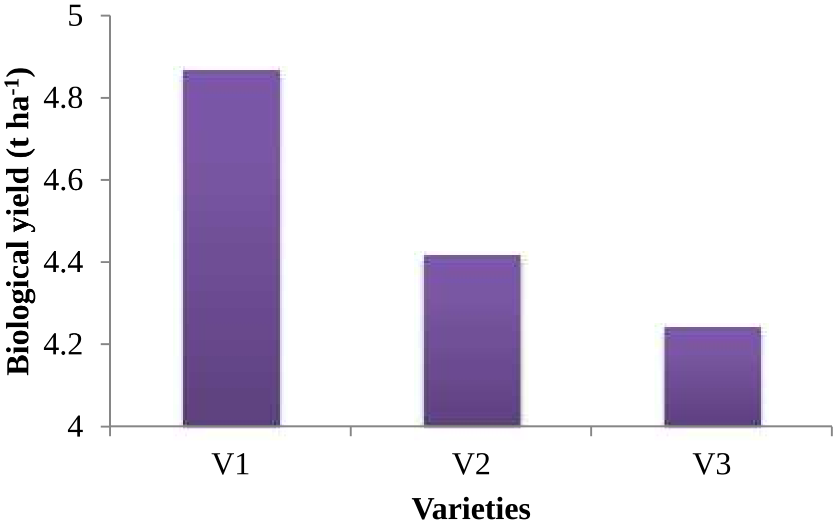
4.11.3 Combined effect of variety and different application of calcium

Combined effect of variety and different application of calcium varied significantly on stover yield (Table 8). The highest stover yield (3.43 t ha^{-1}) was obtained from the combination V_1T_2 which showed similarity with V_1T_3, V_1T_4, V_2T_2 and V_3T_2; while the lowest (2.51 t ha^{-1}) was found from the combination V_3T_5 which showed similarity with V_1T_1, V_1T_5, V_2T_1, V_2T_3, V_2T_4, V_2T_5, V_3T_1, V_3T_3 and V_3T_4.

4.12 Biological yield (t ha^{-1})

4.12.1 Effect of variety

Significant difference was observed among the varieties on the biological yield (Fig. 23). V_1 achieved the highest (4.8 t ha^{-1}) biological yield where as V_3 attained the lowest (4.24 t ha^{-1}) biological yield which was statistically similar with V_2.

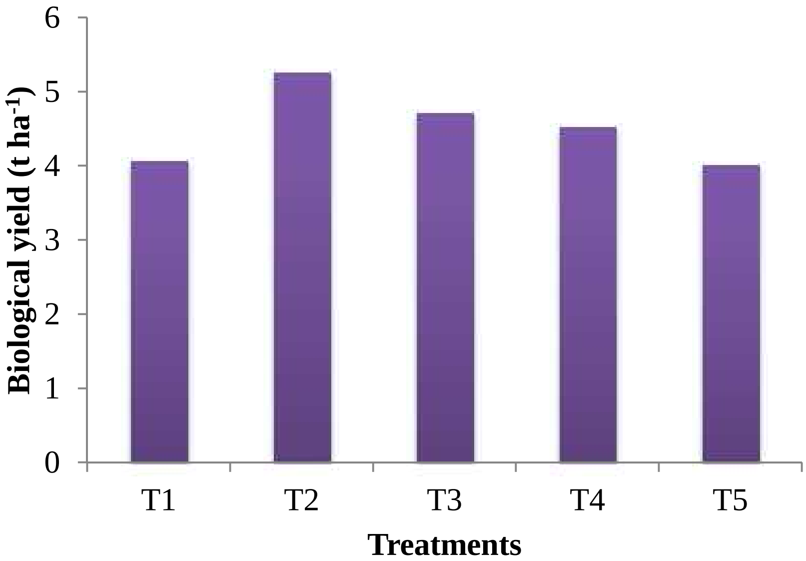


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 23. Effect of different varieties on biological yield of groundnut (LSD $_{(0.05)}$ = 0.21)

4.12.2 Effect of different application of calcium

Different application of calcium had significant effect on biological yield (Fig. 24). It was observed that the highest biological yield (5.25 t ha^{-1}) was found in T_2 and the lowest biological yield (4.00 t ha^{-1}) was recorded found from T_5 which was statistically similar with T_1. This result was in agreement with the findings of Kabir *et al*. (2013) who stated that calcium level had significant variation on biological yield.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5= NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 24. Effect of calcium application on biological yield of groundnut (LSD $_{(0.05)}$ = 0.31)

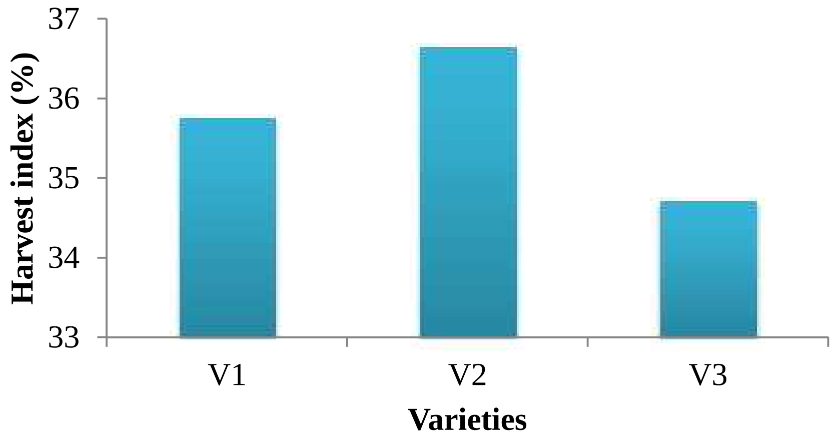
4.12.3 Combined effect of variety and different application of calcium

Combination effect of variety and different application of calcium exerted significant variation on biological yield (Table 8). The result revealed that, the highest biological yield (5.73 t ha^{-1}) was obtained from the combination V_1T_2 which was statistically similar with V_2T_2. The lowest biological yield (3.74 t ha^{-1}) was found from the combination V_3T_5 which was statistically similar with V_1T_1, V_2T_1, V_2T_5, V_3T_1 and V_3T_4.

4.13 Harvest index (%)

4.13.1 Effect of Variety

Variety showed no significant variation in harvest index (Fig. 25). BINA Chinabadam-4 (V_2) showed the highest harvest index (36.64 %) whereas lowest harvest index (34.71 %) in Dhaka-1(V_3).

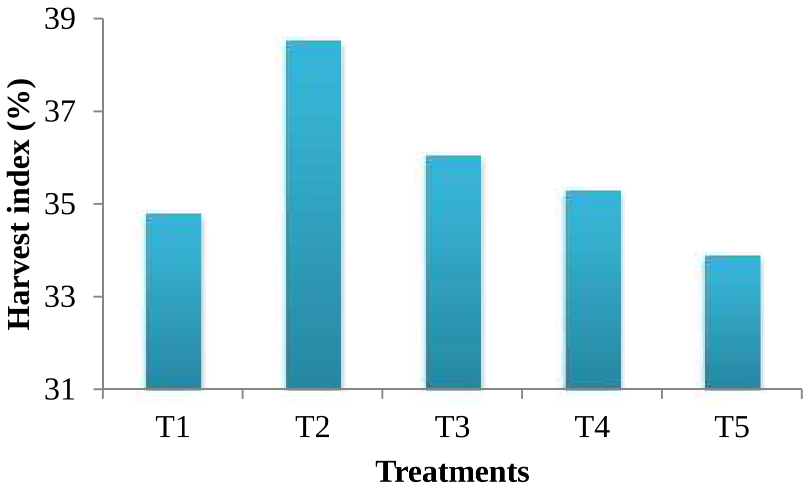


V_1= BARI Chinabadam-8, V_2= BINA Chinabadam-4 and V_3= Dhaka-1

Figure 25. Effect of different varieties on harvest index of groundnut (LSD $_{(0.05)}$ =3.07)

4.13.2 Effect of different application of calcium

Significant variation was observed in harvest index due to the effect of calcium application (Fig. 26). The highest harvest index (38.52 %) was found from T_2. T_5 gave the lowest harvest index (33.88%) which was statistically similar with all other calcium application except $T_{2.}$ Similar findings were observed by Habib (2014) and Kabir *et al.* (2013) who stated that calcium level had significant variation on harvest index.



T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Figure 26. Effect of calcium application on harvest index of groundnut (LSD $_{(0.05)}$ = 2.37)

4.13.3 Combined effect of variety and different application of calcium

Combined effect of variety and calcium application showed significant variation in harvest index (Table 8). The highest harvest index (40.21 %) was observed from V_1T_2 which was statistically similar with V_2T_2, V_2T_3, V_2T_4 and V_3T_2. The lowest harvest index (32.98 %) was obtained from the combination V_3T_5 which was similar with all other combinations except V_1T_2, V_2T_2 and V_2T_3.

Table 8. Combined effect of different varieties and calcium application on pod yield, stover yield, biological yield and harvest index of groundnut

Treatment Combination	Pod yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_1T_1	1.50 d-g	2.72 c-e	4.22 d-g	35.62 b-d
V_1T_2	2.30 a	3.43 a	5.73 a	40.21 a
V_1T_3	1.75 c	3.25 ab	5.00 b	35.04 b-d
V_1T_4	1.70 cd	3.30 ab	5.00 b	33.98 cd
V_1T_5	1.48 e-g	2.89 b-e	4.38 c-f	33.92 cd
V_2T_1	1.43 e-h	2.58 e	4.02 e-g	35.66 b-d
V_2T_2	2.03 b	3.18 a-c	5.21 ab	39.03 ab
V_2T_3	1.75 c	2.92 b-e	4.67 b-d	37.57 a-c
V_2T_4	1.55 c-f	2.74 c-e	4.29 c-f	36.19 a-d
V_2T_5	1.35 f-h	2.54 e	3.89 fg	34.73 cd
V_3T_1	1.30 gh	2.64 de	3.94 e-g	33.07 d
V_3T_2	1.75 c	3.07 a-d	4.82 bc	36.31 a-d
V_3T_3	1.58 c-e	2.87 b-e	4.44 c-e	35.52 b-d
V_3T_4	1.52 d-f	2.74 c-e	4.26 d-g	35.67 b-d
V_3T_5	1.23 h	2.51 e	3.74 g	32.98 d
LSD $_{(0.05)}$	0.21	0.47	0.54	4.10
CV (%)	7.82	9.57	7.16	81

V_1= BARI Chinabadam-8,
V_2= BINA Chinabadam-4 and
V_3= Dhaka-1

T_1= NPKCa as basal (Control),
T_2= NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS),
T_3= NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS),
T_4= NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and
T_5=NPK as basal + 400 kg Ca ha^{-1} at flowering stage (45 DAS)

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during September, 2014 to January, 2015 to study the effect of calcium on the growth and yield of groundnut varieties cv. BARI Chinabadam-8, BINA Chinabadam-4 and Dhaka-1. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors. Factor A: Variety (3 levels); V_1: BARI Chinabadam-8, V_2: BINA Chinabadam-4 and V_3: Dhaka-1, and factor B: Calcium fertilizer (5 levels); T_1: NPKCa as basal (Control), T_2: NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS), T_3: NPK as basal + 200 kg Ca ha^{-1} at flowering stage (45 DAS), T_4: NPK as basal + 300 kg Ca ha^{-1} at flowering stage (45 DAS) and T_5: NPK as basal + 400 kg Ca ha^{-1} at flowering stage(45 DAS). There were 15 treatment combinations. The total numbers of unit plots were 45. The size of unit plot was 3.8 m × 1.8 m. Variety was placed along the main plot and treatments were placed along the sub plot. For control plot half of urea along with other fertilizers as per treatment were applied during final land preparation as basal dose and thoroughly mixed with soil. For other plots half urea and all other fertilizers except gypsum as per treatment were applied by broad casting during final land preparation as basal dose and thoroughly mixed with soil. The other half urea and rest of gypsum fertilizers were applied at flower initiation (45 DAS) by side dressing as per treatment. The groundnut seeds were sown in lines maintaining a line to line distance of 30 cm and plant to plant distance of 15 cm having 2 seeds $hole^{-1}$ in the well prepared plot.

The data on growth parameters viz. plant height (cm), leaves $plant^{-1}$ (no.), branches $plant^{-1}$ (no.), dry matter weight $plant^{-1}$ (g) were recorded during the period from 20 to 100 DAS. At harvest, characters like pods $plant^{-1}$ (no.), seeds pod^{-1} (no.), 1000 seeds weight (g), pod yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}), harvest Index (%) were recorded.

The highest plant height (44.80 cm) and the lowest plant height (39.33 cm) were found at 100 DAS from V_2 and V_3, respectively. The highest plant height (45.83 cm) was found from T_2 and the lowest plant height (38.90 cm) was found at 100 DAS from T_5. The tallest plant height (48.28 cm) and shortest plant height (36.43 cm) was found at 100 DAS from treatment combination V_1T_2 and V_3T_5, respectively.

The highest number of leaves plant^{-1} (71.67) was recorded from V_1 and the lowest number of leaves plant^{-1} (56.65) was recorded from V_3 at 100 DAS. The highest number of leaves plant^{-1} (74.77) was found in T_2 whereas the lowest number of leaves plant^{-1} (58.56) was recorded from T_5 at 100 DAS. The highest leaves plant^{-1} (80.53) was observed from V_1T_2 whereas the lowest leaves plant^{-1} (48.50) was observed from V_3T_5 at 100 DAS.

The maximum dry matter weight plant^{-1} (14.94 g) was achieved from V_1 and minimum dry matter weight plant^{-1} (12.83 g) was observed from V_3 at 100 DAS. Treatment T_2 gained the highest dry matter weight plant^{-1} (16.65 g) and the lowest dry matter weight plant^{-1} (11.03 g) was attained by T_5 at 100 DAS. Combination V_1T_2 scored the highest dry matter weight plant^{-1} (17.41 g) while combination V_3T_5 scored the lowest one (9.30 g) at 100 DAS.

The maximum crop growth rate (0.17 g m^{-2} d^{-1}) was achieved from V_3 and minimum crop growth rate (-0.05 g m^{-2} d^{-1}) was observed from V_1 at 100-80 DAS. Treatment T_1 gained the maximum crop growth rate (0.21 g m^{-2} d^{-1}) and the minimum crop growth rate (-0.09 g m^{-2} d^{-1}) was attained by T_4 at 100-80 DAS. Combination V_3T_2 scored the maximum crop growth rate (0.84 g m^{-2} d^{-1}) while combination V_3T_5 scored the minimum crop growth rate (-0.42 g m^{-2} d^{-1}) at 100-80 DAS.

The maximum relative growth rate (0.96 mg $g^{-1}d^{-1}$) was achieved from V_3 and minimum relative growth rate (-0.34 mg $g^{-1}d^{-1}$) was observed from V_1 at 100-80 DAS. Treatment T_1 gained the maximum relative growth rate (1.88 mg g^{-1} d^{-1}) and the minimum relative growth rate (-1.23 mg $g^{-1}d^{-1}$) was attained by T_5 at 100-80 DAS. Combination V_3T_3 scored the maximum relative growth rate (3.85 mg g^{-1} d^{-1}) while combination V_3T_5 scored the minimum relative growth rate (-4.10 mg g^{-1} d^{-1}) at 100-80 DAS.

The maximum branches plant^{-1} (6.76) was achieved from V_1 and minimum branches plant^{-1} (5.66) was observed from V_3 at 100 DAS. Treatments T_2 gained the highest branches plant^{-1} (6.80) and the lowest branches plant^{-1} (5.66) attained by T_5 at 100 DAS. Combination V_1T_2 scored the highest branches plant^{-1} (7.53) while combination V_3T_5 scored the lowest one (5.17) at 100 DAS.

The highest pods plant^{-1} (34.99), seeds pod^{-1} (1.70), 1000 seeds weight (46.13 g), pod yield (1.75 t ha^{-1}), stover yield (3.12 t ha^{-1}) and biological yield (4.87 t ha^{-1}) were recorded from V_1 whereas the lowest pods plant^{-1} (29.35), 100 seeds weight (34.27 g), pod yield (1.48 t ha^{-1}), stover yield (2.77 t ha^{-1}) and biological yield (4.24 t ha^{-1}) were recorded from V_3; lowest seeds pod^{-1} (1.63) was recorded from V_2. The highest harvest index (36.64%) and lowest harvest index (34.71%) was recorded from V_2 and V_3, respectively.

The highest pods plant^{-1} (36.70), seeds pod^{-1} (1.74), 100 seeds weight (44.11 g), pod yield (2.03 t ha^{-1}), stover yield (3.23 t ha^{-1}), biological yield (5.25 t ha^{-1}) and harvest index (38.52%) were recorded from T_2 whereas the lowest pods plant^{-1} (27.07) was recorded from T_1; lowest seeds pod^{-1} (1.56), 1000 seeds weight (38.22 g), pod yield (1.36 t ha^{-1}), stover yield (2.65 t ha^{-1}), biological yield (4.00 t ha^{-1}) and harvest index (33.88%) were recorded from T_5.

The highest pods plant^{-1} (39.20), seeds pod^{-1} (1.76), 100 seeds weight (50.33 g), pod yield (2.30 t ha^{-1}), stover yield (3.43 t ha^{-1}), biological yield (5.73 t ha^{-1}) and harvest index (40.21%) were recorded from V_2T_2 whereas the lowest pods plant^{-1} (24.02) was recorded from V_3T_5, lowest seeds pod^{-1} (1.51) from V_2T_5, lowest 1000 seeds weight (31.33 g), pod yield (1.23 t ha^{-1}), stover yield (2.51 t ha^{-1}), biological yield (3.74 t ha^{-1}) and harvest index (32.98%) were recorded from V_3T_5.

It may be concluded that calcium management invariably important in groundnut cultivation as it was required in optimum amount during flower initiation stage of groundnut for its growth, development and maximum yield. BARI Chinabadam-8 showed the superiority over other tested varieties of groundnut. Application of NPK as basal + 100 kg Ca ha^{-1} at flowering stage (45 DAS) of three varieties of groundnut found effective for maximum pod yield (2.03 t ha^{-1}).

RECOMMENDATION

The new era of this study was made for one year and found some interesting results which could be further verified in different groundnut growing areas of Bangladesh for technological diffusion among the farmers.

References

REFERENCES

Adams, J. F. and Hartzog, D. L. (1991). Seed quality of runner peanuts as affected by gypsum and soil calcium. *J. Plant. Nutri*. **14**: 841-851.

Adams, J. F., Hartzog, D. L. and Nelson D. B. (1993). Supplemental calcium on yield, grade, and seed quality of runner peanut. *Agron. J*. **85**: 86-93.

Agasimani, C. A., Bablad, H. B. and Hosmani, M. M. (1992). Response to time, form and level of calcium application in groundnut(*Arachis hypogaea* L.). *Indian J. Agron*. **37**(3): 493-495.

Agasimani, G. A., Palled, Y. B., Naik, H. D. and Kulkarni, G. K. (1986). Response of groundnut cultivars to different spacings. *Indian J. Agron.* **31**(3): 264-268.

Anonymous. (1988a). The Year Book of Production. FAO, Rome, Italy.

Anonymous. (1988b). Land Resources Appraisal of Bangladesh for Agricultural Development. Report No. 2. Agroecological Regions of Bangladesh, UNDP and FAO. pp. 472-496

Anonymous. (2004). Annual Internal Review for 2000-2001. Effect of seedling throwing on the grain yield of wart land rice compared to other planting methods. Crop Soil Water Management Program Agronomy Division, BRRI, Gazipur-1710.

Bagarama, F. M., Shenkalwa, E. and Matata, Z. P. (2012). The effect of gypsum and NPK AS BASAL fertiliser on groundnut performance in Western Tanzania. Third RUFORUM Biennial Meeting 24 - 28 September 2012, Entebbe, Uganda.

Blamey, F. P. C. and Chapman, J. (1982). Soil amelioration effects on peanut growth, yield and quality. *Plant Soil*. **65**(3): 319-334.

Boote, K. J. (1982). Growth stages of peanut (*Arachis hypogaea* L.). *Peanut Sci*. **9**: 35-40.

Brown, R. H. (1994) In: growth of the green plant. Physiological basis of crop growth and development. Teasar, M. B. (Ed.). Madison, Wisconsin. pp. 1533-173.

Das, R. and Garnayak, K. B. (1995). Response of groundnut to calcium application in red alluvia soils of Orissa. *Environ. Ecol.* 1**3**(1): 59-62.

Emery, D. A. (1963). Reproductive efficiency in virginia type peanuts. I. Differences among varieties. Peanut Improvement Working Group Proc. Oklahama State Univ. p. 107-108.

FAO STAT, 2013. Available at http://faostat.fao.org/.

Gascho, G. J., Hodges, S. C., Alva, A. K., Csinos, A. S. and Mullinix, Jr. B. G. (1993). Calcium source and time of application for runner and virginia peanuts. *Peanut Sci.* **20**: 31-35.

Gashti, A. H., Vishekaei, M. N. S. and Hosseinzadeh, M. H. (2012). Effect of potassium and calcium application on yield, yield components and qualitative characteristics of peanut (Arachis hypogaea L.) in Guilan province, Iran. *World Appl. Scis. J.* **16**(4): 540-546.

Gomez, K. A. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. 2nded. John Wiley and Sons. New York. p. 64.

Grichar, W. J., Besler, B. A. and Melouk, H. A. (2004). Peanut (*Arachis hypogaea* L.) response to agricultural and power plant by product calcium. *Peanut Sci.* **31**(2): 95-101.

Habib, M. A. (2014). Calcium management towards peg and pod development of groundnut. M. S. Thesis. Department of Agronomy. Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh.

Hall , A. M. (1975). Effect of phosphorus, potassium, and calcium on peanuts at Mauke(Cook Islands). *New Zealand J. Exptl. Agri.* **3**(2): 117-120.

Hartzook, A. (1967). On the problem of reproduction in groundnut. *Oleagineux.* **22**: 677-678.

Hassan, A. Z. A. and Mahmoud, A. M. (2014). Effect of different sources of calcium, organic and inorganic nitrogen on sandy soil, peanut yield and components. *Topcals. J. Agric. Res*. **2**(1): 8.

Jordan, D. L., Swann, C. W., Swann, J. F., Swann, R. L., Brandenburg, J. E. and Tucker, M. R. (2000). Comparison of Virginia and runner market-type peanut (*Arachis hypogaea* L.) grown in the Virginia-Carolina production area. *Peanut Sci*. **27**: 71-77.

Kabir, R., Yeasmin, S., Islam, A. K. M. M. and Sarkar, M. A. R. (2013). Effect of phosphorus, calcium and boron on the growth and yield of groundnut (*Arachis hypogea* L.). *Intl. J. Bio-Sci. Bio-Technol.* **5**(3): 51-59.

Kalaiyarasan, C., Vaiyapuri, V. and Chandrasekharan, M. V. S. (2003). Effect of sulfur sources and levels on the nutrient uptake, crop quality and sulfur use efficiency in groundnut. *Ann. Agric. Res. New Series.* **24**: 478-480.

Kamara, E. G., Olympio, N. S. and Asibuo, J. Y. (2011). Effect of calcium and phosphorus fertilizer on the growth and yield of groundnut (*Arachis hypogaea* L.). *Intl. Res. J. Agril. Sci. Soil Sci.* **1**(8): 326-331.

Kvien C. S., Branch, W. D., Sumne, M. E. and Csinos, A. S. (1988). Pod characteristics influencing calcium concentrations in the seed and hull of peanut. *Crop Sci.* **28**: 666-671.

Lee, J. S., Cho, K. J., Nam, M. H. and Kang, U. G. (1998). Influence of gypsum and micro element fertilization on groundnut with inoculation of Rhizobium. *Soil Soc. America*. **62**: 67-71.

Mandal, S., Samui, R. C. and Mondal, A. (2005). Growth, yield and yield attributes of groundnut (*Arachis hypogaea* L.) cultivars as influenced by gypsum application. *Leg. Res*. **28**: 119-121.

Meena, S., Malarkodi, M. and Senthilvalavan, P. (2007). Secondary and micronutrients for groundnut - A review. *Agric. Rev*. **28**(4): 295-300.

Norman, K., Wieck, L., Harden, P. and Baker, G. (2005). Peanut production guide. National Library of Australia Cataloguing-in-Publication Data. p. 36.

Ntare, B. R., Diallo, A. T., Ndjeunga, A. T. and Waliyar, F. (2008). Groundnut Seed Production Manual. Patancheru 502324, Andhra Pradesh, India. *Int. Crops Res. Inst. Semi-Arid Topcs. (ICRISAT)*. p. 20.

Pathak, B. P. (2010). Effect of calcium on peanut (*Arachis hypogaea* L.) pod and seed development under field conditions. M. S. Thesis. Dept. Agron., University of Florida.

Patil, P. S., Patil, S. S. and Deokar, A. B. (1984). Flowering pattern and pod production in bunch groundnut as influenced by season. *Madras Agric. J*. **71**(3): 141-146.

Quaggio, J. A., Gallo,P. B., Owino-gerroh, C., Abreu,M. F. and Cantarella, H. R. (2004). Peanut response to lime and molybdenum application in low pH soils. *Bras. Ci. Solo*. **28**: 659-664.

Rahman, L. and Mia, M. N. I. (1978). Selection for number of pods and oil content on the basis of flowering pattern and coefficients of fertility and productivity in groundnut. *Bangladesh J. Sci. Res.* **13**(l/4): 1-8.

Rahman, M. A. (2006). Effect of Calcium and *Bradyrhizobium* inoculation of the Growth, Yield and quality of groundnut (*A. hypogaea* L.*). Bangladesh J. Sci. Ind. Res*. **41**(3-4): 181-188.

Ramachandrappa, B. K. and Kulkarni, K. R. (1992). Response of groundnut (*Arachis hypogaea* L.) to calcium sources and saturation levels in two soils. *J. Oilseeds Res*. **9**(1): 80-86.

Rao, S. S. and Shaktawat, M. S. (2005). Effect of organic manure, phosphorus and gypsum on nutrient uptake in groundnut. *Agropedology*. **15** (2): 100-106.

Reddy, L. J. and Kaul, A. K. (1986). The status and prospects of groundnut production in Bangladesh. Bangladesh Agric. Res. Council, Dhaka. pp. 1-12.

Reddy, Y. M., Reddi, M. V. and Reddy, K. R. (1990). Effect of growing period on reproductive efficiency in genotypes of groundnut (*Arachis hypogaea* L.). *Indian J. Agric. Sci.* **6**(1): 56-60.

Safarzadeh Vishkaee, M. N. (1999). The peanut crop (textbook). Islamic Azad University. Rasht Press, Iran. p. 46.

Safarzadeh Vishkaee, M. N. (2004). Effect of gypsum application time and rate on growth and yield of peanut in Guilan province. Rasht press, Iran. p. 100.

Salke, S. R., Shaikh, A. A. and Dalavi, N. D. (2010). Influence of phosphatic fertilizers, gypsum and sulfur on growth contributing characters of groundnut (*Arachis hypogaea* L.). *Adv. Res. J. Crop Improv.* **1**: 106-110.

Sarkar, A. K. (2002). Second annual report, ICAR network project on soil characterization and resource management of acid soils region for increasing productivity.

Sharma, B. M. and Yadav, J. S. P. (1997). Availability of phosphorus to grain as influenced by phosphatic fertilization and irrigation regimes. *Indian J. Agril. Sci.* **46**: 205-210.

Singh, F. and Oswalt, D. L. (1995). Groundnut production practices. Skill development series number 3. Training and fellowship program of international crops institute for the semi-arid tropics, Patancheru 502 324, Andra Pradesh, India.

Slak, T. E. and Morrill, L. G. (1972). A comparison of a large-seeded (NC2) and a small-seeded (Starr) peanut (*Arachis hypogaea* L.) cultivar as affected by levels of calcium added to the fruit zone. *Soil Soc. America*. **36**: 87-90.

Smart, J. (1994). The groundnut crop: A scientific basis for improvement. London. Chapman and Hall, improvement. *Crop Sci*. **18**(1015-1021): 734.

Sorensen, R. B. and Butts, C. L. (2008). Pod yield and mineral concentration of four peanut cultivars following gypsum application with subsurface drip irrigation. *Peanut Sci*. **35**: 86-91.

Sumner, M. E. (1995). Gypsum as a calcium and sulfur source for crops and soils in the southeastern United States. FIPR Project # 93-01-118 Final Report, Florida Institute of Phosphate Research, Bartow, FL.

Sumner, M. E., Kvien, C. S., Smal, H. and Csinos, A. S. (1988). On the Ca nutrition of peanut (*Arachis hypogaea* L.) *Intl. Conceptual model. J. Fert.* **5**: 97-102.

Teixeira, S. D., Pereira, R. A. S. and Ranga, N. T. (2006). Components of fecundity and abortion in a tropical tree, *Dahlstedtia pentaphylla* (Leguminosae). *Brazilian Arch. Biol. Technol.* **49**: 905-913.

Thilakarathna, S. M. C. R., Kirthisinghe, J. P., Gunathilaka, B. L. and Dissanayaka, D. M. P. V. (2014). Influence of gypsum application on yield and visual quality of groundnut (*Arachis hypogaea* L.) grown in Maspotha in Kurunegala district of Sri Lanka. *Topcal. Agril. Res*. **25**(3): 432-436.

Ursal, G. R., Jadhav, A. S. and Bachchhav, S. M. (1994). Effects of calcium fertilization on yield, quality and nutrient uptake by groundnut. *Maharashtra-Agri Unit.* **19**(3): 404-407.

Walker, M. E. and Keisling, T. C. (1978). Response of five peanut cultivars to gypsum fertilization on soils varying in calcium content. *Peanut Sci.* **5**: 57-60.

Wenxin, W., Jiaju, C., Ensheng, Z., Hanzhang, L., Qun, L. and Xueyun, Y. (2001). Effects of calcium and boron on the growth, yield and quality of peanut. *Subtopcal. Plant Sci.* **30**(2): 20-23.

Wesis, E. A. (1983). Oilseed crops. *Longman Inc. NY*. p. 660.

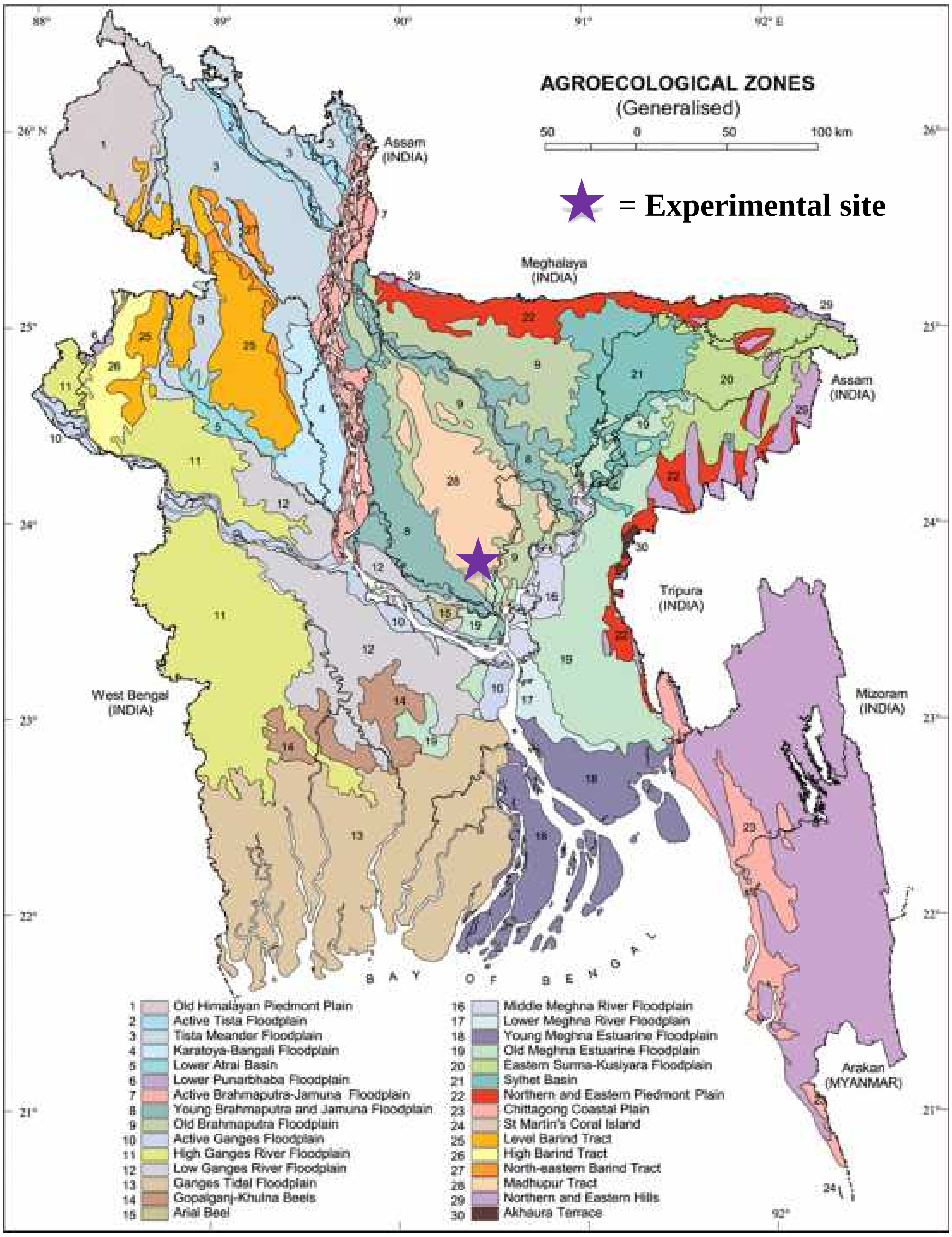
Wiatrak, P. J., Wright, D. L., Marois, J. J. and Wilson, D. (2006). Influence of gypsum application on peanut yield and quality. Online. Crop Management doi:10.1094/CM-2006-0223-01-RS.

Yadav, R., Jat, L. K., Yadav, S. N., Singh, R. P. and Yadav, P. K. (2014). Effect of gypsum on growth and yield of groundnut (*Arachis hypogaea* L.). *Environ. Ecol*. **33**(2): 676-679.

Appendices

APPENDICES

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



Appendix II. Characteristics of soil of experimental field

A. Morphological characteristics of the experimental field

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

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

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

Appendix III. Monthly meteorological information during the period from September, 2014 to January, 2015

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2014	September	31.46	14.82	73.20	161
	October	30.18	14.85	67.82	137
	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	0
2015	January	24.57	12.53	68	0

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

Appendix IV. Layout of experimental field

Total number of unit plots: 15 × 3 = 45
Unit plot size: 3.8 m × 1.8 m = 6.84 m^2
The main plot and unit plots were separated by 1m and 0.5m, respectively.

Replication 1	V_1T_1	V_1T_2	V_1T_3	V_1T_4	V_1T_5
	V_2T_3	V_2T_5	V_2T_4	V_2T_2	V_2T_1
	V_3T_2	V_3T_4	V_3T_5	V_3T_1	V_3T_3
Replication 2	V_2T_1	V_2T_2	V_2T_3	V_2T_4	V_2T_5
	V_1T_3	V_1T_5	V_1T_4	V_1T_2	V_1T_1
	V_3T_4	V_3T_1	V_3T_2	V_3T_5	V_3T_3
Replication 3	V_1T_5	V_1T_2	V_1T_1	V_1T_3	V_1T_4
	V_3T_1	V_3T_3	V_3T_5	V_3T_4	V_3T_2
	V_2T_2	V_2T_1	V_2T_4	V_2T_5	V_2T_3

Appendix V. Analysis of variance of the data on plant height (cm) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square of plant height (cm) at different days after sowing (DAS)				
		20	40	60	80	100
Replication	2	7.86	13.90	0.84	3.99	21.51
Variety (A)	2	4.86^{NS}	18.77*	125.89^{NS}	97.28*	115.54*
Error	4	2.85	1.60	31.14	6.63	2.37
Calcium (B)	4	0.69^{NS}	23.59*	29.60*	46.76*	62.14*
Variety (A) X Calcium (B)	8	0.85*	0.16*	2.43*	0.96*	0.89*
Error	24	1.27	4.58	8.58	11.45	9.19

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on leaves plant^{-1} (no.) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square of leaves plant^{-1} (no.) at different days after sowing (DAS)				
		20	40	60	80	100
Replication	2	0.24	11.82	53.60	210.15	160.51
Variety (A)	2	2.13*	730.02*	288.35*	942.50*	970.58*
Error	4	0.14	12.19	9.58	55.57	78.86
Calcium (B)	4	18.56*	195.98*	337.90*	355.79*	340.54*
Variety (A) X Calcium (B)	8	16.84*	29.16*	12.68*	9.02*	9.05*
Error	24	2.54	29.07	54.90	52.52	44.45

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on above ground dry matter plant^{-1} (g) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square of above ground dry matter plant^{-1} (g) at different days after sowing (DAS)				
		20	40	60	80	100
Replication	2	0.03	0.06	2.12	0.27	0.15
Variety (A)	2	0.16*	3.28*	44.01*	30.57*	17.86*
Error	4	0.01	0.31	1.46	2.88	3.04
Calcium (B)	4	0.09*	2.89*	18.05*	38.89*	44.93*
Variety (A) X Calcium (B)	8	0.22*	0.33*	2.81*	1.34*	1.17*
Error	24	0.04	0.20	1.61	0.83	1.27

*Significant at 5% level of significance

NS Non significant

Appendix VIII. Analysis of variance of the data on crop growth rate (g m^{-2} d^{-1}) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square of crop growth rate (g m^{-2} d^{-1}) at different days after sowing (DAS)			
		40-20	60-40	80-60	100-80
Replication	2	0.03	0.12	0.00	0.002
Variety (A)	2	0.50*	6.16*	0.60*	0.20*
Error	4	0.03	0.05	0.02	0.00
Calcium (B)	4	0.54*	1.64*	3.20*	0.20*
Variety (A) X Calcium (B)	8	0.10*	0.51*	1.16*	0.36*
Error	24	0.02	0.13	0.01	0.002

*Significant at 5% level of significance

NS Non significant

Appendix IX. Analysis of variance of the data on relative growth rate (mg g^{-1} d^{-1}) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square of relative growth rate (mg g^{-1} d^{-1}) at different days after sowing (DAS)			
		40-20	60-40	80-60	100-80
Replication	2	6.50	30.64	0.10	0.001
Variety (A)	2	91.99*	143.21*	79.92*	6.63*
Error	4	15.57	21.85	2.06	0.01
Calcium (B)	4	145.01*	3.29*	184.06*	14.63*
Variety (A) X Calcium (B)	8	144.26*	47.02*	103.16*	16.39*
Error	24	20.47	25.91	0.98	0.002

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Analysis of variance of the data on branches plant^{-1} (no.) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square of branches plant^{-1} (no.) at different days after sowing (DAS)				
		20	40	60	80	100
Replication	2	0.14	0.06	0.74	0.27	0.03
Variety (A)	2	0.75*	5.58*	8.59*	4.71*	5.13*
Error	4	0.03	0.08	1.84	0.32	0.25
Calcium (B)	4	0.42*	2.23*	2.66*	1.67*	1.69*
Variety (A) X Calcium (B)	8	0.37*	0.10*	0.21*	0.20*	0.25*
Error	24	0.12	0.55	0.66	0.36	0.43

*Significant at 5% level of significance

^{NS} Non significant

Appendix XI. Analysis of variance of the data on pods plant^{-1} (No.), seeds pod^{-1} (No.) and 1000 seed weight (g) of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square value		
		Pods plant^{-1} (No.)	Seeds pod^{-1} (No.)	1000 seed weight(g)
Replication	**2**	3.68	0.03	9.36
Variety (A)	**2**	154.16*	0.02^{NS}	555.29*
Error	**4**	9.38	0.02	8.02
Calcium (B)	**4**	148.27*	0.04*	49.63*
Variety (A) X Calcium (B)	**8**	6.07*	0.003*	3.23*
Error	**24**	9.65	0.02	9.80

*Significant at 5% level of significance

^{NS} Non significant

Appendix XII. Analysis of variance of the data on seed yield (t ha^{-1}), stover yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index of groundnut as influenced by combined effect of different varieties and calcium application

Source of variation	df	Mean square value			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index
Replication	**2**	0.02	0.09	0.20	0.62
Variety (A)	**2**	0.28*	0.58*	1.56*	13.98^{NS}
Error	**4**	0.01	0.07	0.04	9.19
Calcium (B)	**4**	0.64*	0.56*	2.37*	27.88*
Variety (A) X Calcium (B)	**8**	0.02*	0.03*	0.06*	4.10*
Error	**24**	0.02	0.08	0.10	5.92

*Significant at 5% level of significance

^{NS} Non significant