

EFFECT OF CALCIUM AND BORON ON GROWTH, DRYMATTER PARTITIONING AND YIELD OF GROUNDNUT

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B.Sc. (Ag.)

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(CROP PHYSIOLOGY)**



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EFFECT OF CALCIUM AND BORON ON GROWTH, DRYMATTER PARTITIONING AND YIELD OF GROUNDNUT

BY

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B.Sc. (Ag.)

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2019

DECLARATION

I, **Ms. P. HEENA KAUSAR** hereby declare that the thesis entitled **“EFFECT OF CALCIUM AND BORON ON GROWTH, DRYMATTER PARTITIONING AND YIELD OF GROUNDNUT”** submitted to the **Acharya N.G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

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CERTIFICATE

Ms. P. HEENA KAUSAR has satisfactorily prosecuted the course of research and that the thesis entitled **“EFFECT OF CALCIUM AND BORON ON GROWTH, DRYMATTER PARTITIONING AND YIELD OF GROUNDNUT”** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

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No part of the thesis has been submitted by the student for the award of any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

%	:	Per cent
@	:	At the rate
°C	:	Degree Celsius
°E	:	Degree east
°N	:	Degree north
µg	:	Micro grams
B: C	:	Benefit- Cost
CD	:	Critical difference
CGR	:	Crop growth rate
cm	:	Centimetre
cm ²	:	Square centimeter
DAP	:	Di ammonium phosphate
DAS	:	Days after sowing
day ⁻¹	:	Per day
dSm ⁻¹	:	Decisiemen per metre
<i>et al.</i>	:	and other people
g	:	Gram
g ⁻¹	:	Per gram
ha ⁻¹	:	Per hectare
HI	:	Harvest index
Kg	:	Kilogram
l	:	Litre
LAD	:	Leaf area duration
LAI	:	Leaf area index
LAR	:	Leaf area ratio
LWR	:	Leaf Weight Ratio
LWR	:	Leaf weight ratio
M	:	Million
m.ha	:	Million hectare
m.t	:	Million tonnes
m ⁻²	:	Per square meter
Mg	:	Milligram
N	:	Nitrogen
NAR	:	Net assimilation rate

P	:	Phosphorous
Plant ⁻¹	:	Per plant
ppm	:	Parts per million
R	:	Correlation Co-efficient
RDF	:	Recommended dose fertilizers
RWR	:	Root Weight Ratio
SCMR	:	SPAD chlorophyll meter reading
SLA	:	Specific leaf area
TDM	:	Total dry matter
<i>viz.</i> ,	:	Namely

ABSTRACT

Author of the thesis : **P. HEENA KAUSAR**
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A field experiment was conducted entitled effect of calcium and boron on growth, drymatter partitioning and yield of groundnut under rainfed conditions during *kharif* 2018 in dryland farm, S.V Agricultural College, Tirupati. The experiment was laid out in randomized block design and replicated thrice with ten treatments and one variety Dharani. The groundnut differed in response to treatments (soil and foliar application of calcium and boron) in physiological, biochemical and yield characters.

Among the all the treatments RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3% recorded highest plant height followed by RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% recorded which highest leaf area , and total drymatter when compared to control.

The growth parameters CGR, RGR, LWR, LAI were recorded highest in the treatment RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% followed by RDF + foliar application of borax at 35 DAS @ 0.1 % + foliar application of calcium nitrate at 35 DAS @ 0.3% when compared to control. The growth parameter leaf area ratio was recorded highest in RDF + gypsum application as basal @ 500 kg ha⁻¹.

The treatment RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1 % also recorded highest biochemical activity, reproductive efficiency when compared to control. Root nodulation parameters such as number of nodules were recorded highest in RDF+ Foliar application of Borax at 35 DAS @0.1% and partitioning of drymatter content in different plant parts was observed more in kernels which shows that the photosynthates diverting to the sink i.e., pods.

Computing yield advantage and B:C ratio of the treatments RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% recorded maximum pod yield followed by RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3%.

The present study revealed that gypsum application at 35 DAS @ 500 kg ha⁻¹ along with foliar application of borax @ 0.1% recorded the highest physiological, growth parameters and yield. The other treatments such as RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3%, soil and basal application of gypsum, borax showed moderate performance. Hence it can be recommended that foliar application of borax along with gypsum at 35DAS is ideal in order to obtain good yield.

Chapter ~ I



Introduction

Chapter – I

INTRODUCTION

Groundnut (*Arachis hypogaea* L.) is one of the most important food and oilseed crop cultivated and consumed in most parts of the world. It is widely accepted as an excellent source of nutrition to both human and animals due to its high protein content (25%) and edible oil (50%). Groundnut is called as the “King of oilseeds” and one of the cash crops of our country. Though Groundnut is a valuable source of all the nutrients, it is a low-priced commodity. It is also called as wonder nut and poor man’s cashew nut. It is the most versatile legume because of its drought tolerant characters, soil restoring properties, weeds smothering, multi-purpose confectionary and dilatory uses. As a legume oil yielding crop, it fits well into most of the cropping systems.

Groundnut (*Arachis hypogaea*) is the sixth most important oil crop in the world (Ikechukwu *et al.*, 2014). Groundnut is cultivated over an area of 4.97 million hectares, with a production of 8.2 million tonnes and an average productivity of 1674 kg ha⁻¹.

In India, 70-75 per cent of the groundnut area (4.19 m ha) and production (5.62 m tonnes) is concentrated in four states *i.e.*, Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka (Madhusudhana, 2013). Andhra Pradesh ranks second in the country both in area (7.8 lakh hectares) and production (8 lakh tonnes) with an average productivity of 1035 kg ha⁻¹ (FAOSTAT, 2016).

Groundnut efficiency dimension of our nation is far beneath the world profitability level. A few reasons are credited for low yield levels *viz*, absence of improved high yielding cultivars, development under shallow soils of low maturity, uneven precipitation dispersion, continuous cropping

without rotation of crop, low plant populace, frequency of foliar infections and absence of utilization of micronutrients.

True to its name “UNPREDICTABLE LEGUME” the response of groundnut to applied fertilizers has always been highly varying in respect of location, season and soil. Groundnut being an oilseed crop is considered heavy feeder of nutrients. An average crop of groundnut yielding 19 qha⁻¹ removes 170 kg nitrogen, 30 kg phosphorous, 110 kg potassium, 39 kg of calcium and 15 kg sulphur from soil (Aulakh *et al.*, 1985). Therefore, cultivation of groundnut depletes the soil fertility unless the crop is adequately fertilized. To realize then higher yields, it is very much essential to supply adequate but balanced amounts of major and micronutrients.

Increased yield through continuous development with high yielding cultivars, utilization of synthetically unadulterated NPK composts, and constrained utilization of natural organic manures and confined reusing of crop residues are some significant elements which quicken loss of micronutrients from soil. In few spots, typical yield of harvests couldn't be accomplished despite balanced use of NPK because of micronutrient insufficiency in soils. The incessant efforts for enhancing food grain production from shrinking land resources will further magnify the depletion of limited micronutrient reserves and would cause the deficiency of other micronutrients besides accentuating the existing ones.

For an optimum plant growth and yield, apart from major nutrients, secondary and micronutrients are also need to be taken care. Though, micronutrients required in small quantities but play significant role in biochemical activities. Calcium and Boron nutrients has been universally recognized as the most important for growth and development of groundnut. Calcium (Ca) is required by groundnut plants from the time when pegs begin to appear, fruit formation, until the pods are mature. Calcium deficiency leads to high percentage of aborted seeds (empty pods),

improperly filled pods, and causes of the aborted or shriveled fruit, including darkened plumules and production of pods without seed. In low Calcium content soils, gypsum can also increase seed oil content. In contrast, there are also indications that high levels of soil Ca is associated with reduced incidence of various root rots.

Further, Calcium can only enter the kernel by direct diffusion from the soil solution, which requires good soil moisture. Therefore in dry soils seed quality can be affected by reduced calcium uptake, even though plenty of calcium may be present. Hence calcium is recommended to apply at flowering stage in the form of Gypsum. However in rainfed condition its adoption is poor. Hence application of gypsum as basal is ideal. Similarly now farmers are supplied with boron along with seed by government agencies for both soil and foliar application. Hence it is necessary to investigate application of Ca and B as basal and foliar application in groundnut and compute its yield advantage and cost economics.

Boron is a key element needed by the Peanut plant for nutrition and growth, and it aids in improving the development and yield of groundnut. (Quamruzzaman *et al.*, 2017). Boron is used to regulate the plants carbohydrate metabolism. It plays a significant role in forming the seeds and in synthesis of proteins. (BARC 2005). Boron has an important role in stigma receptivity to increase pollination by making pollen grain fertile (Kaisher *et al.*, 2010). A recent study showed that, gas exchange, basically stomatic effects as well as photosynthesis was lead by boron application in peanut plants. This is why the application of micronutrients (B) in the soils is increasing gradually. But the boron application needs to be done carefully. Even little higher amount of application may result in toxicity which reduces groundnut yields. However the amount of boron recommended on a soil test report improves good kernel development in groundnut, increase the growth, development and at the same time to increase the yield of crops. The

application of B also promotes the absorption of N by groundnut and increases the plant height, plant dry weight and the total number of pods.

Depletion of secondary and micronutrients necessitates periodic or yearly supply of these nutrients. Further, we should replenish secondary and micronutrients appropriately because their dearth can hinder groundnut response to major nutrients, irrigation and several other agronomic practices. The nutrient requirement of groundnut is high especially at pegging and pod development stages. The requirement at these stages cannot be fulfilled merely by soil application alone and need to be supplemented through foliar application.

The optimization of mineral nourishment is the way to upgrade the generation of groundnut production as it has high supplement necessity and recently released high yielding groundnut varieties evacuate still more macro and micronutrients from the soil. On the contrary, groundnut growing farmers in most parts of the semi-arid region use very less micronutrient fertilizers and sometimes only one or two nutrients resulting in severe mineral nutrient deficiencies. Lacking and irregular utilization of supplements is one of the key points responsible for low yield in groundnut. Keeping in view of the importance of calcium and boron the present study is proposed to study the effect of calcium and boron on growth, dry matter partitioning and yield of groundnut.

Objectives

1. To assess the efficacy of both soil and foliar application of Ca and B on growth, drymatter partitioning and yield of groundnut.
2. To assess the efficacy of Ca and B through foliar application above on growth, drymatter partitioning and yield of groundnut.
3. To study the cumulative effect of Ca and B on yield attributes.

Chapter ~ II



Review of Literature

Chapter – II

REVIEW OF LITERATURE

Researches worked extensively on **“Effect of calcium and boron on growth, drymatter partitioning and yield of groundnut”**. The present study showed concordance with the earlier findings. Hence, literature on similar crops is also included wherever necessary.

2.1 EFFECT OF CALCIUM AND BORON ON PHYSIOLOGICAL AND GROWTH PARAMETERS

2.1.1 Field Emergence Per cent

Maiti and Moreno-Limon (2000) reported that high germination and seedling establishment contribute directly to the crop yield.

Hadas and Russo (1974) further observed that a good stand can be ensured by a complete and fast germination and if germinating seed is slow in taking up water, emergence is impaired and consequently the final stand is reduced.

2.1.2 Days to 50% Flowering

Lim and Hamdan, (1984) observed that plants whose flowering was stimulated initiated the largest percentage of pegs and high growth rate of intact pegs but plants with the least number of flowers formed the lowest percentage of pegs, and the peg growth rate declined by 50 percent.

Fruiting efficiency depends on the pattern of flowering (number of flowers at different period of flowering), which is more important than total number of flowers per plant (Lee et al., 1972).

Patil *et al.* (2018) reported that days to 50 per cent flowering and days to maturity significantly delayed and the plants took more number of days for 50 per cent flowering (42.59 days) and crop maturity (106.36 days) in (site specific nutrient management) SSNM for target yield of 2.5 t ha⁻¹ + Sulphur + borax + ZnSO₄ compared to recommended package (NPK + FYM) (35.24 and 100.91 days for 50 per cent flowering and maturity, respectively)

2.1.3 Plant Height

Maximum plant height (23.16 cm) was recorded with combined application of NPK – 25:50:20 kg ha⁻¹ + gypsum @ 200 kg ha⁻¹) followed by NPK @ 25:50:20 kg ha⁻¹ + gypsum @ 100 kg ha⁻¹. The lowest values was recorded with control (Yadav *et al.*, 2015).

Foliar spray of 2.0% urea + DAP + MOP combination produced taller plant (23.94 cm) compared to control. However, it was on par with all other foliar treatments except 1.5% MOP 20.76 cm and 6.34 plant⁻¹ respectively (Vinod Kumar and Salakinkop, 2017).

Yenagi *et al.* (2015) revealed that application of 37.5 kg borosan along with 100% recommended NPK at the time of sowing recorded significantly tallest plants, however, it was comparable with split application of 12.5 kg ha⁻¹ boroson at sowing + 12.5 kg ha⁻¹ boroson at 20 DAS. The shortest plants were observed with control.

Kumar *et al.* (2016) found that the plant height of groundnut differed significantly due to soil application of nutrients at different crop growth stages. At harvest, significantly higher plant height (25.93 cm) was recorded with soil application of RDF (25:75:25 kg NPK ha⁻¹ + 10 t FYM ha⁻¹ + 500 kg gypsum ha⁻¹) + 20 kg MgO ha⁻¹ + 5 kg borax ha⁻¹ while the lowest plant height (20.53 cm), was recorded in control

Kabir *et al.* (2013) reported that highest plant height was obtained for highest level of three fertilizers P (50 kg ha⁻¹), Ca (110 kg ha⁻¹) and B (2.5 kg ha⁻¹).

2.1.4 Leaf Area

Highest leaf area was recorded with the nitrogen dose of 40 kg per acre combined with 25 ppm boron in fababean (Mahmoud *et al.*, 2006).

The highest leaf area (814.95 cm²) was observed with the application fertilizer based on SSNM for target yield of 2.5 t ha⁻¹ + Sulphur (10 kg ha⁻¹) + Boron (10 kg ha⁻¹) + Zinc (12.50 kg ha⁻¹) over recommended dose of fertilizer (RDF) is 25:75:37.50 kg NPK ha⁻¹ + FYM @ 10 t ha⁻¹ which recorded 576.19 cm² leaf area. The extent of increase in leaf area was 41.4 per cent over recommended package (Patil *et al.*, 2018)

2.1.5 Total Drymatter

Harris and Brolman (1966) also reported that shoot dry weight increased with the application of boron in peanut.

Geeta *et al.* (2001) reported that the main root length and root dry weight in groundnut were significantly influenced by the seed treatment with calcium + Zinc + Manganese.

Elayaraja and Singaravel (2012) reported that highest dry matter production (5296 kg ha⁻¹) was released with 150 percent NPK + zinc sulphate @ 30 kg ha⁻¹ + borax @ 15 kg ha⁻¹. The lowest dry matter production (3473 kg ha⁻¹) was recorded in control.

Total dry weight plant⁻¹ was significantly enhanced by all the three fertilizers (P, Ca and B). The highest dry matter (33.0 g plant⁻¹) was recorded with P (50 kg ha⁻¹), Ca (110 kg ha⁻¹) and B (2.5 kg ha⁻¹) at 100 DAS and the lowest one (25.90 g of total dry weight) was found at control (P₀ × Ca₀ × B₀) (Kabir *et al.*, 2013).

Jafar Ullah *et al.* (2016) reported that pod dry weight plant^{-1} was adversely affected in control but with the application of varying levels of boron in peanut a significant increment in pod dry weight plant^{-1} was found. The Results showed that 2 kg B ha^{-1} produced the highest value of pod dry weight plant^{-1} compared to that of control and he recorded var; BARI Chinabadam-8 produced maximum pod dry weight.

Kumar *et al.* (2016) found that the drymatter of groundnut differed significantly due to soil application of nutrients at different crop growth stages. At harvest, significantly total dry matter accumulation per plant ($12.20 \text{ g plant}^{-1}$) was recorded with soil application of RDF ($25:75:25 \text{ kg NPK ha}^{-1} + 10 \text{ t FYM ha}^{-1} + 500 \text{ kg gypsum ha}^{-1} + 20 \text{ kg MgO ha}^{-1} + 5 \text{ kg borax ha}^{-1}$) while the lowest total dry matter accumulation was recorded in control (4.8 g plant^{-1}).

Conjunctive application of fertilizer based on site specific nutrient management (SSNM) for target yield of $2.5 \text{ t ha}^{-1} + \text{Sulphur } (10 \text{ kg ha}^{-1}) + \text{Boron } (10 \text{ kg ha}^{-1}) + \text{Zinc } (12.50 \text{ kg ha}^{-1})$ recorded pod weight plant^{-1} (12.05 g) over recommended dose of fertilizer (RDF) is $25:75:37.50 \text{ kg NPK ha}^{-1} + \text{FYM @ } 10 \text{ t ha}^{-1}$ (Patil *et al.*, 2018)

2.1.8 Growth Parameters

Brolman (1966) stated that due to the application of boron root weight increased.

Kabir *et al.* (2013) reported that LAI was significantly affected by P and Ca individually but not affected by B alone and the interaction effect of P, Ca and B on LAI was not significant

He explained that Crop growth rate was significantly enhanced by all the three fertilizers (P, Ca and B). The highest crop growth rate ($22.22 \text{ g m}^{-2} \text{ d}^{-1}$) was recorded with P (50 kg ha^{-1}), Ca (110 kg ha^{-1}) and B (2.5 kg ha^{-1}) at 100 DAS and the lowest one ($16.89 \text{ g m}^{-2} \text{ d}^{-1}$) was found at control ($P_0 \times Ca_0 \times B_0$)

Vinod Kumar and Salakinkop (2017) reported that leaf area index (2.97) leaf area duration (40.69 days) total dry matter production (40.22 g plant⁻¹) net assimilation rate (0.136 g dm⁻² day⁻¹) and crop growth rate (0.124 g dm⁻² day⁻¹) were higher in foliar spray of 2.0 % urea + DAP + MOP combination compared with control in groundnut crop.

Application of Boron at 2 kg ha⁻¹ produced significantly higher leaf mass ratio and root mass ratio at all growth stages. The highest NAR was recorded from 2 kg ha⁻¹ boron application at 30 DAP, at the rest of sampling dates control treatment produced the highest NAR (Quamruzzaman *et al.*, 2017).

2.2 EFFECT OF CALCIUM AND BORON ON ROOT NODULATION PARAMETERS

Tahir *et al.* (2013) evaluated the production of mungbean (*Vigna radiate* L.) in response to sulphur and boron and showed that sulphur at 24 kg ha⁻¹ and boron 4 kg ha⁻¹ significantly increased number of nodules.

Naiknaware *et al.* (2015) revealed that the groundnut crop fertilized with 8 kg boron showed remarkably number of nodules at 50-55 DAS (102.00) was increased significantly when crop fertilized with 8 kg B ha⁻¹ and application of 40 kg ha⁻¹.

2.3 EFFECT OF CALCIUM AND BORON ON BIOCHEMICAL PARAMETERS

Guerrero *et al.* (2014) reported that amino acids, the end product of nitrate assimilation, have been shown to act as negative effects with regard to the synthesis of active NR. Thus, it was possible that the accumulation of free amino acids in leaves on boron-deficient plants resulted in a feedback inhibition of nitrate reductase synthesis.

Shen *et al.* (1993) indicated that nitrate reductase activity in the leaves of rape plants (Ningyou No. 7 and Ningyou No. 8) grown on nutrient solutions increased markedly with increasing boron concentration (from 0.025 $\mu\text{g B/mL}$ to 0.1 $\mu\text{g B/mL}$).

Shete *et al.* (2018) reported that highest oil content (45.4%) and oil yield (1016 kg ha^{-1}) was recorded with foliar spray of 2% $\text{Ca (NO}_3)_2$ over control.

Among the treatments tried, the application of 2.5 kg ha^{-1} boroson at sowing + 12.5 kg ha^{-1} boroson at 20 DAS recorded higher oil content (35.9%) in groundnut, however, it was at par with boroson application treatments except control. (Yenagi *et al.*, 2015).

Nayak *et al.* (2009) observed that higher oil content (38.4%) in groundnut was obtained by NPK fertilizer along with soil application of zinc @ 5 kg ha^{-1} + boron @ 1.0 kg ha^{-1} + molybdenum @ 0.5 kg ha^{-1} in sandy loam soils of Bhubaneswar, Odisha.

Singh and Singh (2006) conducted field experiments on soybean cv. Birsa to determine the optimum level of S (0, 20, 40 and 60 kg ha^{-1}) and B (0, 0.5, 1.0 and 2.0 kg ha^{-1}). The oil and protein contents in soybean seed increased with successive increase of S and B levels. Increasing levels of S significantly increased the protein content in soybean seed. The maximum protein content (37.79%) in seed was recorded at 40 $\text{kg S} + 0.5 \text{ kg B ha}^{-1}$.

Shankhe *et al.* (2004) studied the effects of boron and molybdenum, applied as soil or foliar treatment on the yield and quality of groundnut (TAG-24). Foliar application of boron (0.5% borax) + soil application of molybdenum (1 kg ha^{-1}) along with recommended dose of fertilizers significantly increase protein content from 27.37 to 29.31% and oil content from 46.23 to 48.45 per cent were observed.

2.4 EFFECT OF CALCIUM AND BORON ON REPRODUCTIVE EFFICIENCY

The conversion of flowers to mature pods was the most important factor contributing to high pod yield (Songsri *et al.*, 2009).

Pod number and eventual crop yield is determined by the number of floral buds that form flowers, the number of flowers that are fertilized and produce pegs, and the number of pegs that successfully penetrate the soil surface and produce pods (Prasad *et al.*, 1999).

Corlett *et al.* (1992) and Öneilli, (2004) also indicated that the percentage of flowers turned to pods, but not the number of flowers, is important for determining the yield of groundnut. The flower to peg ratio and peg to pod ratio were good indicators of pod yield and if the relationship between the beginning of the first flowering and maturity is known, the time of harvest can be estimated for healthy crops.

The groundnut crop fertilized with 8 kg boron showed remarkably increased plant growth parameters viz., No. of pegs per plant (43.88) was increased significantly when crop fertilized with 8 kg B ha⁻¹ and application of 40 kg ha⁻¹(Naiknaware *et al.*, 2015)

2.5 EFFECT OF CALCIUM AND BORON ON YIELD ATTRIBUTES

Subrahmaniyan *et al.* (2001) reported that the response of groundnut was highly significant to the applied micronutrients. Combined application of ZnSO₄ @ 5 kg ha⁻¹ + borax @ 5 kg ha⁻¹+ FeSO₄ @ 10 kg ha⁻¹ recorded the maximum yield compared to other treatments under sandy loam soils with low fertility status.

Bagewadi *et al.* (2003) observed that, the seed treatment with different micronutrients (Mo, B and Zn @ 8, 6 and 8 g kg⁻¹ seed, respectively) in addition to RDF gave the highest pod yield of groundnut (2958 kg ha⁻¹) over control (1967.46 kg ha⁻¹).

Nayak *et al.* (2009) observed that maximum yield (1.53 t ha^{-1}) of groundnut was obtained by NPK fertilizer along with soil application of zinc @ 5 kg ha^{-1} + boron @ 1.0 kg ha^{-1} + molybdenum @ 0.5 kg ha^{-1} in sandy loam soils of Bhubaneswar, Odisha.

The yield of dry pod (32.6 q ha^{-1}), kernel (22.36 q ha^{-1}) and haulm (39.1 q ha^{-1}) of groundnut were increased significantly with foliar spray of 2% $\text{Ca}(\text{NO}_3)_2$ which was at par with 2 % 19:19:19 spray and significantly superior over control (Shete *et al.*, 2018)

Patil *et al.* (2018) reported that fertilizer based on SSNM for target yield of 2.5 t ha^{-1} + Sulphur (10 kg ha^{-1}) + Boron (10 kg ha^{-1}) + Zinc (12.50 kg ha^{-1}) produced significantly higher pod yield (2565 kg ha^{-1}) and haulm yield (3449 kg ha^{-1}) over recommended dose of fertilizer ($25:75:37.50 \text{ kg NPK ha}^{-1}$ + FYM @ 10 t ha^{-1}) 2060 kg ha^{-1} and 2731 kg ha^{-1} pod and haulm yield, respectively.

Quamruzzaman *et al.* (2017) noted that Boron was highly responsible for better yield of groundnut and a significant positive seed yield was recorded from application of boron. The highest groundnut seed yield (1.53 t ha^{-1}) was found from boron at 2 kg ha^{-1} and the lowest from control.

Meki chirwa *et al.* (2016) reported that the response of groundnut to the combined application of N 20 kg , P 30 kg and Ca 100 kg ha^{-1} resulted in increase in kernel yield by 65.5 per cent and haulm yield by 83.4 per cent compared to the control.

Yenagi *et al.* (2015) reported that the groundnut crop responded linearly up to 37.5 kg ha^{-1} boron application. Application of 37.5 kg boron along with 100% recommended NPK at the time of sowing recorded significantly highest pod yield of 2180 kg ha^{-1} and haulm yield of 5200 kg ha^{-1} as compared to 100% recommended dose NPK (1435 and 3300 kg ha^{-1} of pod and haulm yield, respectively). The yield increase was to the tune of 51.92% over control.

Subhendu Mandal *et al.* (2005) observed that gypsum application for summer and rainy season groundnut at West Bengal sandy loam soils @ 400 kg ha⁻¹ recorded maximum gross returns and B : C ratio.

Noor *et al.* (1997) and Venkatesh *et al.* (2006) observed an increment in pod weight, seed index and pod yield of groundnut with foliar application of Boron.

Elayaraja and Singaravel (2012) revealed that application of 22.5:51:81 NPK kg ha⁻¹ + Borax @ 15 kg ha⁻¹ along with composted coirpith @ 12.5 t ha⁻¹ increased the nutrient availability, growth and yield of groundnut. The yield increase recorded with borax application @ 15 kg ha⁻¹ along with composted coir pith was 18.47 percentage of pod and 13.71 percentage of haulm compared to control.

2.7 EFFECT OF CALCIUM AND BORON ON NUTRIENT CONTENT

Study revealed that application of different levels of boron significantly influenced the nutrient uptake in groundnut pods and haulm. The highest nitrogen content in pod (4.12%) and haulm (1.46%), Phosphorous content in pod (0.64%) and haulm (0.38%), Potassium content in pod (0.76%) and haulm (0.96%) and boron content in pod (19.16 mg kg⁻¹) and haulm (14.05 mg kg⁻¹) was recorded with 2 kg B ha⁻¹ followed by 1 kg B ha⁻¹ in clay loam soils of Gujarat (Patel, 2018).

Groundnut responded to the application of N 20 kg, P 30 kg, K 40 kg, Ca 100 kg and Boron 1 kg ha⁻¹ resulted in increase in Ca uptake by 21%, N uptake by 55.5 per cent and P uptake by 51 per cent compared to the control (Meki Chirwa *et al.*, 2016)

Abd EL-Kader *et al.* (2013) indicated that, application of sulfur (S) and foliar spraying with micronutrient (Zn and B) together had the significant effect on peanut seed yield and its attributes as well as seed quality. Their

highest values were obtained when plants treated with sulfur (S) combined with foliar spraying with (Zn + B). Meanwhile, the highest amount of nutrient contents were obtained with 200 kg S/fed. combined with foliar spraying with 3.33 g ($\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$)/L/plot, (2.7 kg Zn SO_4 / fed) and 0.83 g ($\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$) /L/plot (0.7 kg borax /fed)), for Zn and B respectively.

Mohapatra and Dixit (2010) concluded that with application of FYM @ 5 t ha⁻¹ + 75% RDF + gypsum @ 250 kg ha⁻¹ + boron @ 1 kg ha⁻¹ showed highest uptake of nutrients (151.4- 17- 58.6 -10.8 -0.07 kg N-P-K-S-B ha⁻¹). Whereas calcium uptake was highest (48.6 kg ha⁻¹) with 5 t FYM ha⁻¹ + 75% RDF + lime + boron @1 kg ha⁻¹.

Shankhe *et al.* (2004) revealed that foliar application of boron (0.5% borax) + soil application of molybdenum (1 kg ha⁻¹) along with recommended dose of fertilizers was found to be superior in increasing production levels as well as availability of boron and molybdenum and their uptake by groundnut over recommended doses of fertilizers alone.

The positive influence of gypsum fertilization owing to be the results of improved nutritional environment in the rhizosphere as well as in the plant system which leads to translocation of N, P and S to reproductive parts which ultimately increased the concentration of these nutrients in kernel (Alcordero and Rechcigl, 1993).

Ismail *et al.* (1998) also reported increased N, P and K uptake in groundnut due to gypsum application. Plant requires calcium in large amounts and the calcium content of healthy plant tissues is generally more than 0.1 per cent -1 per cent of dry matter (White, 2001).

Calcium plays a variety of structural roles in cells. Calcium also functions as a second messenger in plant growth, development and adaptation to environment (White and Broadley, 2003).

Application of gypsum at 250 kg ha⁻¹ significantly increased kernel N, P K, Ca, Mg and S concentration over no gypsum (Rao and Shaktawat, 2005).

Availability of calcium (Ca) in the pod environment of the groundnut plant is one of the most important soil fertility factors influencing the success of reproductive growth of groundnut, and hence pod and kernel yields (Zharare *et al.*, 2009).

O'Neill *et al.* (2004) reported that boron supply increased the uptake and reutilization of N, P, K, Na, Ca and other nutrients in mungbean.

Harmankaya *et al.* (2008) reported that the leaf B concentration of chickpea genotypes increased by 12 per cent in B soil application and 37 per cent in B foliar application over control in B deficient calcareous soils.

Nandini *et al.* (2012) revealed that soil application of boron @ 1.5 kg ha⁻¹ resulted in higher total uptake in soybean.

Ganie *et al.* (2014) reported a marked increase in N, P, K, S and B concentration and uptake in pods and stover at pod picking and seeds and stover at harvesting stages of the crop (French bean) with the application of boron. The contents and uptake of these nutrients increased significantly by increasing boron level up to 1.5 kg ha⁻¹.

Chapter ~ III



Material and Methods

Chapter – III

MATERIAL AND METHODS

The details of material and methods adopted in the present investigation on "**Effect of Calcium and Boron on Growth, drymatter partitioning and yield of groundnut**" are briefly described in this chapter.

3.1 LOCATION OF EXPERIMENTAL SITE

The field experiment was carried out in Field No. 99 of Dryland Farm, S.V. Agricultural College, Tirupati campus of Acharya N.G. Ranga Agricultural University, which is geographically situated at 13.5°N latitude and 79.5°E longitude, with an altitude of 182.9 m above the mean sea level in the Southern Agro-Climatic Zone of Andhra Pradesh.

3.2 SOIL CHARACTERISTICS

Soil samples were drawn at random from 0 to 30 cm depth from the experimental field. The composite soil samples were analyzed for various physico-chemical properties.

The particulars of physico-chemical properties and methods employed for each of them are presented in Table 3.1. The soil was sandy loam in texture, neutral in soil reaction, low in available nitrogen and organic carbon, high in phosphorus and medium in potassium.

3.3 METEOROLOGICAL DATA

The weather data during the crop period (01-07-2018 to 28-10-2018) recorded at S.V. Agricultural College meteorological observatory are presented in Table 3.2 and depicted in Fig. 3.1.

Table 3.1. Physico-chemical properties of soil of the experimental field

Particulars	Soil depth (cm)	Method adopted
	0-30 cm	
I. Physical characteristics		
Coarse sand (%)	49.2	Bouyoucos Hydrometer (Piper, 1950)
Fine sand (%)	27.5	
Silt (%)	08.2	
Clay (%)	15.1	
Soil texture	Sandy, Loam	
II. Chemical characteristics		
Soil pH (1.0: 2.5 soil water suspension)	High	Glass electrode pH meter (Jackson, 1973)
Electrical Conductivity (dS m ⁻¹)	Low	Conductivity bridge (Jackson, 1973)
Organic carbon (%)	Low	Wet digestion method (Walkley and Black, 1934)
Available N (kg ha ⁻¹)	Low	Alkaline potassium permanganate method (Subbiah and Asija, 1956)
Available P ₂ O ₅ (kg ha ⁻¹)	High	Olsen’s method (Olsen <i>et al.</i> , 1954)
Available K ₂ O (kg ha ⁻¹)	Low	Flame photometry (Jackson, 1973)
Available Calcium (cmol (p ⁺) kg ⁻¹)	High	EDTA titration method
Available Boron (ppm)	Low	Azomethine-H method (John <i>et al.</i> , 1975).

Table 3.2. Standard week wise meteorological data during the crop growth period of groundnut (01-07-2018 to 28-10-2018)

Standard week	Date and Month	Temperature (°C)				Mean relative humidity (%)		Rainfall (mm)		Number of rainy days		Mean evaporation (mm day ⁻¹)		Mean bright sunshine (hours day ⁻¹)	
		Maximum		Minimum											
		A	DN	A	DN	A	DN	A	DN	A	DN	A	DN	A	DN
		23	04 Jun – 10 Jun	35.8	-1.57	26.90	0.28	51.20	-23.295	66.2	49.29	2	0	6.90	-0.87
24	11 Jun – 17 Jun	35.5	-1.35	26.40	-0.14	59.60	-15.22	18.8	5.08	2	1	5.90	-1.39	3.80	-0.85
25	18 Jun – 24 Jun	35.9	-0.52	26.10	-0.27	58.80	-14.575	10.8	-12.13	2	0	5.70	-2.04	5.60	0.81
26	25 Jun – 01 Jul	36.5	-0.05	26.60	0.16	50.05	-21.1	16.2	-2.56	2	1	5.70	-1.78	2.40	-2.20
27	02 Jul – 08 Jul	36.5	0.75	26.90	0.37	54.85	-14.2	12.6	-7.44	2	1	6.70	0.12	3.10	-0.58
28	09 Jul – 15 Jul	33.8	-0.71	26.10	0.17	59.75	-7.745	26.2	1.38	3	2	5.30	-1.18	2.40	-1.98
29	16 Jul – 22 Jul	36.0	1.20	26.40	0.84	52.50	-14.86	7.00	-17.43	1	-1	6.10	-0.03	4.50	0.90
30	23 Jul – 29 Jul	38.3	3.83	27.30	2.11	47.30	-18.055	5.00	-21.82	1	-1	8.10	2.12	9.30	5.64
31	30 Jul – 05 Aug	35.1	0.91	26.50	0.86	57.20	-8.04	43.8	29.41	1	0	6.50	0.86	5.10	1.94
32	06 Aug – 12 Aug	32.9	-2.42	25.10	-0.60	70.04	7.235	57.60	38.73	3	2	4.60	-2.08	4.20	-0.21
33	13 Aug – 19 Aug	32.6	-1.55	24.30	-0.43	72.10	11.065	70.60	28.26	3	0	3.10	-2.52	3.50	-1.15
34	20 Aug – 26 Aug	33.2	-0.78	23.10	-1.74	74.20	19.245	152.80	112.84	5	3	5.10	-0.06	3.40	-1.78
35	27 Aug – 02 Sep	32.6	-0.93	24.30	0.03	71.30	14.69	95.80	61.60	2	0	3.00	-1.64	3.80	-0.06
36	03 Sep – 09 Sep	33.1	-0.46	24.20	-0.16	77.31	17.515	60.60	23.24	3	1	4.80	-0.30	6.50	2.50
37	10 Sep – 16 Sep	28.0	-5.43	24.50	0.20	73.00	16.695	5.40	-21.22	1	-1	3.60	-1.01	5.20	0.45
38	17 Sep – 23 Sep	33.2	-0.54	23.70	-0.93	67.30	11.165	37.60	17.62	3	2	5.00	-0.07	4.90	0.09
39	24 Sep – 30 Sep	30.4	-4.09	23.70	-0.87	81.00	26.19	65.80	39.72	4	3	3.30	-1.68	0.90	-4.64
40	01 Oct – 07 Oct	31.7	-1.77	20.50	-3.29	78.50	23.54	135.80	108.01	6	5	5.10	0.66	5.60	0.36
41	08 Oct – 14 Oct	32.2	-1.65	24.00	0.93	76.55	23.62	46.00	21.38	4	3	3.20	-1.10	4.70	-0.68
42	15 Oct – 21 Oct	32.0	-1.35	23.00	0.61	75.25	21.525	23.40	-1.97	2	0	2.40	-2.21	3.20	-2.50
43	22 Oct – 28 Oct	32.5	0.58	23.00	1.14	65.50	16.005	0.40	-45.13	0	-2	5.00	0.83	5.00	0.06

A : Actual; DN : Deviation from decennial mean

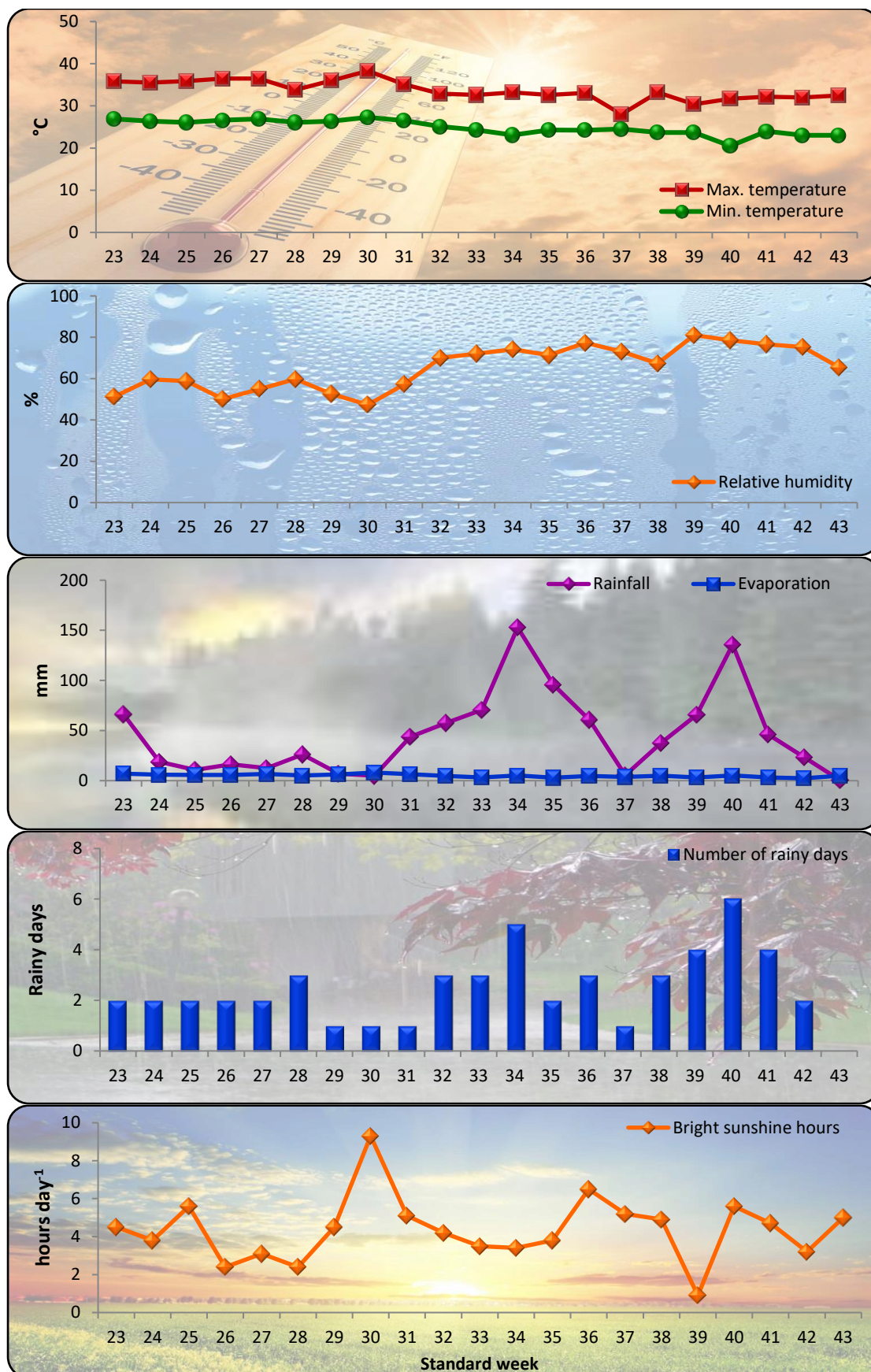


Fig 3.1. Standard week wise meteorological data during the crop growth period (01-07-2018 to 28-10-2018)

3.3.1 Rainfall

A total rainfall of 367.8 mm was received with 23 rainy days during the crop growth period from 01-7-2018 to 28-10-2018.

3.3.2 Temperature

The weekly mean maximum temperature during the crop period (01-7-2018 to 28-10-2018) ranged from 32 to 37.2°C. The weekly mean minimum temperature during the crop growth period varied from 20 to 28°C.

3.3.3 Sun Shine Hours

The weekly mean bright sunshine hours day⁻¹ during the crop growth period (01-7-2018 to 28-10-2018) ranged from, 0.3 to 7.6 with an average of 4.54 hr.

3.3.4 Relative Humidity

The weekly mean relative humidity during the crop growth period (01-7-2018 to 28-10-2018) ranged from 39.6 to 80.62 per cent, with an average of 60.13 per cent.

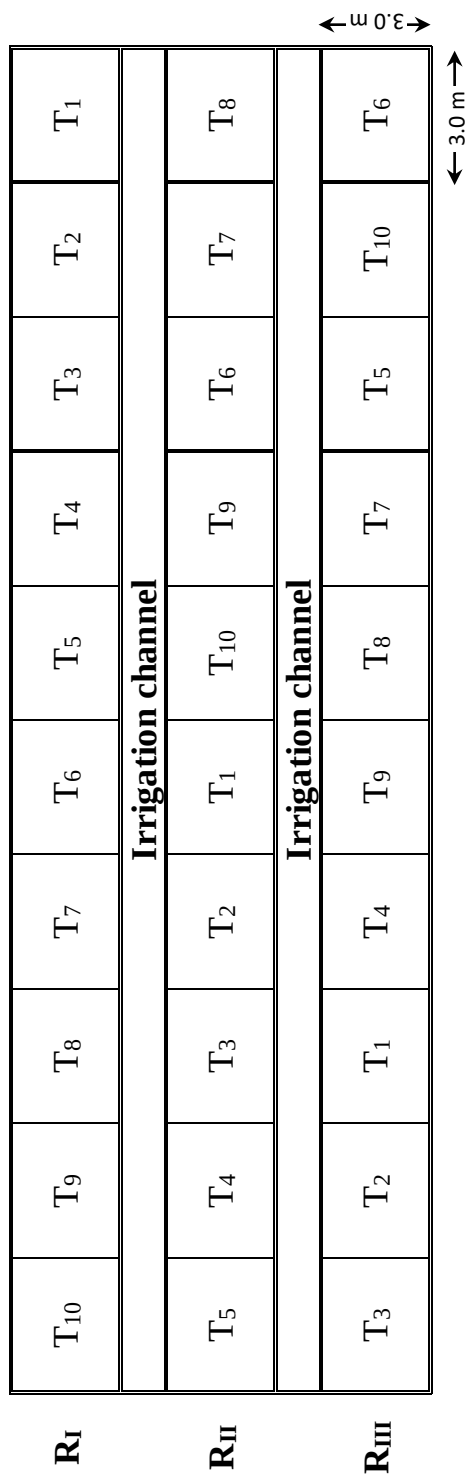
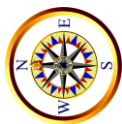
3.3.5 Mean Evaporation

During the crop period (01-7-2018 to 28-10-2018), the weekly mean evaporation (USWB Class-A Open Pan evaporimeter) ranged from 3.7 to 7.0 mm day⁻¹, with an average of 5.59 mm day⁻¹.

3.4 EXPERIMENTAL DETAILS

3.4.1 Design and Layout

The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and replicated thrice as per the details given below. The details of layout plan are given in Fig. 3.2.



Treatments

T ₁ : Control	T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%

Fig. 3.2. Lay-out plan of the experimental field



Plate 1. Field view of experimental layout

3.4.2 Crop : Groundnut

Variety : Dharani

Treatments : Ten

T₁ : Control

T₂ : RDF (N, P, K-20, 50, 40 kg ha⁻¹)

T₃ : RDF+ Gypsum application as basal @ 500 kg ha⁻¹

T₄ : RDF+ Borax application as basal @ 10 kg ha⁻¹

T₅ : RDF+ Basal application of Gypsum @ 500 kg ha⁻¹ + Borax @10 kg ha⁻¹ (T₃+T₄)

T₆ : RDF+ Gypsum application at 35 DAS @ 500 kg ha⁻¹ to soil.

T₇ : RDF+ Foliar application of Borax at 35 DAS @ 0.1% (1 g lit⁻¹)

T₈ : RDF+ Foliar application of Calcium Nitrate at 35 DAS @ 0.3%

T₉ : RDF+ Gypsum application to soil during flowering @ 500 kg ha⁻¹ + Foliar application of Borax at 35 DAS @ 0.1% (1 g lit⁻¹) (T₆ + T₇).

T₁₀ : RDF+ Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3% (T₇ + T₈)

3.5 CULTIVATION DETAILS

3.5.1 Preparatory Cultivation

The experimental field was ploughed with tractor drawn cultivator followed by bullock drawn blade harrow. The field was properly levelled with leveling plank.

3.5.2 Fertilizers

A uniform dose of 20 kg N, 50 kg P₂O₅ and 40 kg K₂O ha⁻¹ was applied through urea, single super phosphate and muriate of potash, respectively to all the plots. The entire dose of Nitrogen, phosphorous, potassium were applied as basal at the time of sowing.

3.5.3 Seeds and Sowing

The seed material (variety Dharani) was obtained from Regional Agricultural Research Station, Tirupati. Seeds were treated with Dithane M- 45 @ 3 gm kg⁻¹ of seed. Seeds were sown in lines by dibbling one seed per hill with a spacing of 30 cm × 10 cm on 1st July during *Kharif* 2018.

3.5.4 Weeding

Hand hoeing was taken up twice at 20 and 40 DAS for the control of weeds during critical period of crop weed competition and earthing up of the soil was done around the plant after weeding.

3.5.5 Plant protection

Spraying of Monocrotophos @ 1.6 ml l⁻¹ of water for the control of leaf miner at 25 DAS and emamectin benzoate @ 2 g l⁻¹ of water at 50 DAS respectively.

3.5.6 Sampling procedure

Sampling was done at 20 days interval. For this purpose three plants from each treatment or plot were dug out without roots. The plants were thoroughly washed to free from dirt and surface dried with blotting paper. The leaves, stems and pods were removed separately. Different plant parts were dried in hot air oven at 100°C for 15 minutes and then at 80°C for 48 hours until they attained constant weights.

3.6 OBSERVATIONS RECORDED

3.6.1 Physiological and growth attributes

All the morphological attributes were recorded at 20 days interval from date of sowing to harvest.

3.6.1.1 Field emergence per cent

The total rate of emergence is calculated as field emergence index (Baskin, 1969)

$$\text{Emergence Index} = \frac{n_1}{dn_1} + \frac{n_2}{dn_2} + \dots + \frac{n_x}{dn_x}$$

where,

n_1 : number of 1seeds emerged in day first (1st)

dn_1 : number of days from day of sowing

n_x : number of seeds emerged at final day

dn_x : number of days to final count

3.6.1.2 Days to 50 per cent flowering

The number of days required to 50 per cent flowering was determined as when 50 per cent of the plants in each plot produced flowers.

3.6.1.3 Plant height

Three plants were collected randomly and measured the plant height from base of the plant to shoot tip and expressed in centimeters (cm).

3.6.1.4 Leaf area

After separation of leaves from the plant, leaf area was estimated using leaf area meter (Li-COR model LI 3000) and expressed as cm² plant⁻¹.

3.6.1.5 Total dry matter

The dry weights of oven dried leaves, stem, root and pods were recorded and expressed as total dry matter and expressed as g plant⁻¹.

3.6.2 Growth Parameters

3.6.2.1 CGR (Crop Growth Rate) (g m⁻² day⁻¹):

Crop Growth Rate indicates the dry matter production by a plant community on an unit land in an unit of time. It is used for the estimation of production efficiency of a crop. Watson (1952) used the term CGR. It is influenced by leaf area index (LAI), leaf photosynthetic rate and leaf angle with stem. By using the total dry matter of the plant m⁻², crop growth rate was calculated as per the formula.

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{P}$$

where,

W_1 and W_2 are total dry weight of plant at times t_1 and t_2 and

P is the land area calculated per m².

3.6.2.2 NAR (Net Assimilation Rate) (g dm⁻² day⁻¹)

Net Assimilation Ratio describes the net production efficiency of the assimilatory apparatus. Earlier it was termed as unit leaf rate by Briggs, Kidd and West (1920). Later in 1926 Gregory termed ULR as NAR.

$$NAR = \frac{(\log_e A_2 - \log_e A_1)}{(A_2 - A_1)} \times \frac{(W_2 - W_1)}{(t_2 - t_1)}$$

3.6.2.3 Leaf area index (LAI)

Leaf area index denotes cumulative green leaf area over unit land area. Leaf area index was computed taking into account, the area occupied by each plant as per the following formula (Watson, 1952). The leaf area index was calculated by dividing the total leaf area with the corresponding ground area.

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

3.6.2.4 LAD (Leaf area duration) (Days)

Leaf area integrated over time period is called leaf area duration. It takes account of both of the magnitude of the leaf area and its persistence in time. In effect, it represents the leafiness of the crop's growing period.

$$LAD = \frac{(LAI_1 + LAI_2)(t_2 - t_1)}{2}$$

where,

LAI_1 : Leaf area index at time interval t_1 and

LAI_2 : Leaf area index at time interval t_2 .

3.6.2.5 LAR (Leaf Area Ratio)(cm^2g^{-1}) :

It gives the relative size of the assimilatory apparatus. Hence it is called capacity factor. It represents the leafiness characters of crop plants.

$$LAR = \frac{LA}{W}$$

where,

LA = Leaf area

W = Total plant dry weight

3.6.2.6 RWR (Root Weight Ratio)

Root Weight Ratio is expressed as the dry weight of roots to whole plant dry weight and is expressed as $g\ g^{-1}$ (Kvet *et al.*, 1971).

$$LWR = \frac{\text{Root dry weight}}{\text{Plant dry weight}}$$

3.6.2.7 LWR (Leaf Weight Ratio) ($g\ g^{-1}$)

Leaf Weight Ratio is expressed as the dry weight of leaves to whole plant dry weight and is expressed as $g\ g^{-1}$. (Kvet *et al.*, 1971)

$$LWR = \frac{\text{Leaf dry weight}}{\text{Plant dry weight}}$$

3.6.2.7 Drymatter partitioning (%)

Plant samples were collected from the field and separated the leaves, shoot and root. These plant parts were dried in oven at 100°C for 15 minutes followed by 80°C for 2 days till they attained constant weights. Drymatter were recorded individually. Calculate the drymatter partitioning by using of dry weights and following formula (Talwar *et al.*, 1987). Total drymatter production ($g\ plant^{-1}$) was obtained by adding dry weights of individual plant parts of root, stem, leaves and pods.

$$= \frac{\text{Dry weight of individual plant part}}{\text{Total plant dry weight}} \times 100$$

3.7 ROOT NODULATION PARAMETERS (20, 30, 50 DAS)

3.7.1 Number of nodules on root

Three plants were tagged ,plants were uprooted carefully and soil mass embodying the roots of the plants was washed off in running water. The total number of nodules per plant was counted and average was calculated. Intensity of nodules was noticed on lateral and primary roots.

3.8 BIOCHEMICAL PARAMETERS

3.8.1 Nitrate Reductase in Leaves (20, 30, 50 DAS)

The enzyme nitrate reductase was estimated as per the method given by Sadasivam and Manickam (1992) by incubating 200 mg leaf sample in the test tube containing 2 ml Potassium phosphate buffer, 1 ml Potassium nitrate and 0.1 ml n-propanol for one hour in dark. Then the incubated tubes were kept in water bath for 30 minutes at 30°C and for 2 minutes at 100°C. 400 µl of the extract cooled to room temperature was added to test tube containing 1 ml of sulphanilamide and 1 ml of N-(1 naphthyl) Ethylenediamine Dihydrochloride. The final volume was made to 8 ml with distilled water. Blank was also run without the enzyme extract. The sample and blank tubes were thoroughly shaken and left for 15 minutes. Absorbance was recorded at 540 nm.

3.8.1 Total Carbohydrates in Kernels (g g⁻¹)

Total carbohydrates were estimated by Anthrone method given by Sadasivam and Manickam (1992). Carbohydrates are first hydrolyzed into simple sugars using dilute hydrochloric acid. In hot acidic medium, glucose is dehydrated to hydroxymethyl furfural. This compound forms with anthrone, a green colored product with an absorption maximum at 630 nm.

3.8.2 Total Free Amino Acids in Kernels (µg ml⁻¹)

Total free amino acids was estimated as per the method given by Sadasivam and Manickam (1992). Ninhydrin, a powerful oxidizing agent, decarboxylates the alpha-amino acids and yields an intensely colored bluish purple product which is calorimetrically measured at 570 nm.

3.8.3 Oil Content in Kernels (%)

The oil content of the kernel was estimated by Infratec TM 1241 Grain analyzer and expressed as percentage.

3.8.4 Protein Content (%)

The protein content of the kernel was estimated by Infratec TM 1241 Grain analyzer and expressed as percentage.

3.9 REPRODUCTIVE EFFICIENCY

3.9.1 Flower to peg ratio:

Total number of flowers and pegs were recorded from randomly labeled three plants in each plot. Flower to peg Ratio was calculated by using below formula (Bhagavatha *et al.*, 2017).

$$= \frac{\text{Number of pegs per plant}}{\text{Number of flowers per plant}} \times 100$$

3.9.2 Peg to pod ratio:

Count the total number of pegs and pods for randomly labeled three plants in each plot. Peg to pod ratio was calculated by using below formula. (Bhagavatha *et al.*, 2017).

$$= \frac{\text{Number of pods per plant}}{\text{Number of pegs per plant}} \times 100$$

3.10. YIELD ATTRIBUTES

3.10.1 Shelling percentage

Shelling percentage was calculated using the formula

$$\text{Shelling percentage} = \frac{\text{Kernel yield plant}^{-1} \text{ (g)}}{\text{Pod yield plant}^{-1} \text{ (g)}} \times 100$$

100 g pods were taken and shelled to get shelling percentage of each genotype.

3.10.2 Number of pods plant⁻¹

The total number of pods from randomly selected labeled plants were counted averaged and expressed as number of pods plant

3.10.3 Number of filled pods plant⁻¹

Five randomly labeled plants were harvested separately and count the total number of filled pods per plant and mean of five plants was computed.

3.10.4 100-kernel weight (g)

After through sun drying of pods to constant weight and take five lots of 100 pods randomly from each variety and take weight, averaged the five lots and expressed as hundred pod weight in g.

3.10.5 Harvest Index (HI) (%)

Harvest Index was calculated by using the formula

$$\text{Harvest Index (HI)} = \frac{\text{Economic yield plant}^{-1} \text{ (g)}}{\text{Biological yield plant}^{-1} \text{ (g)}} \times 100$$

Mean value of five sample plants per each replication was recorded and considered as harvest index in percentage.

3.10.6 Sound mature kernel percentage

Take 100 kernels randomly from each variety and record the weight, separate the bold seeds (smooth seed coat) from 100 kernels and take the weight of these bold seeds calculate the SMK by using following formula.

$$\text{SMK\%} = \frac{100 \text{ kernal weight (g)}}{\text{bold seed weight (g)}} \times 100$$

3.10.7 Pod Yield (kg ha⁻¹)

Pods from net plot area separated from haulms sundried till constant weight attained.

3.10.8 Haulm Yield (kg ha⁻¹)

The plants in the net plot area after removal of the pods from the haulms are sun dried thoroughly till constant weights was attained and haulm yield was recorded.

3.10.9 Benefit-Cost ratio (B:C Ratio)

The total cost of cultivation ha⁻¹ was calculated for each treatment on the basis of input cost. Gross returns hectare⁻¹ were computed by considering the prevailing market price of the output. Net returns ha⁻¹ were arrived at by deducting the cost of cultivation of respective treatments from gross returns for the corresponding treatments. Benefit-cost ratio was worked out for each treatment by using the following formula

$$\text{Benefit-Cost ratio} = \frac{\text{Gross returns (₹ ha}^{-1}\text{)}}{\text{Cost of cultivation (₹ ha}^{-1}\text{)}} \times 100$$

3.11 QUANTIFICATION OF CALCIUM AFTER HARVEST AND BORON BEFORE FLOWERING AND AFTER HARVEST

3.12.1 Sampling procedure for Calcium

Sampling was done before flowering. For this purpose three plants from each treatment or each plot were dug out along with roots. The plants were thoroughly washed to free from dirt and surface dried with blotting paper. The roots, stem, leaves and pods were separated. Then the plant were dried in hot air oven at 100°C for 15 minutes and then at 80°C for 48 hours until they attained constant weights. Oven dried samples were grinded into fine powder and estimated calcium content by using Di-acid digestion

method. 1 gram of plant sample was digested in 10 ml of di-acid mixture overnight. Later digested samples were kept on hot plate at 60-80°C to yield white precipitate. That precipitate was filtered and titrated by using 0.1 N EDTA, 16% NaOH and calcon indicator (Jackson, 1973).

3.12.2 Sampling Procedure for Boron

Sampling was done before flowering and after harvest. For this purpose three plants from each treatment or each plot were dug out along with roots. The plants were thoroughly washed to free from dirt and surface dried with blotting paper. The roots, stem, leaves and pods were separated. Then the plant were dried in hot air oven at 100°C for 15 minutes and then at 80°C for 48 hours until they attained constant weights. Oven dried samples were grinded into fine powder and estimated calcium content by using Di-acid digestion method. One gram of plant sample was digested in 10 ml of di-acid mixture overnight. Later digested samples were kept on hot plate at 60-80°C to yield white precipitate.

Pipette 1 ml aliquot of sample. Add 4 ml of curcumin-oxalic acid solution and mix. Place on water bath maintained at $55 \pm 3^\circ\text{C}$. Maintain dishes on a steam at this temperature for at least 15 minutes after solution evaporates. Cool the dishes to room temperature and then add 25 ml of ethyl alcohol. Rub the residue with a rubber policeman to ensure complete extraction of the coloured compound by the alcohol. Using a Whatmann no. 1 filter paper, filter into an appropriate container and read the absorbance of solutions at 540 nm. Prepare an absorbance-B concentration curve from the absorbance reading of the standard solutions containing upto 2.0 µg of B/ml. Read concentration of B in the sample from the standard curve (Tandon, 1998).

$$B = R \times \frac{100}{\text{Sample}}$$

Where, R is the colorimeter reading for 1 ppm B

3.13 STATISTICAL ANALYSIS

The experimental data were analyzed statistically by following standard procedure outlined by Panse and Sukhatme (1985). Significance was tested by comparing 'F' value at 5 per cent level of probability. Correlation studies were undertaken for different parameters of growth analysis, yield attributes and biochemical parameters according to the method proposed by Fisher and Yates (1963).

Chapter ~ IV



Results & Discussion

Chapter – IV

RESULTS AND DISCUSSION

In this chapter the results and their interpretation on physiological, biochemical, yield and yield attributes of groundnut as influenced by calcium and boron are presented. The data were given in tables accordingly and depicted in graphs wherever necessary.

4.1 PHYSIOLOGICAL AND GROWTH PARAMETERS

4.1.1 Field Emergence per cent

Field emergence was recorded at early stages of crop growth and given in Table 4.1.

Under field conditions, the first recognizable effect of early vigor of treatment is the field emergence index. High seed emergence and early seedling establishment showed to contribute high yield under drought conditions (Gupta, 1985)

The result from the present data revealed that field emergence T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (89%) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (88%) T₇-RDF+ foliar application of borax at 35 DAS @ 0.1%. (87%), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (87%).

Wright and Bell (1992) also opined that the cultivars with vigorous early growth, relatively larger biomass accumulation and capacity for remobilizing stored assimilates to reproductive sinks.

This might be due to the application of boron because boron is the important micronutrient that helps to facilitate early germination and faster growth of the hypocotyl.

Table 4.1. Effect of calcium and boron application on field emergence index (%) in groundnut

	Treatments	Field emergence index (%)
T ₁	: Control	75.20
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	79.80
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	85.86
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	81.82
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	88.89
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	85.86
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	87.88
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	89.90
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	80.81
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	87.88
CD		NS
SEm±		4.33
Mean		84.60

Rerkasem (1990) reported that low boron is responsible for poor seed germination and/or seedling establishment in peanut.

4.1.2 Days to 50 per cent flowering

The data pertaining to days to 50% flowering of groundnut are presented in the Table 4.2.

Days to 50 per cent flowering denotes the crop maturity. Result revealed that the basal application of Borax showed early flowering (4 days) compared to other treatments because application of Borax had pronounced influence on flowering. Within the treatments the variability was observed from 29 to 36 days. However there was no significant difference among the treatments.

Among the treatments the early flowering was observed in treatment T₄-RDF + Borax application as basal application @ 10 kg ha⁻¹ (29 days) followed by T₅-RDF + Basal application of gypsum @ 500 kg ha⁻¹ + Borax @ 10 kg ha⁻¹ (30 days), T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @0.1% (30 days).

Singh *et al.* (2009) reported that Borax application caused 2-3 days of early flowering in peanut. There was an evidence that application of boron reduced days to 50% flowering by 4-5 days over control in peanut (Ansari *et al.*, 2016).

4.1.3 Plant Height (cm)

The plant height of groundnut variety Dharani was recorded at 20 days interval and presented in Table 4.3.

Plant height had a continuous increase till crop reached maturity. Significant differences among the treatments were observed throughout the crop growth except at 80 DAS and harvest.

Table 4.2. Effect of calcium and boron application on days to 50% flowering in groundnut

	Treatments	Days to 50% flowering
T ₁	: Control	36
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	34
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	30
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	29
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	30
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	34
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	36
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	34
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	30
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	36
CD		4.47
SEm±		1.49
Mean		31.73

Table 4.3. Effect of calcium and boron application on plant height (cm) in groundnut

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control	6.67	16.20	22.46	30.02	31.42
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	5.73	17.00	28.28	31.74	34.21
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	5.20	18.93	26.45	31.49	35.75
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	6.43	17.60	28.50	34.00	36.30
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	5.98	14.97	25.72	32.89	33.66
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	6.42	18.57	28.78	33.06	35.80
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	7.10	16.23	30.63	35.66	34.01
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	6.23	17.90	23.79	32.33	33.27
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	5.47	19.43	32.04	37.40	38.63
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	5.47	17.33	30.80	35.67	38.86
CD 5%	0.76	2.30	3.66	NS	NS
SEm±	0.25	0.77	1.22	1.78	2.02
Mean	6.07	17.42	27.75	33.53	36.19

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher plant height than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded numerically higher values when compared to RDF alone

Among the treatments the highest plant height was recorded in T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (38.86 cm) followed by T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (38.63 cm) followed by T₄- RDF + foliar application of borax at 35 DAS @ 0.1% (36.30 cm), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (35.80 cm), when compared with control during harvest.

It is a fact that boron is essential in enhancing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant. Boron being essential for N fixation, which ensured better N supply to the crop and also improved plant height (Duyingqiong *et al.*, 2002 and Patil *et al.*, 2014)

4.1.4 Leaf Area (cm²)

Data on leaf area was recorded at 20 days interval and were presented in Table 4.4.

Leaf area per plant is an important determinant in production and photosynthesis (Watson, 1952). Positive correlation between leaf area and yield (Alluwar and Deotale, 1991) suggests its importance in determining yield.

The leaf area per plant showed a gradual increase till 80 DAS and then declined in all the treatments and the significant difference was observed only during 60 DAS and 80 DAS.

Table 4.4. Effect of calcium and boron application on leaf area (cm²) groundnut

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control	187.64	291.48	439.31	709.49	649.86
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	120.05	319.67	568.46	823.11	819.84
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	130.29	355.99	711.62	1083.15	964.76
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	154.20	336.27	723.47	1058.30	927.26
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	134.08	363.49	735.94	1051.94	898.39
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	154.03	367.59	770.47	1103.71	1024.90
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	137.02	379.26	773.30	1206.60	1029.69
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	170.89	332.97	642.99	923.34	676.15
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	186.95	513.05	845.27	1272.99	1089.34
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	143.81	421.97	844.33	1220.91	1067.64
CD 5%	NS	NS	220.30	386.56	NS
SEm±	20.54	43.79	73.58	129.10	128.97
Mean	151.90	368.17	705.52	1025.35	914.78

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher leaf area than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

Among the treatments the highest plant leaf area was recorded in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (1272.99 cm²) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3% (1220.91 cm²), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (1206.60 cm²), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (1103.71 cm²) when compared with control during 80 DAS.

The highest leaf area recorded along with Sulphur + Boron + Zinc over recommended dose of fertilizer (RDF) NPK + FYM was 41.4 per cent over recommended package. The timely release of nutrients favourable for crop growth which favoured increased activity of meristematic cells and cell elongation and hence the increased leaf area. The present findings are in conformity with Subramaniyan *et al.* (2001), Anand (2010), Veeramani *et al.* (2012) and Rahevar *et al.* (2015).

4.1.5 Total Drymatter (g plant⁻¹)

Data on total dry matter of leaf, stem, root and pods was recorded at 20 days interval and presented in table 4.5 and 4.5 a, 4.5b, 4.5c and 4.5d.

Total dry matter continuously increased from 20 DAS to harvest. Significant differences for leaf dry weight among the treatments were found from 60 DAS to harvest.

The results from the present study revealed that nutrient application of calcium and boron treatments are significantly higher total dry matter

than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the present study revealed table 4.5 that the dry matter was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (42.06 g) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (36.29 g), T₇-RDF + foliar application of borax at 35 DAS @ 0.1% (32.48 g), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (30.81 g), when compared with control at harvest.

The results from the present study revealed that the leaf dry weight Table 4.5a was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (14.18 g) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (12.25 g), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (10.35 g), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (10.14 g) , when compared with control 80 DAS.

The results from the present study revealed that the stem dry weight Table 4.5b was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (15.03 g) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (13.03 g), T₇- RDF + foliar application of borax at 35 DAS @ 0.1% (12.15 g), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (11.20 g), when compared with control at harvest.

The results from the present study revealed that the root dry weight Table 4.5c was recorded highest in T₉- RDF+ gypsum application to soil

during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (1.38 g) which is on par with T₁₀-RDF + foliar application of borax at 35 DAS @0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (1.31 g), followed by T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (1.22 g), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (0.99 g) , when compared with control at harvest.

The results from the present study revealed that the pod dry weight Table 4.5d was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (16.16 g) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (12.34 g), T₇- RDF + foliar application of borax at 35 DAS @ 0.1% (9.56 g), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (9.47 g) , when compared with control at harvest.

Dry matter production is the measure of growth and overall development of plant. Foliar application of secondary and micronutrients might have helped the groundnut plants to increase their growth and dry matter accumulation due to increased chlorophyll content, activation of several enzyme systems and auxins. Further, larger leaf area development aids in more interception of light leading to higher dry matter production.

Similar results were evinced by Elayaraja and Singaravel (2012). The pod weight, which were significantly higher and these in turn depended on growth parameters particularly total dry matter production and its accumulation in pods. The results are corroborative of the findings of Anand (2010).

Boron helped in flowering, pod retaining and thus increased pod weight (Ansari *et al.*, 2013).

Table 4.5 Effect of calcium and boron application on total drymatter (g plant⁻¹) in groundnut.

Treatments		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁	: Control	2.20	3.54	9.60	14.14	17.59
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	1.59	4.017	10.42	20.27	23.60
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	1.70	4.997	10.78	20.98	25.15
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	1.85	4.923	12.85	26.22	28.94
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	1.71	4.663	13.93	24.71	27.32
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	2.23	4.883	13.50	26.08	30.81
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	1.96	5.003	16.11	28.23	32.48
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	2.40	4.843	10.73	21.45	25.74
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	2.50	5.763	17.45	35.76	42.06
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	1.90	4.48	16.71	32.69	36.29
CD 5%		NS	NS	2.24	2.44	4.30
SEm±		0.22	0.46	0.75	0.81	1.44
Mean		2.00	4.71	13.21	25.05	15.15

Table 4.5a Effect of calcium and boron application on leaf dry weight (g plant⁻¹) in groundnut.

Treatments		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁	: Control	1.02	1.64	4.15	6.38	5.28
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	0.74	2.03	4.39	9.92	7.68
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	0.83	2.61	5.27	9.32	8.12
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	0.85	2.46	5.97	11.19	8.86
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	0.82	2.32	5.90	9.33	9.00
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	1.03	2.38	6.52	10.14	9.40
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	0.92	2.40	6.80	10.35	9.99
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	1.11	2.60	5.04	9.30	7.92
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	1.15	2.84	7.44	14.18	10.61
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.82	1.77	7.13	12.25	10.13
CD 5%		NS	0.59	1.52	2.17	1.88
SEm±		0.12	0.20	0.51	0.73	0.63
Mean		0.93	2.30	5.86	10.24	8.70

Table 4.5b. Effect of calcium and boron application on stem dry weight (g plant⁻¹) in groundnut

Treatments		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control		1.06	1.72	4.56	5.69	7.72
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)		0.71	1.76	4.39	6.81	9.31
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹		0.77	2.17	3.95	7.61	10.40
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹		0.91	2.14	4.42	8.09	10.96
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹		0.79	2.24	5.33	8.37	10.97
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil		1.06	2.27	4.28	8.60	11.20
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%		0.92	2.30	6.48	8.73	12.15
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		1.07	2.02	4.22	7.59	10.06
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%		1.23	2.56	6.91	10.23	15.03
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		0.94	2.40	6.71	9.44	13.03
CD 5%		NS	NS	0.97	2.18	3.04
SEm±		0.11	0.38	0.32	0.73	1.02
Mean		0.95	2.16	0.79	8.12	11.08

Table 4.5c. Effect of calcium and boron application on root dry weight (g plant⁻¹) in groundnut

Treatments		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁	: Control	0.12	0.31	0.22	0.54	0.40
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	0.13	0.31	0.35	0.60	0.50
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	0.11	0.24	0.44	0.80	0.59
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	0.09	0.19	0.35	0.82	0.67
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	0.09	0.22	0.54	0.95	0.69
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	0.14	0.22	0.53	0.99	0.73
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	0.12	0.21	0.63	1.22	0.78
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.20	0.36	0.39	0.65	0.50
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	0.14	0.22	0.76	1.38	0.92
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.13	0.23	0.66	1.31	0.80
CD 5%		NS	NS	0.29	0.45	0.28
SEm±		0.02	0.06	0.10	0.15	0.10
Mean		0.13	0.25	0.49	0.92	0.66

Table 4.5d. Effect of calcium and boron application on pod dry weight (g plant⁻¹) in groundnut

	Treatments	60 DAS	80 DAS	Harvest
T ₁	: Control	0.67	1.27	4.19
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	1.30	2.95	6.11
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	1.12	3.50	6.04
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	2.11	6.28	8.45
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	2.16	6.02	6.65
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	2.17	6.38	9.47
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	2.20	8.32	9.56
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	1.07	3.18	7.26
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	2.34	10.04	16.16
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	2.21	9.78	12.34
CD 5%		0.62	1.95	3.21
SEm±		0.21	0.65	1.07
Mean		1.73	5.77	8.62

4.1.6 Growth Parameters

4.1.6.1 Crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$)

Crop Growth Rate indicates the dry matter production by a plant community on an unit land in an unit of time. It is used for the estimation of production efficiency of a crop. Data on crop growth rate was recorded at 20 days interval and were presented in Table 4.6

Total crop growth rate was gradually increased up to 80 DAS and there after decreased at harvest. Significant differences among the treatments were found from 40 DAS to 80 DAS and was highest during 60-80 DAS.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher crop growth rate than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the crop growth rate was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹+ foliar application of borax at 35 DAS @ 0.1%(30.34 g m⁻² day⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1%+ foliar application of Calcium nitrate at 35 DAS @0.3% (24.25 g m⁻² day⁻¹), T₇- RDF+ foliar application of borax at 35 DAS @ 0.1% (23.84 g m⁻² day⁻¹), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (23.33 g m⁻² day⁻¹), when compared with control at 60-80 DAS.

This might be due to the fact that those plants the nutrients calcium and boron are supplied at the required stage which enable them to have higher leaf area, net assimilation rate thus enhancing the crop growth. The decline in crop growth rate might be due to loss in drymatter on account of senescence (Kalyani *et al.*, 1993).

Table 4.6. Effect of calcium and boron application on crop growth rate ($\text{g m}^{-2} \text{ day}^{-1}$) in groundnut

Treatments		20-40 DAS	40-60 DAS	60-80 DAS	80 DAS – Harvest
T ₁ : Control		2.21	9.00	8.07	3.44
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)		4.01	9.01	14.31	3.96
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹		5.44	12.71	16.88	6.24
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹		5.07	12.15	18.81	6.01
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹		4.87	13.19	20.71	6.38
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil		4.38	14.89	23.33	6.92
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%		5.03	18.56	23.84	6.95
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		4.02	11.71	14.89	4.77
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%		5.39	19.73	30.34	12.24
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		4.26	19.29	24.25	8.28
CD 5%		NS	4.23	5.39	NS
SEm±		0.75	1.41	1.80	2.05
Mean		4.47	14.02	19.54	6.52

Crop growth rate was significantly enhanced by all the three fertilizers (P, Ca and B) The highest crop growth rate was recorded with P, Ca and B at 100 DAS and the lowest one was found at control ($P_0 \times Ca_0 \times B_0$) (Kabir *et al.*, 2013).

4.1.6.2 Net assimilation rate ($\text{g d m}^{-2} \text{ day}^{-1}$)

Net assimilation rate describes the net production efficiency of the assimilatory apparatus. Data on net assimilation rate was recorded at 20 days interval during and were presented in Table 4.7.

Total net assimilation rate was gradually increased up to 80 DAS and there after decreased at harvest. Significant differences among the treatments were found from 40 DAS to 80 DAS.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher net assimilation rate than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the net assimilation rate was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% ($0.036 \text{ g d m}^{-2} \text{ day}^{-1}$) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3 %.($0.030 \text{ g d m}^{-2} \text{ day}^{-1}$), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% ($0.027 \text{ g d m}^{-2} \text{ day}^{-1}$), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ ($0.023 \text{ g d m}^{-2} \text{ day}^{-1}$), when compared with control at 60-80 DAS.

The growth parameters of groundnut were significantly influenced by boron application. The result showed that the values of Leaf area, Leaf area ratio, Leaf mass ratio, net assimilation ratio were the highest for 2 ppm of

Table 4.7. Effect of calcium and boron application net assimilation rate ($\text{g dm}^{-2} \text{ day}^{-1}$) in groundnut.

Treatments		20-40 DAS	40-60 DAS	60-80 DAS	80 DAS – Harvest
T ₁	: Control	0.007	0.016	0.015	0.004
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	0.02	0.021	0.015	0.005
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	0.025	0.026	0.023	0.006
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	0.024	0.024	0.022	0.006
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	0.021	0.028	0.024	0.006
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	0.022	0.029	0.025	0.008
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	0.022	0.033	0.027	0.009
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.015	0.023	0.018	0.005
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	0.02	0.038	0.036	0.011
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.019	0.037	0.03	0.011
CD 5%		NS	0.013	0.01	NS
SEm±		0.004	0.004	0.003	0.003
Mean		0.02	0.03	0.02	0.011

boron, while the values of the traits were the lowest for B (0 ppm) This was most relevant in higher RGR and NAR because of application boron at 2 ppm. Moreover, the optimal supply of boron in treatment B₃ (2 ppm) could have the resulted in the maximum physiological growth (Quamruzzaman *et al.*, 2017)

4.1.6.3 Leaf area index

Leaf area index denotes cumulative green leaf area over unit land area. Leaf area index was computed taking into account, the area occupied by each plant as per the following formula (Watson, 1952).

Data on leaf area index was recorded at 20 days interval and were presented in Table 4.8.

Total leaf area index was gradually increased up to 80 DAS and there after decreased at harvest. Significant differences among the treatments were found from 60 DAS and 80 DAS.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher leaf area index than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the leaf area index was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (4.07) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (3.93), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (3.86), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (3.53) when compared with control at 80 DAS.

Table 4.8. Effect of calcium and boron application on leaf area index in groundnut

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control	0.60	0.94	1.42	1.63	2.08
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	0.38	1.03	1.83	2.63	2.62
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	0.42	1.15	2.29	3.47	3.09
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	0.49	1.09	2.33	3.39	2.97
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	0.43	1.18	2.38	3.37	2.87
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	0.50	1.19	2.48	3.53	3.28
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	0.44	1.23	2.50	3.86	3.29
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.55	1.08	2.08	2.95	2.16
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	0.60	1.66	2.73	4.07	3.48
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.46	1.36	2.73	3.93	3.42
CD 5%	NS	NS	0.72	1.07	NS
SEm±	0.06	0.14	0.24	0.36	0.42
Mean	0.49	1.19	2.28	3.28	2.93

The highest leaf area index might be due to better nutrient availability, increased metabolic processes, meristematic activities and also formation and retention of higher number of leaves per plant, ultimately resulting in improved photosynthetic surface (LAI) of the plants. (Geethanjali *et al.*, 2015).

The favourable effect of all the nutrients on nitrogen metabolism, cell division, cell enlargement, manifesting the leaf tissues to grow better, producing larger leaf area and there by improved the quality of vegetative growth. Similar results were recorded by Jat and Ahlawat (2009), Nadia Gad (2012), Kabir *et al.* (2013) and Sree Ganesh *et al.* (2015).

4.1.6.4 Leaf area duration ($\text{cm}^2 \text{ day}^{-1}$)

Leaf area integrated over time period is called leaf area duration. It takes account of both of the magnitude of the leaf area and its persistence in time. In effect, it represents the leafiness of the crop growing period.

Data on leaf area duration was recorded at 20 days interval and were presented in Table 4.9.

Total leaf area duration was gradually increased up to 80 DAS and there after decreased at harvest. Significant differences among the treatments were found from 40 DAS to harvest.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher leaf area duration than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the leaf area duration was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹+ foliar application of borax at 35 DAS @ 0.1% (75.59 cm² day⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% +

Table 4.9. Effect of calcium and boron application on leaf area duration ($\text{cm}^2 \text{ day}^{-1}$) in groundnut.

	Treatments	20-40 DAS	40-60 DAS	60-80 DAS	80 DAS – Harvest
T ₁	: Control	15.41	23.64	30.52	37.10
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	14.16	28.66	44.69	52.58
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	15.63	34.34	57.54	65.53
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	15.81	34.22	57.20	63.54
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	16.04	35.52	57.44	62.41
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	16.82	36.67	60.13	68.11
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	16.66	37.25	63.58	71.56
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	16.22	31.58	50.37	51.18
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	22.60	43.87	68.01	75.59
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	18.21	40.84	66.54	73.46
CD 5%		NS	9.69	14.13	15.99
SEm±		1.78	3.24	4.72	5.34
Mean		16.76	34.66	55.60	62.11

foliar application of Calcium nitrate at 35 DAS @ 0.3% ($73.46 \text{ cm}^2 \text{ day}^{-1}$), T₇-RDF + foliar application of borax at 35 DAS @ 0.1% ($71.56 \text{ cm}^2 \text{ day}^{-1}$), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ ($68.11 \text{ cm}^2 \text{ day}^{-1}$), when compared with control at 80 DAS to harvest.

The decline in the leaf area might be due to senescence and abscission of the leaves resulting decreased leaf area and leaf area index.

Similar results were reported by Sunil Kumar Pande *et al.* (2010) in mungbean.

4.1.6.5 Leaf area ratio ($\text{cm}^2 \text{ g}^{-1}$)

It gives the relative size of the assimilatory apparatus. Hence it is called capacity factor. It represents the leafiness characters of crop plants.

Data on leaf area ratio was recorded at 20 days interval and were presented in Table 4.10.

Total leaf area ratio was gradually increased up to 60 DAS and there after decreased at harvest. Significant differences among the treatments was not observed.

The results from the present study revealed that nutrient application of calcium and boron treatment recorded significantly higher leaf area ratio than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the leaf area ratio was recorded highest in T₃-RDF+ gypsum application as basal ($52.47 \text{ cm}^2 \text{ g}^{-1}$) followed by T₅-RDF + Basal application of gypsum and borax ($49.84 \text{ cm}^2 \text{ g}^{-1}$), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ ($40.75 \text{ cm}^2 \text{ g}^{-1}$), when compared with control at 80 DAS.

Table 4.10. Effect of calcium and boron application on leaf area ratio (cm²g⁻¹) in groundnut

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control	84.76	84.94	48.90	37.08	36.98
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	75.27	80.84	43.70	37.47	32.81
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	77.00	73.31	68.18	52.47	37.09
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	83.12	71.08	56.74	41.53	31.86
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	78.39	82.99	60.62	49.84	35.77
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	67.53	74.82	61.60	40.75	33.36
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	70.36	76.18	47.57	39.12	31.79
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	71.22	68.92	54.81	39.83	26.56
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	74.21	94.00	48.39	35.43	27.57
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	76.02	93.01	51.24	40.09	27.17
CD 5%	NS	NS	NS	NS	NS
SEm±	3.64	13.59	7.56	41.36	4.02
Mean	75.79	80.01	54.17	37.08	32.64

Higher leaf area accelerates the production of metabolites. Prieto *et al.* (2007) stated that higher leaf area resulted in an increase in the plant's ability to intercept light. The higher the growth parameter i.e. LA (leaf area), LAR (leaf area ratio) and LMR (leaf weight ratio) might be because of supply of 2 ppm boron containing the required nutrient which has the ability to produce higher metabolites in groundnut. The growth analysis data suggest that boron at 2 ppm provided better nutrition to the plant.

4.1.6.6 Root weight ratio (g g^{-1})

Root weight ratio is expressed as the dry weight of root to whole plant dry weight. Data on root weight ratio was recorded at 20 days interval and were presented in Table 4.11.

Total root weight ratio was gradually increased up to 80 DAS and there after decreased at harvest. There was no significant differences among the treatments were found during the crop period.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher root weight ratio than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the leaf weight ratio was recorded highest in T₉-RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (0.401 g g⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (0.363 g g⁻¹), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (0.332 g g⁻¹), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1 % (0.318 g g⁻¹), when compared with control at 80 DAS.

Table 4.11. Effect of calcium and boron application on root weight ratio (g g⁻¹) in groundnut

Treatments		20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control		0.052	0.053	0.09	0.146	0.261
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)		0.091	0.056	0.156	0.176	0.28
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹		0.06	0.044	0.144	0.197	0.267
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹		0.048	0.045	0.192	0.266	0.316
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹		0.057	0.048	0.195	0.283	0.269
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil		0.068	0.049	0.201	0.282	0.332
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%		0.063	0.061	0.175	0.324	0.318
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		0.094	0.046	0.137	0.203	0.3
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%		0.049	0.058	0.178	0.318	0.401
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		0.073	0.071	0.172	0.337	0.363
CD 5%		NS	NS	0.058	0.086	0.076
SEm±		0.011	0.012	0.019	0.029	0.025
Mean		0.0655	0.0531	0.164	0.253	0.310

The longer roots, as well as the highest root weight, might be responsible for the highest nutrient uptake from soil. And the highest RWR could be responsible for the highest vegetative growth of plants, as concluded by Nigam *et al.* (1994).

Therefore, RWR in the present study might also be the highest for the application of boron.

4.1.6.8 Leaf weight ratio (g g^{-1})

Leaf Weight Ratio is expressed as the dry weight of leaves to whole plant dry weight. Data on leaf weight ratio was recorded at 20 days interval and were presented in Table 4.12.

Total leaf weight ratio was gradually increased up to 80 DAS and there after decreased at harvest. There was no significant differences among the treatments were found during the crop period.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher leaf weight ratio than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the leaf weight ratio was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹+ foliar application of borax at 35 DAS @ 0.1% (0.46 g g⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1 % + foliar application of Calcium nitrate at 35 DAS @ 0.3% (0.45 g g⁻¹), T₇-RDF + foliar application of borax at 35 DAS @ 0.1% (0.44 g g⁻¹), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (0.43 g g⁻¹) when compared with control at 80 DAS.

Prieto *et al.* (2007) stated that higher LA resulted in an increase in the plant's ability to intercept light. The higher the growth parameter i.e. LA

Table 4.12. Effect of calcium and boron application on leaf weight ratio (g g⁻¹) in groundnut

Treatments	20 DAS	40 DAS	60 DAS	80 DAS	Harvest
T ₁ : Control	0.96	0.39	0.42	0.34	0.27
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	0.75	0.47	0.42	0.40	0.27
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	0.86	0.48	0.42	0.41	0.30
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	0.87	0.51	0.43	0.40	0.30
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	0.88	0.51	0.43	0.42	0.31
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	1.22	0.51	0.46	0.43	0.31
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	0.84	0.52	0.46	0.44	0.31
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	1.10	0.48	0.42	0.40	0.30
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	1.31	0.54	0.52	0.46	0.36
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	1.00	0.52	0.46	0.45	0.31
CD 5%	NS	NS	NS	NS	NS
SEm±	0.19	0.05	0.03	0.03	0.03
Mean	0.98	0.49	0.44	0.42	0.30

(leaf area), LAR (leaf area ratio) and LMR (leaf weight ratio) might be because of supply of 2 ppm boron containing the required nutrient which has the ability to produce higher metabolites in groundnut.

4.1.6.9 Drymatter Partitioning Percentage (leaf, stem, root, pods)

Data on drymatter partitioning was calculated at 80 DAS and at harvest and are presented in the Table 4.13.

The results from the present study revealed that nutrient application of calcium and boron treatment recorded significantly higher drymatter partitioning than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The study revealed that at harvest the drymatter partitioning was recorded highest in the treatment T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @0.1% Leaf : 25.79 per cent, stem : 34.36 per cent, root : 2.18 per cent, pods : 37.93 per cent followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% Leaf : 27.97 per cent, stem : 34.09 per cent, root : 2.20 per cent, pods : 35.75 per cent, where the drymatter partition was observed more in the pods when compared with other parts of the plant.

This shows that a good source –sink relation was established and diverting the assimilate to the desirable sinks i.e. pods. Similar results have been reported by Mondal (2007) in mungbean.

Table 4.13. Effect of calcium and boron application on drymatter partitioning (%) in groundnut.

Treatments	80 DAS				Harvest		
	Leaf	Stem	Root	Pods	Leaf	Stem	Root
T ₁ : Control	45.25	40.11	5.57	9.07	30.04	43.89	2.24
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	48.67	33.67	2.94	14.71	32.53	39.46	2.11
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	44.50	35.81	2.61	17.08	31.67	41.65	2.34
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	42.25	31.11	2.51	24.13	30.83	37.57	2.38
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	37.82	33.87	4.05	24.27	33.07	40.06	2.55
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	38.90	32.95	3.65	24.50	30.49	36.30	2.39
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	36.67	30.97	2.93	29.44	30.81	37.38	2.40
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	43.77	35.92	6.15	14.16	31.28	38.75	1.97
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	39.61	28.63	3.66	28.10	25.79	34.36	2.18
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	37.61	28.69	3.72	29.97	27.97	34.09	2.20
							35.75

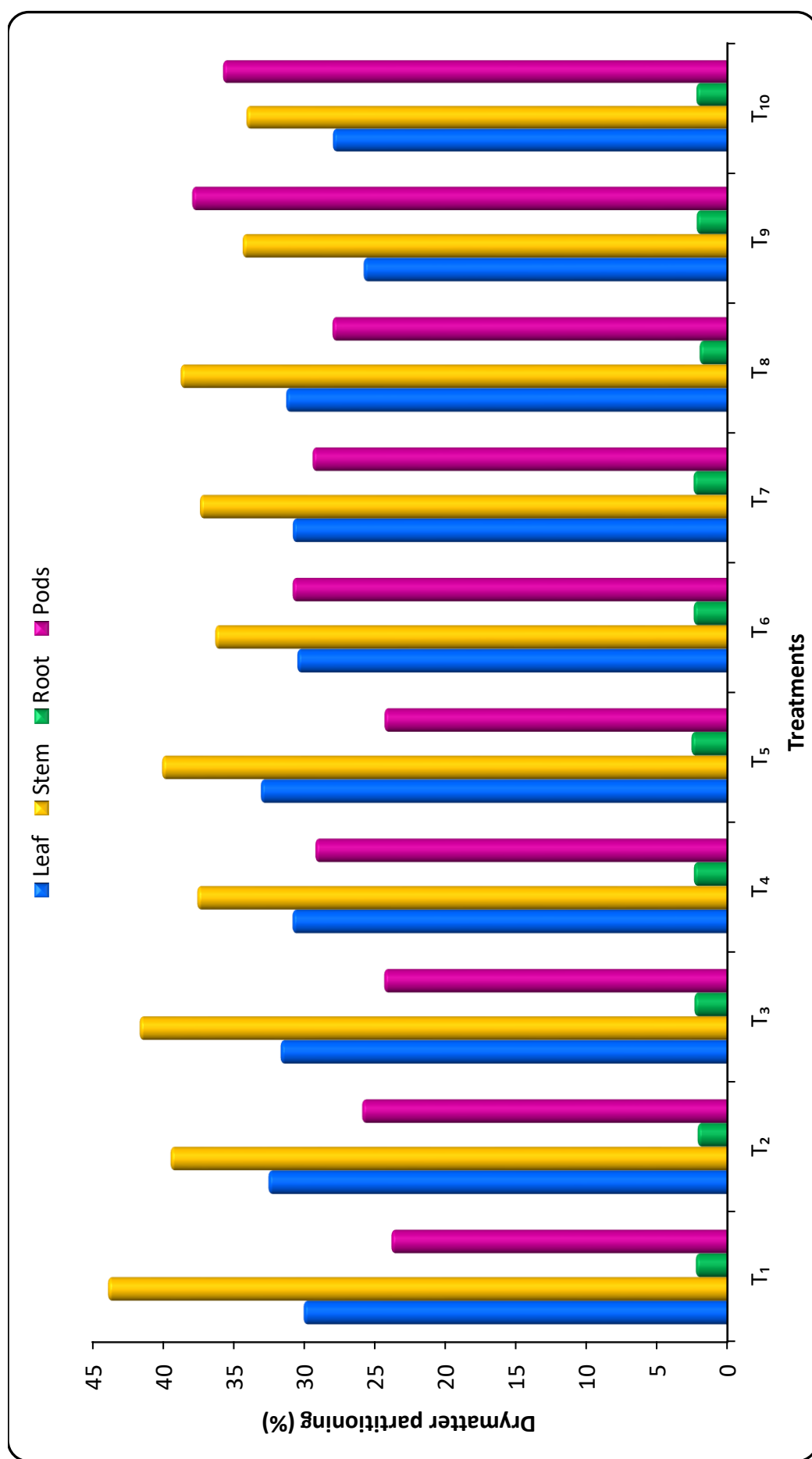


Fig. 4.1. Effect of calcium and boron application on drymatter partitioning (%) in groundnut at harvest.

4.2 ROOT NODULATION PARAMETERS

4.2.1 Number of Nodules on Root

Data on nodule count on root was recorded at 20, 30, 50 DAS and were presented in Table 4.14.

Number of nodules on roots increased gradually and significant difference was observed at 50 DAS.

The results from the present study revealed that nutrient application of calcium and boron treatment recorded significantly higher nodule count than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the experiment revealed that the number of nodules was recorded highest in T₇- RDF + foliar application of borax at 35 DAS @ 0.1% (55) followed by T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹+ foliar application of borax at 35 DAS @ 0.1% (54) which is on par with T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (54) when compared with control at 50 DAS and the distribution of nodules was observed more on lateral roots when compared with primary roots.

Nodulation and nitrogenase activity in groundnut plant was increased when plant were treated with Zn @ 25 kg, B 10 kg and Mo 1.0 kg ha⁻¹ alone or in combination but pod yield, dry matter and leaf area was enhanced with combined application Tripathy *et al.* (1999).

This study also shows that, in addition to the special Ca²⁺ requirement for nodulation, both B and Ca²⁺ are important for nodule development and function, because the decrease in either nutrient also inhibited nitrogen fixation. Following nodule development, rhizobia invade the plant through a trans cellular tunnel (the infection thread) sheathed with cell wall material

Table 4.14. Effect of calcium and boron application on number of nodule on root in groundnut.

Treatments		30 DAS	50 DAS
T ₁ : Control		24	42
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)		31	47
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹		31	52
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹		36	51
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹		35	52
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil		32	54
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%		31	55
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		30	48
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%		33	54
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		30	49
CD 5%		NS	NS
SEm±		2.912	3.211
Mean		31.40	50.32

and an endocytosis-like process from un walled infection droplets (Brewin 1991). Boron plays an important role at these stages because it is able to modulate plant–bacteria cell surface interactions.

4.3 BIOCHEMICAL PARAMETERS

4.3.1 Nitrate reductase ($\mu\text{mol g}^{-1} \text{ hr}^{-1}$)

Nitrate reductase is the main molybdenum containing protein enzyme that catalyzes the reduction of nitrate to nitrite which is important and first step in nitrate assimilation.

Data on nitrate reductase was recorded at 20, 30 and 50 DAS and were presented in Table 4.15.

Activity of nitrate reductase enzyme was not significant among the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatment recorded significantly higher nitrate reductase activity than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the nitrates reductase was recorded highest in T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (2.54 $\mu\text{mol g}^{-1} \text{ hr}^{-1}$) followed by T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (2.21 $\mu\text{mol g}^{-1} \text{ hr}^{-1}$) which is on par with T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1%+ foliar application of Calcium nitrate at 35 DAS @0.3% (2.23 $\mu\text{mol g}^{-1} \text{ hr}^{-1}$) when compared with control at 50 DAS.

The nitrate reductase activity in the leaves of rape plants (Ningyou No. 7 and Ningyou No. 8) grown on nutrient solutions increased markedly

Table 4.15. Effect of calcium and boron application on nitrate reductase ($\mu\text{mol g}^{-1} \text{ hr}^{-1}$) in groundnut

Treatments		20 DAS	30 DAS	50 DAS
T ₁ : Control		1.13	1.51	1.59
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)		0.23	1.25	1.95
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹		0.50	1.59	2.12
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹		0.57	1.02	1.53
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹		0.29	1.49	1.93
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil		0.66	1.86	2.54
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%		0.34	1.52	2.08
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		1.05	1.50	2.14
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%		1.13	2.07	2.21
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		1.57	1.67	2.23
CD 5%		NS	NS	NS
SEm $\pm$		0.432	0.302	0.401
Mean		0.75	1.55	2.03

with increasing boron concentration (from 0.025 $\mu\text{g B/mL}$ to 0.1 $\mu\text{g B/mL}$). Shen *et al.* (1993).

4.3.2 Total carbohydrate in kernels

Data on total carbohydrate in kernels was recorded in kernels after harvest and is presented in the Table 4.16.

Total carbohydrate in kernels content was increased in all treatments compared to control but the increase was numerical and there was no significant difference between the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher total carbohydrate than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher shelling percentage than the individual applications and other treatment.

Total carbohydrate in kernels was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (0.13 g g⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (0.11 g g⁻¹) which is on par with T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (0.11 g g⁻¹), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (0.10 g g⁻¹) when compared with control at harvest.

Increased nutrient availability had favorably influenced on ability to produce more assimilates, cell differentiation, Carbohydrate metabolism and increased transformation of photosynthetic activity towards growing plant parts (Tejeswara Rao and Subbaiah, 2006).

4.3.3 Total amino acids in kernels

Data on total amino acids in kernels was recorded after harvest and is presented in the Table 4.16.

Total amino acids in kernels content was increased in all treatments compared to control but the increase was numerical and there was no significant difference between the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher total amino acids than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher shelling percentage than the individual applications and other treatment.

Total amino acids in kernels was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (3659.88 µg ml⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (3578.97 µg ml⁻¹) which is on par with T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (3540.40 µg/ml), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (3423.22 µg ml⁻¹) when compared with control at harvest.

Amino acids, the end product of nitrate assimilation, have been shown to act as negative effects with regard to the synthesis of active NR. Thus, it was possible that the accumulation of free amino acids in leaves on boron-deficient plants resulted in a feedback inhibition of nitrate reductase synthesis Guerrero *et al.* (1981)

4.3.4 Oil Content (%)

Data on oil content was recorded in kernels after harvest and is presented in the Table 4.16

Kernel oil content was increased in all treatments compared to control but the increase was numerical and there was no significant difference between the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher oil content than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher shelling percentage than the individual applications and other treatment.

Oil content was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (48.60%) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (48.20%), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (48.13%), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (48.03%) , when compared with control at harvest.

The role of boron in translocation of assimilates, potassium in improving the quality parameters and sulphur supplied helped in enhancing the oil content (Nandini Devi *et al.*, (2012) and Sarkar and Malik, (2001)).

Similar results were reported by Ahmad and Garib (2010) in canola, Nandini Devi *et al.* (2012) in soybean.

4.3.5 Protein Content (%)

Data on protein content was recorded in kernels after harvest and is presented in the Table 4.16.

Kernel protein content was increased in all treatments compared to control but the increase was numerical and there was no significant difference between the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher protein content than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher shelling percentage than the individual applications and other treatment.

Protein content was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (48.60%) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (48.20%), T₇-RDF + foliar application of borax at 35 DAS @ 0.1% (48.13%), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (48.03%), when compared with control at harvest.

This might be because of the appropriate supply of boron was containing the required nutrient to produce the higher protein as well as oil. Because boron played an important role in the synthesis of essential amino acids, and protein that acts as an electron carrier in the photosynthetic process. (Naiknaware *et al.*, 2015).

Similar results were reported by Ahmad and Garib (2010) in canola , Nandini devi *et al.* (2012) in soybean.

Table 4.16. Effect of calcium and boron application on total carbohydrate, total amino acids, oil content, protein content in groundnut

Treatments		Total carbohydrate (g g ⁻¹)	Total amino acids (µg ml ⁻¹)	Oil content (%)	Protein content (%)
T ₁	: Control	0.066	2,636.31	47.10	21.43
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	0.073	2,911.89	47.80	21.67
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	0.093	3,112.44	47.50	23.20
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	0.087	3,033.23	48.03	23.27
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	0.104	3,345.31	47.43	23.67
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	0.107	3,423.22	48.03	23.77
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	0.113	3,540.40	48.13	24.17
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.081	3,032.74	47.27	22.83
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	0.13	3,659.88	48.60	25.57
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	0.113	3,578.97	48.20	24.30
CD 5%		NS	NS	NS	NS
SEm±		0.026	222.704	0.32	1.32
Mean		0.0967	3,227.44	47.81	23.39

4.4 REPRODUCTIVE EFFICIENCY

4.4.1 Number of Flowers Plant⁻¹

Data on number of flowers per plant was recorded and were presented in Table 4.17.

Number of flowers increased gradually till reproductive stage and then decreased. However the significant difference was observed among the treatments during flowering.

The results from the present study revealed that nutrient application of calcium and boron treatment recorded significantly higher number of flowers per plant than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the number of flowers per plant was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (124) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1%+ foliar application of Calcium nitrate at 35 DAS @ 0.3% (121), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (119), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (114) , when compared with control at harvest.

Peanut produced higher flowering and yield attribute due to boron fertilization 1.0 kg ha⁻¹ as a soil and 0.1% as a foliar spray (Sing *et al.*, 2008).

Boron is very useful in the production of legume seed and also for proper seed setting and seed quality and helps in the absorption of nitrogen to a certain extent (Shinde and Kale, 1985).

4.4.2 Flower to Peg Ratio

Data on number of flowers to peg ratio was recorded and were presented in table 4.17

The results from the present study revealed that nutrient application of calcium and boron treatment have significantly higher flower to peg ratio than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

The results from the study revealed that the flower to peg ratio was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (48.02) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3% (48), T₇- RDF+ foliar application of borax at 35 DAS @ 0.1% (46), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (45) , when compared with control at harvest.

It probably seems that due to the positive effect of gypsum on chemical properties of soil especially around the rhizosphere. Thus, all of these factors could directly or indirectly cause to increase of nutrients absorption from the soil and finally led to increase of number of peg. (Adhikari *et al.*, 2003)

4.4.3 Peg to Pod Ratio

Data on number of peg to pod ratio was recorded and were presented in Table 4.17.

The results from the present study revealed that nutrient application of calcium and boron treatment recorded significantly higher peg to pod ratio than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone.

Table 4.17. Effect of calcium and boron application on number of flowers, flower to peg ratio, peg to pod ratio in groundnut

Treatments	Number of flowers	Number of pegs	Flower to peg ratio	Peg to pod ratio
T ₁ : Control	79	33.33	43.23	45.00
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	84	35.33	43.40	46.49
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	116	46.33	45.03	57.57
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	72	43.33	44.97	61.08
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	80	48.67	45.17	62.57
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	139	51.33	45.77	63.53
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	104	54.00	46.14	73.13
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	101	45.33	44.46	53.65
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	132	57.33	48.02	80.13
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	110	53.33	48.00	75.11
CD 5%	29.56	13.85	NS	NS
SEm±	9.95	4.66	2.011	9.95
Mean	103.40	46.83	45.42	61.83

The results from the study revealed that the peg to pod ratio was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (80) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1%+ foliar application of Calcium nitrate at 35 DAS @ 0.3% (75), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (73), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (63), when compared with control at harvest.

4.5 YIELD ATTRIBUTES

4.5.1 Shelling Percentage (%)

Shelling percentage is an important yield component in groundnut, for attaining higher pod weight and price for the farmers.

Data on shelling percentage was recorded and were presented in Table 4.18a.

Significant difference among the treatments was not observed.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher shelling percentage than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher shelling percentage than the individual applications and other treatment.

The results from the study revealed that the shelling percentage was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹+ foliar application of borax at 35 DAS @ 0.1% (69.6%) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (68.12%), T₇-RDF+

foliar application of borax at 35 DAS @ 0.1% (68.54%), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (68.27%) when compared with control at harvest.

Gypsum application significantly affected the shelling percentage of groundnut and the highest shelling percentage was obtained with 100 kg Ca ha⁻¹ (67.19) whilst the 0 kg Ca ha⁻¹ had the least (59.12) reported by Kamara (2010).

Different levels of P, Ca and B fertilizer application also significantly influenced the shelling percentage. Highest shelling percentage (68.0) was obtained from the treatment combination of P₂ × Ca₁ × B₂ (P (50 kg ha⁻¹), Ca (110 kg ha⁻¹) and B (2.5 kg ha⁻¹) which implies that this treatment combination gave the healthier seeds compared to others (Kabir *et al.*, 2013).

Increased photosynthates accumulation and their subsequent translocation to storage organs resulted in better fill up and gave healthier seeds compared to other treatments which in turn improved the 100- kernel weight and shelling percentage (Tirumala Reddy *et al.*, 2011).

4.5.2 Number of pods per plant

Data on number of pods per plant was recorded and were presented in Table 4.18b.

Number of pods per plant showed significant difference among the treatment.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher number of pods per plant than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly highest number of pods per plant than the individual applications and other treatment.

The number of pods per plant was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (45) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1%+ foliar application of Calcium nitrate at 35 DAS @0.3% (40), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (39), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (30) when compared with control at harvest.

Higher number of pods per plant might be due to increased dry matter accumulation in the reproductive parts and formation of higher sink capacity with the addition of secondary and micronutrients (Meena *et al.*, 2007).

The main yield attributes that contributed for higher yield in SSNM for target yield of 2.5 t ha⁻¹+ Sulphur + Borax + ZnSO₄ were viz., total number of pods plant⁻¹ (19.57), pod weight plant⁻¹ (12.05), shelling percentage (75.32) and hundred kernel weight (34.74 g) which were significantly higher. These in turn depended on growth parameters particularly total dry matter production and its accumulation in pods. These yield components were significantly superior compared to recommended package (NPK + FYM) and 150% Rec. NPK + Sulphur + Borax + ZnSO₄ + Rhizobium. The results are corroborative of the findings of Anand (2010) and Veeramani *et al.* (2012).

4.5.3 Number of filled pods per plant

Data on number of filled pods per plant was recorded and were presented in Table 4.18a.

Number of filled pods per plants showed significant difference among the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher number of filled pods per plant than control. Treatments with RDF + gypsum and

boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly highest number of filled pods per plant than the individual applications and other treatment.

Number of filled pods per plant was recorded highest T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (38) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (36), T₇- RDF+ foliar application of borax at 35 DAS @ 0.1%(34), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (26), when compared with control at harvest.

The dry matter accumulation which subsequently improved the number of filled pods per plant

Number of filled pods per plant (17.00) was recorded in RDF + 20 kg MgO ha⁻¹ + 5 kg borax ha⁻¹ over other treatments. This was in collobarative with Ananth kumar *et al.* (2016).

4.5.4 100- Kernel weight (g)

Data on hundred kernel weight was recorded and were presented in Table 4.18a.

Hundred kernel weight showed significant difference among the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher hundred kernel weight than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications

recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher hundred kernel weight than the individual applications and other treatment.

Hundred kernel weight was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (88.25 g) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3% (85.26 g), T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (85.17 g), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (84.61 g) when compared with control at harvest.

The highest 100-kernel weight due to foliar application of secondary and micronutrients might be attributed to steady supply of nutrients which enhanced the dry matter production and translocation of photosynthates to sink (kernel) resulted in bold seeds which in turn increased the 100-kernel weight (Veerabhadrapa and Yeledhalli, 2005).

The 100 and 200 kg gypsum ha⁻¹ applications significantly ($P \leq 0.05$) had higher 100 seed weight than the control. The application of 100 kg Ca ha⁻¹ produced the highest 100 seed weight (37.2 g) whilst the control had the least (31.3 g) (Kamara, 2010).

4.5.4 Sound Mature Kernel Percentage

Data on sound mature kernel percentage was recorded and were presented in Table 4.18b.

Sound mature kernels had no significant difference among the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher sound mature kernel percentage than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications

recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly highest number of sound mature kernels than the individual applications and other treatment.

Number of sound mature kernel percentage was recorded highest in T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (51.91%) followed by T₁₀- RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @0.3% (51.72%), T₇-RDF + foliar application of borax at 35 DAS @ 0.1% (51), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (49.46), when compared with control at harvest.

4.5.5 Pod Yield (kg ha⁻¹)

Pod yield is a function of crop growth rate and duration of reproductive growth and fraction of crop growth partitioned towards pod yield.

Data on pod yield was recorded and presented in table 4.18b.

Pod yield showed the significant difference among the treatments. The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher pod yield than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly highest pod yield than the individual applications and other treatment.

Pod yield was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (3311 kg ha⁻¹) followed by T₁₀-RDF + foliar application of borax at

35 DAS @ 0.1 % + foliar application of Calcium nitrate at 35 DAS @ 0.3% (3222 kg ha⁻¹), T₇-RDF+ foliar application of borax at 35DAS @ 0.1% (2833 kg ha⁻¹), T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (2819 kg ha⁻¹) , when compared with control at harvest.

Highest pod yield might be due to multiple role of sulphur in metabolism and efficient partitioning and translocation of metabolites. (Kamara *et al.*, 2011).

Availability of calcium (Ca) in the pod environment of the groundnut plant is one of the most important soil fertility factors influencing the success of reproductive growth of groundnut, and hence pod and kernel yields (Zharare *et al.*, 2009).

The fertilizer based on SSNM for target yield of 2.5 t ha⁻¹+ S (10 kg ha⁻¹) + B (10 kg ha⁻¹) + Zn (12.50 kg ha⁻¹) produced significantly higher pod yield (2565 kg ha⁻¹) over recommended dose of fertilizer (25:75:37.50 kg NPK ha⁻¹ + FYM @ 10 t ha⁻¹) 2060 kg ha⁻¹ pod yield (Patil *et al.*, 2018).

The positive response of secondary and micronutrients with recommended NPK can be attributed to the availability of sufficient amount of plant nutrients throughout the growth period, resulting in better lateral root growth, catalyzing the metabolism of carbohydrates, increase in enzyme activity, other biological oxidation reactions and yield advantage (Nayak *et al.*, 2009).

Boron was highly responsible for better yield of groundnut and a significant positive seed yield was recorded from application of boron. The highest groundnut seed yield (1.53 t ha⁻¹) was found from boron at 2 kg ha⁻¹ and the lowest from control. (Quamruzzaman *et al.*, 2017).

4.5.6 Haulm Yield (kg ha⁻¹)

Data on haulm yield was recorded and were presented in table 4.18b.

Haulm yield had no significant difference among the treatments.

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher haulm yield than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher haulm yield than the individual applications and other treatment.

Haulm yield was recorded highest in T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (3670 kg ha⁻¹) followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% (3557 kg ha⁻¹) which is on par with T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹, when compared with control at harvest.

Higher haulm yield might be due to higher plant height, leaf area index, dry matter accumulation, more nutrient availability and uptake by groundnut crop. The easy transfer of nutrients through foliar spray could have created the stimuli in the plant system which in turn increased the production of growth regulators in cell system leading to better haulm yield. The results of present investigation confirms the documented evidence of Karmakar *et al.* (2005), Rathore *et al.* (2006), Mohapatra and Dixit (2010), Sharma *et al.* (2011) and Naiknaware *et al.* (2015).

4.5.7 Harvest Index

High HI indicates a high partitioning ability, Bell *et al.* (1991) opined that for a genotype to have high harvest index pattern of assimilates partitioning between vegetative and reproductive components is more important than that of drymatter.

Data on haulm yield was recorded and were presented in table 4.18b.

Harvest index had no significant difference among the treatments

The results from the present study revealed that nutrient application of calcium and boron treatments recorded significantly higher harvest index than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher harvest index than the individual applications and other treatment.

Harvest index was recorded highest in T₁₀-RDF + foliar application of borax at 35 DAS @0.1%+ foliar application of Calcium nitrate at 35 DAS @ 0.3% followed by T₉- RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% when compared with control at harvest.

Optimum utilization of solar radiation, higher assimilates production and its conversion to starch results in higher biomass, pod yield leading to higher harvest index. The results were in agreement with the findings of Kabir *et al.* (2013) and Heba Mohamed Noman *et al.* (2015) who obtained highest harvest index of groundnut.

Table 4.18a. Effect of calcium and boron application on yield and yield components in groundnut

Treatments		Pod yield (kg ha ⁻¹)	SKW (%)	Haulm yield (kg ha ⁻¹)	Harvest index (%)
T ₁	: Control	1519	45.66	2710.33	35.91
T ₂	: RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	2037	48.21	2817.00	41.97
T ₃	: RDF + Gypsum application as basal @ 500 kg ha ⁻¹	2167	48.62	3319.00	39.50
T ₄	: RDF + Borax application as basal @ 10 kg ha ⁻¹	2259	48.51	3161.67	41.68
T ₅	: RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	2322	49.13	3400.33	40.58
T ₆	: RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	2819	49.46	3401.00	45.32
T ₇	: RDF + Foliar application of Borax at 35 DAS @ 0.1%	2833	51.00	3555.00	44.35
T ₈	: RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	2815	48.38	3153.33	47.16
T ₉	: RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	3311	51.91	3670.00	47.43
T ₁₀	: RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	3222	51.72	3557.33	47.53
CD 5%		519	NS	NS	NS
SEm±		173	3.55	309.692	3.19
Mean		2530	48.97	3,274.50	46.62

Table 4.18b. Effect of calcium and boron application on yield and yield components in groundnut

Treatments	No. of pods plant ⁻¹	No. of filled pods plant ⁻¹	100 KW (g)	Shelling (%)
T ₁ : Control	15.00	14.00	75.49	69.71
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	15.33	23.67	80.62	65.96
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	26.67	22.33	82.30	68.76
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	25.67	25.33	78.36	64.80
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	29.33	20.33	77.01	67.46
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	30.33	25.67	84.61	68.27
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	39.33	33.67	85.17	68.54
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	24.33	20.00	75.95	67.61
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	45.33	38.00	88.25	69.60
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	40.00	35.67	85.26	68.12
CD 5%	11.09	13.03	7.55	NS
SEm±	3.70	4.35	2.52	3.534
Mean	29.13	25.87	80.86	67.88

4.7 Benefit – Cost ratio (B : C RATIO)

Benefit cost ratio is calculated and is presented in the Table 4.19.

The maximum net returns was obtained with application of Site specific nutrient management for target yield of 2.5 t ha⁻¹ followed by application of site specific nutrient management for 2.5 t ha⁻¹ + S + ZnSO₄ + Borax owing to higher economic yields obtained in these treatments, whereas, lower net returns was recorded in application of Rec. NPK + FYM due to lower yields . The B : C ratio was found to be higher with in application of site specific nutrient management for target yield of 2.5 t ha⁻¹ followed by application of SSNM for 2.5 t ha⁻¹ + S + ZnSO₄ + Borax but application of Rec. NPK + FYM recorded lowest B : C ratio . Similar results of higher economic benefit with higher fertility levels have been obtained by Anand (2010) and Meena (2015).

From the present study the B:C ratio was highest in the treatment T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (2.76) followed by T₁₀-RDF + foliar application of borax at 35 DAS @0.1%+ foliar application of Calcium nitrate at 35 DAS @0.3%.(2.70) T₇-RDF+ foliar application of borax at 35 DAS @ 0.1% (2.44) T₆-RDF + gypsum application at 35 DAS @ 500 kg ha⁻¹ (2.38) when compared with control at harvest.

4.8 NUTRIENT CONTENT

4.8.1 Quantification of Calcium After Harvest

Data on calcium content was recorded after harvest in stem , leaves and kernels and presented in the table 4.20

Groundnut crop was a heavy feeder of calcium. More (90%) calcium uptake was during flowering and pod formation stages (Sarkar *et al.*, 1999).

Table 4.19. Effect of calcium and boron application on pod yield (kg ha⁻¹) and B : C ratio in groundnut

Treatments	Cost of cultivation	Gross returns	Net returns	B : C ratio
T ₁ : Control	41320	60741	19421	1.47
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	45394	81481	36087	1.79
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	47320	86667	39347	1.83
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	46420	90370	43950	1.95
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	48920	92889	43969	1.90
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	47320	112741	65421	2.38
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	46420	113333	66913	2.44
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	45193	112593	67400	2.49
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	48920	132444	83524	2.76
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	46593	128889	82296	2.70
CD 5%		20,744.30	20,744.31	0.445
SEm±		6,928.23	6,928.23	0.149

The results from the present study revealed that nutrient application of calcium and boron treatments recorded higher calcium content than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35DAS recorded significantly higher harvest index than the individual applications and other treatment.

The results from the study revealed that calcium content in leaf was high for the treatment with T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% is 68.3 per cent higher when compared to control which is respectively high than control and recorded highest uptake of calcium in leaves

The calcium content in stem was high for the treatment with T₉-RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% is 70.4 per cent higher when compared to control which is respectively high than control and recorded highest content of calcium in stem.

The calcium content in kernels was high for the treatment with T₉-RDF+ gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% is 80 per cent higher when compared to control which is respectively high than control and recorded highest uptake of calcium in kernels.

Root calcium content was high for gypsum (0.064%) compared to control (0.035%) which is 45.3 per cent high. Stem calcium content was high for gypsum (0.18%) compared to control (0.055%) which is 70 per cent high. Leaf calcium content was high for gypsum (0.10%) compared to control (0.055%) which is 45 per cent high Deepa *et al.*, (2014).

Table 4.20. Effect of calcium and boron application on calcium content (%) after harvesting in groundnut

Treatments		Stem	Leaf	Kernels
T ₁ : Control		0.025	0.021	0.02
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)		0.031	0.027	0.03
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹		0.054	0.044	0.06
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹		0.045	0.043	0.05
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹		0.062	0.05	0.06
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil		0.064	0.058	0.08
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%		0.066	0.059	0.08
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		0.043	0.038	0.04
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%		0.079	0.071	0.10
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%		0.074	0.067	0.09
CD 5%		0.025	0.018	0.03
SEm±		0.008	0.006	0.01
Mean		0.0543	0.0478	0.06

While control plots recorded significantly lowest value of calcium uptake. The micronutrient foliar spray i.e. boron along with RDF + gypsum recorded superior uptake of calcium. Calcium is the key element in the filling of the developing pods and had synergistic effect with zinc and boron (Ujwala Ranade and Malvi, 2011). Similar findings were reported by Karmakar *et al.* (2005) and Mohapatra and Dixit (2010).

4.8.2 Quantification of boron before flowering and after harvest

Data on Boron content was recorded before flowering in stem, leaves and kernels and presented in the Table 4.21.

The results from the present study revealed that all nutrient application treatment are higher boron yield than control. Treatments with RDF + gypsum and boron individual soil and foliar applications and gypsum + borax basal applications recorded only numerically higher when compared to RDF alone. Only treatment with RDF + gypsum application to soil during flowering + foliar application of borax at 35 DAS recorded significantly higher harvest index than the individual applications and other treatment.

Among the treatments Boron content in leaf ,stem was high for the treatment with RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1% when compared to control which is high than control and recorded highest content of boron before flowering followed by RDF+ Gypsum application as basal @ 500 kg/ha

Among the treatments after harvesting boron content in leaf, stem kernel was high for the treatment with RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1% when compared to control which is high than control and recorded highest content of boron followed by T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3%.

Increased micronutrients uptake by the groundnut crop might be due to increased dry matter production. This might be due to supply of micronutrients through foliar application which lead to quick absorption and avoid nutrient losses. Manasa *et al.* (2015) also recorded similar results with combined foliar application of micronutrients along with RDF in increasing the nutrient uptake.

The data of harvest by haulm and pod revealed that uptake of boron by haulm was higher than that of pods. The boron taken up by the plant will remain in the leaf tissues, and will not move from the leaves to the developing pods where its requirement is high (boron was immobile in plant system), so the uptake by pods was lesser compared to haulm (Meena *et al.*, 2007).

Table 4.21. Effect of calcium and boron application on boron content (ppm) in groundnut

Treatments	Before flowering		After harvesting		
	Stem	Leaves	Stem	Leaves	Kernels
T ₁ : Control	3.10	3.07	3.29	2.99	3.02
T ₂ : RDF (N : 20, P : 50, K : 40 kg ha ⁻¹)	3.30	3.49	3.14	3.28	3.23
T ₃ : RDF + Gypsum application as basal @ 500 kg ha ⁻¹	3.28	4.07	2.87	3.18	3.29
T ₄ : RDF + Borax application as basal @ 10 kg ha ⁻¹	4.10	4.12	3.66	3.44	4.17
T ₅ : RDF + Basal application of Gypsum @ 500 kg ha ⁻¹ + Borax @ 10 kg ha ⁻¹	3.40	4.24	3.27	3.37	3.18
T ₆ : RDF + Gypsum application at 35 DAS @ 500 kg ha ⁻¹ to soil	4.20	4.08	3.62	3.72	4.19
T ₇ : RDF + Foliar application of Borax at 35 DAS @ 0.1%	4.15	4.42	4.16	4.03	4.13
T ₈ : RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	4.13	3.78	3.51	3.63	3.31
T ₉ : RDF + Gypsum application to soil during flowering @ 500 kg ha ⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%	4.80	4.44	5.11	4.50	5.63
T ₁₀ : RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%	4.02	4.23	4.84	4.43	5.43
CD 5%	0.39	0.60	0.74	0.46	0.35
SEm±	0.13	0.20	0.25	0.16	0.12
Mean	3.84	3.99	3.74	3.65	3.95

Chapter ~ V



Summary & Conclusions

Chapter – V

SUMMARY AND CONCLUSIONS

A field experiment was carried out during *kharif* in Field No. 99 of Dryland Farm, S.V. Agricultural College, Tirupati, Acharya N.G. Ranga Agricultural University, Andhra Pradesh to study the "**Effect of Calcium and Boron on Growth, drymatter partitioning and yield of groundnut (*Arachis hypogaeae* L.)**".

The experiment was laid out in randomized block design and replicated thrice. The treatments consisted of ten treatments *viz.*, T₁-Control, T₂-RDF (N, P, K- 20, 50, 40 kg ha⁻¹), T₃-RDF+ Gypsum application as basal @ 500 kg ha⁻¹, T₄-RDF+ Borax application as basal @ 10 kg ha⁻¹, T₅-RDF + Basal application of Gypsum @ 500 kg ha⁻¹ + Borax @10 kg ha⁻¹, T₆-RDF + Gypsum application at 35 DAS @ 500 kg ha⁻¹, T₇-RDF + Foliar application of Borax at 35 DAS @ 0.1%, T₈-RDF + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%, T₉-RDF + Gypsum application to soil during flowering @ 500 kg ha⁻¹ + Foliar application of Borax at 35 DAS @ 0.1%, T₁₀-RDF + Foliar application of Borax at 35 DAS @ 0.1% + Foliar application of Calcium Nitrate at 35 DAS @ 0.3%.

Observations were recorded on Physiological and growth parameters *viz.*, plant height, leaf area, drymatter partitioning, leaf area index and yield attributes *viz.*, number of flowers per plant, flower to peg ratio, peg to pod ratio, root nodulation parameters, number of filled pods plant⁻¹, 100 kernel weight, pod yield and harvest index. Data was also recorded on biochemical parameters and nutrient uptake by the plant for different treatments.

Plant height recorded continuous increase till crop reached maturity. Significant differences among the treatments were observed throughout the crop growth except at 80 DAS and at harvest.

The leaf area per plant showed a gradual increase till 80 DAS and then declined in all the treatments and the significant difference was observed only during 60 DAS and 80 DAS.

Leaf, stem, root dry weight was gradually increased up to 80 DAS and there after diminished at harvest. Critical contrasts for leaf dry weight among the treatments were found from 40 DAS to harvest.

Pod dry weight increased progressively from 60 DAS to harvest .The results from the study revealed that the above parameters was recorded highest in RDF + Gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (T₉) followed by RDF + foliar application of borax at 35 DAS @0.1% + foliar application of Calcium nitrate at 35 DAS @0.3% (T₁₀) which were comparable with each other treatment applied. The lowest values were recorded with control.

The growth parameters viz., CGR, NAR, LAI, LAR and LWR, was gradually increased up to 80 DAS and there after decreased at harvest. Significant differences among the treatments were found from 60 DAS to 80 DAS.

Application of RDF + gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1% was observed higher leaf area index, which was statically at par with RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of calcium nitrate at 35 DAS @ 0.3%, when compared with control at harvest.

The leaf area duration (LAD) and leaf weight ratio (LWR) were observed statistically higher values in treatments received RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1%.

Hundred kernel weight was recorded highest in RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1%, followed by RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @0.3%, RDF+ foliar

application of borax at 35 DAS @ 0.1%, RDF + gypsum application at 35 DAS, RDF + Basal application of gypsum +borax when compared with control at harvest.

The results from the present study revealed that nutrient application of calcium and boron treatment was recorded superior pod and haulm yield than control.

Haulm yield was recorded highest in RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1%, followed by RDF + foliar application of borax at 35 DAS @ 0.1%+foliar application of Calcium nitrate at 35 DAS @ 0.3%, RDF+ foliar application of borax at 35 DAS @ 0.1%, when compared with control at harvest.

Sound mature kernels, shelling percentage and harvest index had no significant difference among the treatments, however, numerically higher values were recorded with RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1% and the lowest was noted with control.

CONCLUSIONS

- Among the treatments experimented, the taller plants were recorded in T₁₀-RDF + foliar application of borax at 35 DAS @ 0.1% +foliar application of Calcium nitrate at 35 DAS @ 0.3%, while the short statured plants were recorded with control treatment.
- Among the treatments the highest plant leaf area was recorded in RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% followed by RDF + foliar application of borax at 35 DAS @0.1%+ foliar application of Calcium nitrate at 35 DAS @ 0.3%, RDF + foliar application of borax at 35 DAS @ 01.%, RDF + gypsum application at 35 DAS when compared with control during 80 DAS.

- Among the treatments experimented, highest leaf, stem and root dry weight was recorded in RDF + Gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% (T₉) while the lowest was recorded with control.
- Crop growth rate (CGR) was recorded highest in treatments received RDF+ gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1%.
- Among the treatments applied, RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% was found higher Net assimilation rate (NAR), Leaf area index (LAI), Leaf area duration (LAD) and it was comparable with RDF + foliar application of borax at 35 DAS @ 0.1%+foliar application of Calcium nitrate at 35 DAS @ 0.3%, while the lowest values was observed with control.
- The highest number of nodules and distribution of nodules were recorded with the application of RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1%, which was comparable with RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3%, RDF + foliar application of borax at 35 DAS @ 0.1% and RDF + gypsum application at 35 DAS. The lowest number of nodules and distribution of nodules were recorded with control, which was significantly lesser than with rest of the treatments.
- The highest number of pods per plant and number of filled pods per plant were recorded RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹+ foliar application of borax at 35 DAS @ 0.1%, however, it was at par with RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3% and RDF + foliar application of borax at 35 DAS @ 0.1%, while the lowest was recorded with control treatment.

- The highest pod yield was recorded with the treatment received RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1% followed by RDF + foliar application of borax at 35 DAS @ 0.1% + foliar application of Calcium nitrate at 35 DAS @ 0.3%. Both treatments were significantly superior to rest of the treatments, the next best treatment was RDF+ foliar application of borax at 35 DAS @ 0.1% and lowest was found with control.
- Biochemical parameters viz., oil content, protein content, total carbohydrates, total amino acids were increased in all treatments compared to control but the increase was numerical and there was no significant difference between the treatments. The above parameters were higher with RDF + gypsum application to soil during flowering @ 500 kg ha⁻¹ + foliar application of borax at 35 DAS @ 0.1%, whereas, the treatment without any application recorded lower value.
- Among the ten treatments highest B : C ratio was recorded in the treatment with RDF + gypsum application during flowering + foliar application of borax at 35 DAS @ 0.1% i.e. (1:2.70).



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