RESPONSE OF GROUNDNUT TO SOIL FERTILITY CONSTRAINTS IN NORTHERN TRANSITION ZONE OF KARNATAKA

Thesis submitted to the
University of Agricultural Sciences, Dharwad
In partial fulfillment of the requirements for the
Degree of

MASTER OF SCIENCE (AGRICULTURE)

IN

SOIL SCIENCE AND AGRICULTURAL CHEMISTRY

By

KALMESH PUJARI

DEPARTMENT OF SOIL SCIENCE AND AGRICULTURAL CHEMISTRY
COLLEGE OF AGRICULTURE, DHARWAD
UNIVERSITY OF AGRICULTURAL SCIENCES,
DHARWAD - 580 005

JUNE, 2012

ADVISORY COMMITTEE

DHARWAD
JUNE, 2012

(P. L. PATIL)
MAJOR ADVISOR

Approved by :

Chairman : ____________________________
(P. L. PATIL)

Members :

1. ____________________________
(G. S. DASOG)

2. ____________________________
(N. S. HEBSUR)

3. ____________________________
(M. V. MANJUNATH)

4. ____________________________
(S. C. ALAGUNDAGI)

CONTENTS

Contd……….

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

1. INTRODUCTION

The continuous increase in human population is leading to disturbance of the earth's ecosystem to produce food and fiber and will place greater pressure on soils to supply essential nutrients. The practice of intensive cropping with hybrid varieties for boosting food production has led to decline in productivity of soils of India. If we do not improve and/or sustain the productivity of our soils, we cannot continue to achieve the food and fiber demand of our growing population.

In the recent past, the concept of watershed based holistic development has emerged as one of the potential holistic approaches in rainfed areas, leading to higher productivity and sustainability in agriculture. Hence, assessing the fertility status and nutrient mapping of soils are needed to identify the extent of soils deficient in nutrients for site specific recommendations. Micronutrients deficiency in soils have become wide spread in recent years and has resulted in low yields, more so with the introduction of high yielding crop varieties coupled with the use of high analysis fertilizer and increased cropping intensity. The information regarding the status of available micronutrients and nutrient mapping of soils is needed to implement the concept of watershed approach successfully.

The soil test based fertilizer recommendation being followed in India and other developed countries of the world have not been able to achieve the intended increase in crop production. This may be mainly attributed to the present system of fertilizer recommendations. The NPK recommendations being advocated to farmers and included in the package of practices were developed about 40 years back by the University in collaboration with ICAR institutions and the development departments. These recommendations may not be relevant in the present day context as there is appreciable decline in fertility level of soil all over the country. This has been amply demonstrated by the results of LTFE studies conducted all over the country. These experiments have revealed that plots receiving 150 per cent of the recommended NPK recorded higher yields than plots receiving 100 recommended NPK. These results warrant the need for re-validation of the package of nutrients recommendations for different crops.

Hence, there is a need to refine the existing soil test based fertilizer recommendations for attaining higher yields. In this study, groundnut- the major crop of zone-8 of Karnataka is selected as test crop.

Groundnut (*Arachis hypogaea* L.) is an important oilseed crop of tropical and sub-tropical regions of the world. It is regarded as “King of oilseed crops” on the account of its diverse uses. Groundnut belongs to the leguminoseae family. It is an herbaceous, annual plant that grows to a height of 20-60 cm. Depending on the species; the plants may grow upright and sideways with their sideward shoots to a breadth of 30-80 cm. The main stem usually remains upright. The taproots penetrate to a depth of 90-120 cm, creating branches within the upper soil levels that are then populated by rhizobia and mycorhiza.

India is the second largest groundnut growing country after China. It is being cultivated on an area of 4.19 million hectares and production is 5.62 million tonnes with the productivity of about 1.3 t ha^{-1} (Department of Agriculture and Cooperation, Ministry of Agriculture, Govt. of India, 2012). Groundnut occupies 29.86 per cent of total nine oilseeds area and contributes 35.22 per cent to total oilseeds production in India. In Karnataka, it is cultivated on an area of 8.5 lakh hectares with a production of 4.0 lakh tonnes and productivity of 493 kg ha^{-1} (Directorate of economics and statistics, Govt. of Karnataka 2009). Further, the cultivation of groundnut is mostly confined to rainfed farming situations. The yields of rainfed groundnut are often low (<1000 kg ha^{-1}) and erratic (ranging from 400-3000 kg ha^{-1}). The fluctuation in yield is mainly due to shortage and ill distribution of rainfall in *kharif* and the low infiltration rate of soil. The area covered by groundnut in northern transition zone (Zone 8) of Karnataka is 2.2 lakh ha. It is an important crop of this area. But, in the past few years this zone is experiencing moderate to severe drought.

Groundnut is an unpredictable legume, since its response to nutrient application is always not optimistic. Excessive application of nitrogen and potassium often resulted in excessive vegetative growth.

Considering the availability of the major nutrients in the soil and quantum of losses due to leaching and/or fixation of the individual elements expected, a proper method and the time of nutrient application are needs of the hour. These facts call for a concerted study on the possibility of more effective utilization of nutrients in divided dosages like basal and top dressing. Though groundnut belongs to the leguminoseae family, it is reported to be relatively heavy feeder. The quantity of nitrogen and phosphorus removed by this crop shows considerable variation from the figures reported by various workers; the quantity of nitrogen removed by crop of groundnut varies from 70 to 167 lb and that of phosphate from 20 to 24.3 lb per acre.

The continuous and imbalanced use of chemical fertilizers without organic manures alone has resulted in deterioration of soil health and lower productivity of groundnut. The optimization of the mineral nutrition is the key to optimize the production of groundnut, as it has very high nutrient requirement particularly with the recently released high yielding groundnut varieties. On the contrary groundnut farmers, in most part of the semi-arid region use very less fertilizer and sometimes only one or two nutrient sources, thus result in severe mineral nutrient deficiencies including micronutrients. The inadequate and imbalance use of nutrients is one of the major factors responsible for low yield in groundnut. India is the world's second largest producer of groundnut where nutritional disorders cause yield reduction from 30-70 per cent depending upon the soil types. Thus, it is high time to look into the mineral nutrition aspects of groundnut for achieving high yields and to modify the package of practices for optimization of yield (Singh, 2004).

In view of the above, the present investigation was taken up with the following objectives;

- To identify soil fertility constraints of selected micro-watershed in northern transition zone of Karnataka using GIS technique.
- To study the response of groundnut to identified soil fertility constraints
- To study the uptake of nutrients by groundnut and residual fertility status of soil

2. REVIEW OF LITERATURE

The nutrient statuses of soils have a great role in influencing the yield and quality of crop in an agro-ecological region. Assessing the fertility status and nutrient mapping of soils are needed to identify the extent of soils deficient in nutrients for soil test based site specific recommendations. Keeping this in view, literature pertaining to nutrient status of different soils, response of groundnut to nutrients and nutrient uptake by groundnut and residual soil fertility are reviewed here under the following headings.

2.1 Nutrient mapping and spatial distribution of nutrients

2.2 Response of groundnut to nutrients

2.3 Nutrient uptake

2.1 Soil fertility status

2.1.1 Nutrient mapping and spatial distribution of nutrients

Ravikumar *et al.* (2007) characterized and classified the soil resources of 48A Distributary of Malaprabha Right Bank Command for sustainable land use planning and to assess the productivity of the soils. The mapping of available nutrient status by GIS technique indicated that majority of the area was low to medium with respect to available N, P and S. The entire study area was high in K. Among the micronutrients, the majority area was deficient in iron and zinc, whereas, manganese and copper status was low to sufficient. The crop cutting experiment revealed that the yields of the crops were in general low as soils were deficient in N, P, S, Zn and Fe. Soils of Bhanapur microwatershed in northern dry zone of Karnataka was studied by Srikant *et al.* (2008), for available nutrient status and mapped by GIS technique. Twenty five surface soil samples from black soils and seventy five surface soil samples from red soils in Bhanapur microwatershed were collected and assessed for the available major nutrient status. The results revealed that the majority of the area (580.42 ha) in the micro-watershed was low in available nitrogen and medium in available phosphorus in major part of the micro-watershed (555.25 ha), but it was low in 26.71 ha, the available potassium content in major portion of the study area was medium and high category in 365.65 and 150.31 ha, respectively. Available sulphur status was low (417.32 ha) to medium (164.64 ha). A study was undertaken by Mathews *et al.* (2009) to map the nutrient status of Mirjan village under the coastal agroecosystem of Karnataka. The soil analysis showed the deficiency of N, P, K and Zn in the study area. From the soil fertility maps it was observed that in the study area 247.3 ha low (69.5 per cent of the study area), 86.50 ha medium and 22.14 ha high in available nitrogen. An area of 249.3 ha was low (70.0 per cent of the study area), 88.40 ha was medium and 18.32 ha was high in available phosphorous. In the case of potassium, 159.15 ha was low (44.7 per cent of the study area), 131.71 ha was medium and 65.39 per cent ha high in available potassium. Zn deficiency was observed in 201.21 ha (56.5 per cent of the study area).

Binita *et al.* (2009) conducted an investigation on soil fertility status in a portion of Ghatprabha left bank canal (GLBC) command area to evaluate the status of major nutrients as affected by the different physiographic units. Two hundred and fourty samples were collected at random in GLBC command area representing all physiographic positions in the landscape and major crops grown. The fertility maps were prepared for the area using Arc View 3.1 and spatial analyst using spline function for interpolation. The nutrient status was discussed in relation with physiographic position and cropping pattern. Due to intensive irrigated agriculture practice in the command area, the nutrient status did not follow any distinct trend with respect to physiographic units and crops grown. Based on the overall assessment, the nutrient status in these soils was optimum.

In an investigation by Sharma *et al.* (2008), on spatial distribution of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) was studied at flag leaf stage of wheat (*Triticum aestivum* L.) by collecting random geo-referenced surface (0-0.15 m) soil samples from 645 sites representing different soils using global positioning system (GPS) and mapped on 1:50,000 scale in Amritsar district of North-West Punjab.

GPS (global positioning system) was used by Tur, *et al,* 2008, for collecting systematic set of geo referenced samples from the Patiala district covering the entire area and the map showing the spatial variability of individual macro-nutrient element (N, P, K and S) were generated using Arc Info GIS (Geographic Information System), both being the frontier technologies for mapping. The multi macro-nutrient status map was also generated by merging the individual macro-nutrient element map using GIS. In Patiala district of Punjab, the 23, 3 and 31 per cent of the samples tested were found to be deficient in P, K and S, respectively. All the samples were found to be deficient in N. It was also clear from the multi-macro nutrient map that only 0.3 percent (1010 ha) of the total geographical area (TGA) of the district was deficient in all the three nutrients i.e. N, P and K represented by category LLL.

Sharma *et al.* (2008) studied the spatial distribution of nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) was taken at flag leaf stage of wheat by collecting random geo referenced surface (0-15 cm) soil samples from 645 sites representing different soils using global positioning system (GPS) and mapped on 1:50,000 scale in Amritsar district of north west Punjab. The plant (flag leaves) samples were also collected simultaneously from every 4^{th} soil sampling site. These soil samples were analyzed for N, P, K and S and plant samples for P, K and S and categorized as low, medium and high as per criteria followed in soil testing laboratories. Soil nutrient maps showing the spatial distribution were prepared in Arc Info GIS. The maps of various nutrient elements clearly indicated the specific locales, where deficiency of nutrient constrained crop production. Multi-nutrient (NPK) map suggested that the combined NPK deficiency at a single place was negligible. Based upon the linear coefficient of correlation between macronutrients and soil properties, a significant positive correlation occurred between organic carbon and N, K and S. the available nutrient showed a negative correlation with $CaCO_3$.

Sood *et al.* (2009) studied the micronutrient status and their spatial variability in soils of Muktsar district of Punjab. A systematic set of geo referenced samples was collected from the Muktsar district covering the entire area using GPS and the maps showing the spatial variability of individual micronutrient cation (Zn, Cu, Mn and Fe) were generated using Arc Info GIS. The multi micronutrient status map was also generated by integrating the individual micronutrient cation map in GIS. The results of the study revealed that in Muktsar district of Punjab. The 39, 7, 8 and 34% of total geographical area (TGA) of the district was deficient in Zn, Cu, Mn and Fe, respectively. It was also clear from the multi micronutrient map that the deficiencies of two or more micronutrient at one location in less prevalent than that of the deficiency of individual micronutrient.

Detailed characterization of soils of Punjab was carried out by Bali, *et al.* (2010). Data for various soil characteristics are presented agro-eco-sub region wise. The descriptive statistics on soil characteristics indicated that the pH of the soils varied from 6.77 to 9.30. The electrical conductivity (EC) ranged from 0.14 to 4.57 dS m^{-1}. The organic carbon (OC) ranged from 0.0 to 1.55%. Calcium carbonate varied from 0.5 to 10.46%. Available K ranged from 33.6 to1192 kg ha^{-1}. Available P ranged from 1.12 to 238 kg ha^{-1}. The exchangeable Ca^{2+}+Mg^{2+} ranged from 1.2 to 14 cmol (p^+) kg^{-1}, Na^+ ranged from 0.12 to 3.06 cmol (p^+) kg^{-1} and K^+ ranged from 0.05 to 3.65 cmol (p^+) kg^{-1}. Cation exchange capacity (CEC) ranged from 1.87 to 15.5 cmol (p^+) kg^{-1}. Exchangeable sodium percentage (ESP) varied from 0.03 to 33.13. The DTPA-Zn ranged from 0.07 to 3.06 mg kg^{-1}. Organic carbon, silt, EC and pH were the important factors in controlling the Zn availability. The GIS-based thematic maps indicated that 10% of the total geographic area of Punjab was affected by the Zn deficiency based on the existing critical limits.

2.1.2 Available N, P and K

Ramamoorthy and Bajaj (1969) assessed the soil fertility status of Indian soils. They observed that soils of majority of the states were low in available nitrogen, medium in available phosphorus and medium to high in potassium status. Dashratha Singh *et al.* (1979) showed that soils under intensive cultivation had become poorer in available nitrogen and potassium. Soils under natural grasslands and cultivated pastures maintained their fertility status with respect to nitrogen and potassium while they became richer in phosphorus. Divakar *et al.* (1989) assessed soil fertility status of five blocks of hilly region representing the horticultural area in Nainital region of Uttar Pradesh and found that all soils were slightly acidic to alkaline.

Available nitrogen was high but available phosphorus and potassium was low in all the soils tested. Chavan *et al.* (1995) observed that the available nitrogen, phosphorus and potassium increased very markedly in the surface layers. The changes of these nutrients were due to decomposition of organic matter added through the leaf litters. The red, black and associated soils of Giddalur mandal of Andhra Pradesh were low in available nitrogen (42 to 105 mg kg^{-1}) and phosphorus (1.40 to 11.50 mg kg^{-1}) while potassium (73 to 210 mg kg^{-1}) was medium to high and the available sulphur content was sufficient (5.00 to 21.20 mg kg^{-1}) in surface soils (Gurumurthy *et al.* 1996).

Ashoka (1998) reported that forest tree species recorded higher available nutrients such as nitrogen, phosphorus, potassium and sulphur both at surface and subsurface soils, respectively. Whereas lower values were recorded in surface and subsurface soils for Agricultural lands. Changes in nutrient status were due to decomposition of organic matter added through the leaf litter. Dhananjaya (2000) found that available nutrients like nitrogen, phosphorus, potassium and sulphur contents were increased in both surface and subsurface soils of Agriculture followed by Agri-hort system.

Invariably the surface soils had higher concentration of water soluble and exchangeable K than sub-surface soils in Karnataka (Hirekurabar *et al.,* 2000). Basavaraju *et al.* (2005) while characterizing and classification of soils of Chandragiri mandal of Chittoor district in Andhra Pradesh found that soils were low in available nitrogen, medium in available phosphorus, high in available potassium but deficient in sulphur, iron and zinc. While studying morphological, physical and physico-chemical characteristics of soils in sivagiri micro-watershed of Chittoor district in Andhra Pradesh, Thangasamy *et al.* (2005) reported that soils were low to medium in available nitrogen, phosphorus and potassium and high in sulphur.

Mruthyunjaya and Kenchanagowda (1993) while studying some salt affected soils of Cauvery and Vanivilas sagar command areas of Karnataka reported that the available nitrogen in the profiles ranged from 30.71 to 10.51 kg per hectare. Nitrogen content decreased with depth. Singh *et al.* (1993) reported that the total nitrogen content of the soils developed from granite-gneiss and Mahananda alluvium ranged from 0.10 to 0.72 per cent. The soils of Sundarbans were deficient in available nitrogen, low to high in available phosphorus and high in available potassium (Maji and Bandyopadhyay, 1995). Sahu and Mishra (1997) reported that available phosphorus content varied between 12.76 to 14.00 kg per ha and available potassium content varied from 171.00 to 211.66 kg per ha and both materials were in medium level. The data on the available P status in the soils of Karnataka showed that about 83 per cent of the soils are low in P and 17 per cent under medium category.

In Karnataka, about 10.3 per cent of soils fall under low category, 35.8 per cent under medium and 53.9 per cent under high category of available nitrogen status, available phosphorus status in the soils of Karnataka showed that about 83 per cent of the soils are low in phosphorus and 17 per cent area is under medium category and the available potassium was medium to high in most of the soils of the Karnataka state except in lateritic soils of coastal plain and Western Ghats and in shallow red and black soils where it is low (Shiva Prasad *et al.* 1998). According to Vara Prasad Rao *et al.* (2008), in typical pedons representing major landforms of Ramachandrapuram Mandal in Chittoor district of Andhra Pradesh, the soils were low in available nitrogen, low to medium in available phosphorus and medium to high in available potassium.

2.1.3 Available sulphur, calcium, magnesium and micronutrients

Balanagoudar (1989) studied 15 soil bodies representing red, black and lateratic soils in north Karnataka for sulphur status and forms of sulphur. The available sulphur content in different soils in surface in decreasing order was red soils > black soils > lateratic soils. In the red, black and associated soils of Giddalur Mandal of Andhra Pradesh, the available sulphur content was sufficient (5.00 to 21.20 mg kg^{-1}) in surface soils (Gurumurthy *et al.* 1996). Sharma and Gangwar (1997) observed that the total sulphur content in Inceptisols of Moradabad district in Uttar Pradesh ranged from 167 to 917 mg kg^{-1}soil and also noticed negative correlation between total sulphur and pH and also between total sulphur and electrical conductivity.

Ashok (2001) examined 12 soil series representing black, red and coastal soils from different agro-climatic zones of Karnataka and 12 surface soil samples from each series are analyzed for sulphur status and distribution of different forms of sulphur, relationship between sulphur and various soil properties. The $CaCl_2$ extracted sulphur content in black, red and coastal soils ranged between 5.08 to 59.95 ppm, 8.66 to 27.15 ppm and 7.26 to 20.32 ppm, respectively.

Madhumitadas *et al.* (1997) observed that higher content of calcium and magnesium in Agricultural lands as compared to fallow land. Dhananjaya (2000) reported that the highest values of exchangeable calcium and magnesium were reported in surface and subsurface soils in silvi-pasture system whereas the lower values were recorded in natural system.

Katyal and Sharma (1991) reported that available zinc varied from 0.12 and 2.80 mg per kg soil in Indian soils. It was nearly one hundredth of the total zinc in Indian soils. Singh *et al*. (1993) found that the highest DTPA extractable Zn and Mn in forest and Agricultural soils but did not show marked differences with waste lands. Rainfed agricultural lands were poorer in micronutrients than irrigated Agricultural lands. Ashoka (1998) reported that DTPA extractable iron, manganese, zinc and copper content of surface and subsurface soils were higher in the lands of forest trees as compared to agricultural lands.

Satyavathi and Suryanarayana Reddy (2004) studied fifty four soil samples from ten pedons of Telangana region of Andhra Pradesh for vertical distribution of DTPA-extractable Zn, Cu, Fe and Mn and their relationship with some soil properties. Soil pH, calcium carbonate, organic carbon and particle size fractions had strong influence on the distribution of these micronutrients. The content of micronutrient increased with the increase in organic carbon and decreased with increase in soil pH and $CaCO_3$. There was no definite trend for the distribution of these micronutrients with respect to depth. As per critical limit prescribed for Zn and Fe, 44 and 20 per cent of the soils could be rated as deficient in available zinc and iron, respectively. Copper and manganese were found to be adequate.

Krishna Murthy and Srinivas Murthy (2005) studied fifty surface soil samples from block and red regions representing different agro climatic zones of Karnataka for the distribution of DTPA- extractable Zn, Cu, Fe, Mn and hot water soluble boron and for their relationship with some soil properties. The deficiency of Zn was noticed in large number of soil series studied compare to Cu and B deficiency. While, Fe and Mn were found to be adequate in all the soil series. In black soil region, available Mn and Zn correlated positively with organic carbon and but non-significantly with clay. In red soil region, available Fe, B and Zn showed significant and positive relationship with clay. Available Cu, Fe, Mn and B showed positive relationship with organic carbon except zinc.

Thangasamy *et al.* (2005) studied the physico-chemical characteristics of soils in Sivagiri microwatershed of Chittoor district in Andhra Pradesh. The soils were high in sulphur whereas, deficient in Fe, deficient to sufficient in available Zn and sufficient in available Cu and Mn.

A study was undertaken by Ravikumar *et al.* (2007) to identify micronutrient constraints of 48 A distributory of Malaprabha right bank command of Karnataka for site-specific recommendations. The mapping of available micronutrient status by GIS technique indicated that the majority of the area was deficient in iron (0.18 to 3.51mg kg^{-1}) and zinc (0.01 to 0.37 mg kg^{-1}), whereas, manganese (0.014 to 11.38 mg kg^{-1}) and copper (0.016 to 6.78 mg kg^{-1}) status was low to deficient. Similarly, the soils of Ramachandrapuram Mandal in Chittoor district of Andhra Pradesh were deficient in DTPA-extractable zinc and iron while these were sufficient in DTPA-extractable copper and manganese (Vara Prasad Rao *et al.,* 2008).

Soil test based fertilizer prescription equations under Integrated Plant Nutrition System (STCR-IPNS) were developed by Gayathri *et al*. 2009, for potato on Ultisols. Making use of these equations, nomograms were formulated for a range of soil test values and desired yield targets of potato. These equations were validated on farmers' fields and it was found that the per cent achievement of the targets aimed was more than 90 and STCR-IPNS for 40 t/ha recorded relatively higher response ratio (38.05 kg kg^{-1}) and benefit-cost ratio (15.3) over other treatments indicating the validity of the equations for prescribing fertilizer doses for potato. Venkatesh Bhardwaj *et al*. (1994) indicated that FYM when applied along with 100 per cent dosage of NPK increased the DTPA extractable micronutrients.

2.2 Response of groundnut to nutrients

2.2.1 Growth parameters

2.2.1.1 Major nutrients

Nitrogen is an integral part of component of protoplasm, protein, nucleic acids, chlorophyll and plays a vital role both in vegetative and reproductive phases. Phosphorus is an important constituent of proteins, high energy compounds such as ATP and has a key role in energy transfers in the metabolic processes of plants. Potassium is another major nutrient essential for carbohydrate metabolism, nitrogen metabolism, synthesis of proteins, regulation of activities of various enzymes and adjustment of stomatal movement and water relations in plants.

Patel *et al.* (1983) observed that groundnut recorded higher plant height (17.1cm) with application of 25 and 50 kg N and P per hectare, respectively when compared to the lower doses i.e., 12.5 and 25 kg N and P per hectare, respectively which recorded plant height of 16.3 cm. In an another study, number of branches per plant, number of leaves per plant and haulm yield per hectare of groundnut was higher with application of 75 kg P_2O_5 per hectare as compared to lower doses of phosphorus (Newase *et al.,* 1990).

Angadi *et al.* (1990) reported that in deep black clay soil, application of 40: 80: 40 NPK kg ha^{-1} significantly increased the total dry matter production of groundnut at harvest (25.86 g/plant) and its dry matter accumulation in pods (12.07 g/plant) as compared to those in control (12.87 and 4.77 g/plant) and 20: 40: 20 NPK kg ha^{-1} (19.19 and 8.55 g/plant). Nimje (1992) observed that increasing levels of phosphorus from 30, 60 and 90 kg P_2O_5/ha significantly improved growth characters like rooting density, nodulation, dry matter and yield attributes. But the pod yield, oil content and protein contents were increased up to 60 kg P_2O_5/ha.

Barik *et al.* (1994) reported that application of 20-80-30 NPK kg per hectare produced increased plant height, number of branches per plant, dry matter accumulation of groundnut when compared to control. The work of Patra *et al.* (1994) reveled that application of 50 kg K_2O per hectare significantly increased the plant height, leaf area index and dry matter accumulation of groundnut when compared to control.

Jakhro (1984) observed that the groundnut recorded higher mean number of pods per plant and nodules per plant with application of 40 kg N per hectare as compared to application of 20 kg N per hectare and control. Kulkarni *et al.* (1986) observed that application of 50 kg P_2O_5 per hectare increased the nodules per plant, weight of pods per plant and dry matter accumulation in pods of groundnut as compared to control. Singh *et al.* (1994) stated that in a sandy loam soil, application of 50 kg P_2O_5/ha significantly increased the number of pods per plant (16.5), weight of pods per plant (9.9 g), kernels per plant (24.2) in groundnut over 0 and 25 kg P_2O_5/ha but was found to be on par with application of 75 kg P_2O_5/ha. They further opined that, application of 25 kg K significantly increased the number of pods per plant over control. Thorave and Dhonde (2005) reported that application of 25:50:00 N, P and K kg ha^{-1} + 5t FYM/ha recorded the highest plant height, plant spread, No. of branches per plant and total dry matter per plant at harvest and yield attributes *viz*., filled pod, dry pod plant and pod and haulm yield of summer groundnut.

2.2.1.2 Secondary and micronutrients

Chaubey *et al.* (2000) observed that application of 45 kg S/ha recorded significantly higher plant height (37.8 cm), number of primary branches per plant (8.69).

Zinc is one of the essential micronutrient for production of quality seeds. The role of zinc in plants metabolism and growth is well documented, zinc increased the chlorophyll content in the leaves, number and weight of nodules, number of plants, pods and pods weight. Srinivasan and velu (1982) reported improved nodulation, increased chlorophyll content and more pod per plant and pod yield on soil application of $ZnSO_4$ (50kg ha^{-1}) in groundnut crop. Gupta and Potalia (1987) revealed that application of Zn (5.0 and 7.5 ppm) gave a higher (9.0g) dry matter production per plant and more yield per plant (11.4g) compared to control (8.5g) in groundnut.

Bahl *et al.* (1986) reported that in 2 years field study conducted on sandy loam the yield of groundnut increased with application of Zn upto 20 kg and sulphur up to 15 kg ha^{-1}. The Zn and S content of pod and their uptake by plants increased and also noticed more number of pods per plant and higher oil content. Soil application of 20 kg Zn per hectare increased the plant height in groundnut (Kulkarni *et al.* 1989a). Whereas, Tomar *et al.* (1990) corroborated that the groundnut crop responded significantly to the zinc sulfate application up to 40 ka per hectare by increasing plant height and dry weight per plant.

Joshi *et al*. (1989) also observed that fertilization with Zn and Mo in a medium calcareous soil with as well as without *Rhizobium* inoculation increased the nodules number, pod per plant and 100 kernel weight in groundnut. Singh *et al.* (1990) observed that the application of Fe, Mn, Zn, Cu, B and Mo in three equal doses at 20, 40 and 60 days after emergence reduced chlorosis and increased the plant height, chlorophyll content in leaves, pod and fodder yields of groundnut significantly. Average increase of pod (43, 40, 27, 22, 13 and 11 %) was observed with foliar applied Fe, Zn, B, Mn, Mo and Cu treatments. The application of 20 kg S/ha as elemental sulfur to the soil before sowing produced 25 per cent more pods and 16 per cent more fodder. Geetha *et al*. (1996) opined that Zn and Mo (8g kg^{-1}) seed treatment to groundnut increased the germination per cent (97.5%), shoot length (3.9cm) and root length (3.7cm). The seed treatment with *Rhizobium* also gave higher 100 seed weight (33.3g) and oil per cent (47.1%) when compared to control (32.7 g and 47%, respectively).

Boron plays an important role in seed quality of both legumes and cereals but more prominently in legumes; its presence in plants is being required in small quantities. This micronutrient used as seed treatment and soil application. The presence of boron in soil will improve the seed quality. Rammurthy and Sudarsan (1992) observed that application of Zn and or B increased the pod yield, shelling %, 100 seed weight, seed protein and oil percentages. Das and Ali (1993) also observed that the foliar application of Zn, B, Mo to groundnut at 30 to 45 DAS, but application of Zn and B increased vegetative growth, Mo increased nodule number per cent, Zn increased flower number, pod number, pod weight and kernel weight. Sudarsan and Ramaswami (1993) reported that application of Zn and or B increased seed yields compared with control. Soil application of 20 kg $ZnSO_4$/ha and 2.5 kg borax/ha + foliar application of 0.5% $ZnSO_4$ at 40 DAS + 0.25% borax at 50 DAS recorded the highest seed yield of 1210 kg ha^{-1}.

Bhuiyan *et al.* (1997) observed that an application of micronutrients (Mo and B) and rhizobial inoculum nodulation was increased in all treatments as compared with untreated and unfertilized controls. Expect for the application of P, K, Mo and B with 50 kg N/ha seed inoculation combined with trace elements P and K gave the best nodulation. Seed yield was the highest (1.66 t/ha) with P, K, Mo and B combined with seed inoculation followed by P, K, Mo and B + 50 kg N/ha (1.59 t), yield as compared to controls 1.10 t/ha, while inoculums alone gave a yield of 1.26 t/ha.

Tripathy *et al.* (1999a) found that soil application of Zn, B and Mo singly or in combination improved nodulation and nitrogenase activity in groundnut, but the dry matter and leaf area index increased only when at least two out of three micronutrients were applied in combination. The increase in pod yield due to application of B, Zn + B, B + Mo, Mo + Zn and Zn + B + Mo over control were 20.4, 34.8, 39.9, 25.0 and 46.9 kg ha^{-1}, respectively. The micronutrient also enhanced nutrient uptake in groundnut.

Tripathy *et al.* (1999b) studied that soil application of Zn, B and Mo singly and in all possible combinations B and Mo improved nodulation and nitrogenase activity in groundnut. Plant dry weight increased significantly when Zn, B and Mo were applied together micronutrients helped to maintain high LAI towards the later stage of growth, Zn alone had no significant effect on pod or oil yield. While B and Mo micronutrient application increased nutrient uptakes high nodulation and nitrogenase activity and gave higher pod and oil yields.

Subrahmaniyan *et al.* (2001) reported that application of zinc sulphate, Borax and ferrous sulphate either alone or in combination registered significant maximum value of growth, yield attributes and pod yield of groundnut over control among the different treatments combined application of zinc sulphate + Borax + ferrous sulphate recorded the highest pod yield 2209 kg ha^{-1} as compared to control.

Vishwakarma *et al.* (2008) revealed that in groundnut maximum plant height (60.33 cm) and number of branches (5.83 per plant) were recorded with application of borax as soil application.

2.2.1.3 Combined application of major, secondary and micronutrients

Lou *et al* (1993) took field trial involving groundnut cultivars during 1987-88 on deficient soil of different sites. Sodium borate were applied to the soils at 7.5 kg ha^{-1} along with NPK fertilizer compared with yield of control (2175.6 kg ha^{-1}). Boron fertilizer application increased the yield, number of pods per plant and oil content.

2.2.2 Yield and Yield attributes

2.2.2.1 Major nutrients

Devarajan and Kothanandaraman (1982) observed that higher shelling percentage in groundnut with the application of 80-90 PK kg per hectare as compared to control. Gajera and Patil (1984) obtained significantly higher pod yield with application of 37.5, 75 NP kg per hectare when compared to application of 12.5-25 NP kg per hectare. Chouhan *et al.* (1987) observed higher pod yield (3.74 t/ha) with the application of 60 kg P_2O_5 per hectare when compared to the lower levels of P_2O_5 at Gwalior during *kharif* season. Chitakala Devi *et al.* (1987) at Bhapatla reported that application of 40N + 17.5P + 250 kg gypsum as basal and 40N + 17.5P + 250 kg gypsum at 30 DAS recorded significantly higher number of filled pods per plant (20.1), shelling percentage (77.25%), 100 kernel weight (34.50 g) and pod yield (2536 kg ha^{-1}) compared to the application of 80N + 35P + 500 kg gypsum/ha as basal. Roshanlal and Gangasaran (1988) observed that among the fertilizer levels, higher pods per plant, dry weight of pods per plant, 100 kernel weight and higher pod yield was recorded with the application of 40-80 NP kg per hectare over control. However it is on par with the application of 20-40 NP kg per hectare.

Joshi *et al.* (1989) obtained increased nodules per plant, pods per plant and 100 seed weight resulting into higher pod yield of 1.25 tonnes per hectare with the application of 40 kg N per hectare as compared to control which recorded a yield of 1.12 tonnes per hectare. Yadav (1990) recorded numerically higher pod yield of groundnut (1.58 t/ha) with the application of 20-40-40 NPK kg per hectare when compared to the application of 20-30-40 NPK kg per hectare. Angadi *et al.* (1990) opined that significantly higher pod yield may be obtained with 40: 80: 40 NPK kg ha^{-1} (27.6 q ha^{-1}) as compared to control (19.55 q ha^{-1}) and 20: 40: 20 NPK kg ha^{-1} (23.22 q ha^{-1}) of groundnut. Mahale *et al.* (1991) observed higher yield of groundnut with the application of 25 kg N per hectare (1.78 t/ha) and yield was not increased with further increase in N level to 50 kg per hectare. Mishra and Vyas (1992) obtained higher pod yield with application of 20-80-20 NPK kg per hectare as compared to the application of 30-120-30 NPK kg per hectare during *kharif* season. Mahakulkar *et al.* (1992) stated that application of 25 kg N/ha on alkaline clay soils increased the pod yield (14.48 q ha^{-1}) of groundnut significantly over control (8.32 q ha^{-1}). However, it was on par with 50 kg N/ha (16.07 q ha^{-1}). They also recorded higher pod yield (14.94 q ha^{-1}) with application of 50 kg P_2O_5/ha over control.

Gnanamurthy and Balasubramanaian (1992) observed that application of 100 and 150 percent of the recommended dose of P and K to groundnut recorded significantly higher pod yield of 15.54 and 15.81 q ha^{-1}, respectively when compared to control (11.14 q ha^{-1}). Further they reported higher pods per plant (12.8), 100-kernel weight (44.88 g), sound mature kernel (79 %) and shelling percentage (65.5 %) with the application of 100 percent recommended dose of P and K. Bhalerao *et al.* (1993) recorded the significantly higher haulm yield (7143 kg ha^{-1}) with the application of 150 percent recommended NPK than 100 percent and 50 percent recommended dose (5992 and 5159kg ha^{-1}, respectively) of groundnut yield. Application of 100 percent of recommended dose (20: 80: 20 N: P_2O_5: K_2O kg ha^{-1}) resulted in 21, 10, 23, 98 percent increase in pod yield over 150, 75 and 50 percent of recommended dose and control, respectively. The haulm, oil yield, shelling percentage, 100 kernel weight and sound kernel were also higher with this dose (Mishra, 1994).

Khan *et al.* (1993) obtained higher pod yield of groundnut (3.1 t/ha) with application of 70 kg P_2O_5 per hectare as compared to application of 40 kg P_2O_5 per hectare under irrigated condition. Purushotham and Sadashivaiah (1994) reported that groundnut given with 20-60-40 NPK kg per hectare produced significantly higher pod yield compared to the control.

Singh *et al.* (1994) stated that in a sandy loam soil, application of 50 kg P_2O_5/ha significantly increased the number of pods per plant (16.5), weight of pods per plant (9.9 g), kernels per plant (24.2) and pod yield (19.54 q ha^{-1}) in groundnut over 0 and 25 kg P_2O_5/ha but was found to be on par with application of 75 kg P_2O_5/ha. They further opined that, application of 25 kg K/ha significantly increased the number of pods per plant over control. Patra *et al.* (1995) reported that application of 40-45 NP kg per hectare recorded higher number of pods per plant and also higher kernel weight and increased oil yield by 20 percent over control.

Prabakaran and Ravi (1996) obtained the higher pod yield of 2.1 tonnes per hectre of groundnut in improved agronomic package (sowing @ 125 kg seeds per hectare, seed treatment with carbendizim, application of 17: 34: 54 kg NPK, 12 kg trace elements (mixture) and 400 kg gypsum per hectare) in equal splits (basal and at pegging stage) compared to farmers practice (sowing rate 100 kg per hectare, the application of 10: 10: 10 kg NPK and 200 kg gypsum/ha (at pegging stage).

Balasubramanaiyan (1997) observed that in an alfisol combined application of NK in equal split doses as basal and at 45 DAS resulted in significantly higher haulm and pod yield (2587 and 2460 kg ha^{-1}, respectively) compared to entire NK basal application (2473 and 2460 kg ha^{-1}, respectively). Shelke *et al.* (1997) reported that significantly higher pod yield (2893 kg ha^{-1}) with application of 60 kg P_2O_5 per hectare over lower doses of 30 kg P_2O_5 per hectare. Tiwari and Dhakar (1997) recorded increased groundnut pod yield with the application of 30-80 NP kg per hectare when compared to control under irrigated condition. Lourdaraj *et al.* (1998a) obtained higher yields of groundnut with the application of recommended rates of N, P and K (17, 34 and 54 kg ha^{-1}, respectively) than individual elements, while addition of gypsum and micronutrients gave the higher yield.

Prabhakaran *et al.* (1998) observed that with application of recommended dose fertilizers (17: 34: 54 kg NPK per hectare) along with gypsum (250 kg ha^{-1}) in two equal splits as basal and top dressing at peg formation and micronutrient mixture (12.5 kg ha^{-1}) as basal application enhanced the pod yield significantly and increase in yield was 17 percent over RDF alone. Vinod Kumar *et al.* (2000) recorded the increase in the pod yield with the increase in level of fertilizer from 10: 20: 10 kg NPK/ha (1611 kg ha^{-1}) to 20: 40: 20 kg NPK/ha (1878 kg ha^{-1}) and 30: 60: 30 kg NPK/ha (2849 kg ha^{-1}).

The application of basal NPK + 12.5 tonnes basal FYM + 17 kg P_2O_5/ha at 30 DAS + 400 kg gypsum at 40 DAS recorded highest pod yield, shelling percentage and oil yield of groundnut. Whereas, lowest pod yield was found with the application of only basal fertilizer (17: 34: 54 kg NPK/ha) (Kumaran, 2000). Shinde *et al.* (2000) while worked on groundnut concluded that application of 100 percent RDF (25: 50: 0 kg NPK/ha) produced maximum 100 pod weight (84.09 g), dry pod (43.31 q ha^{-1}) and haulm yield (88.18 q ha^{-1}) which were more by 0.07, 5.47 and 0.36 percent, respectively compared to 75 percent RDF.

The residual effect of different organic and inorganic nutrient sources on yield and nutrient uptake of succeeding summer groundnut was studied by Badole *et al.* (2003). Integrated nutrient supply system showed significant residual effect on groundnut. It recorded maximum dry pod (2537 kg ha^{-1}) and haulm yield (4388 kg ha^{-1}) of groundnut. The organic nutrient sources along with biofertilizers produced higher dry pod and haulm yield as compared to untreated.

2.2.2.2 Secondary and micronutrients

Kadam *et al.* (2000) reported that groundnut fertilization with 40 kg S/ha resulted in highest dry pod (39.2 q ha^{-1}) and haulm (76.4 q ha^{-1}) yield, but was on par with the application of 20 kg S/ha.

Sahu *et al.* (1995) found that application of boron alone was more effective than application of lime. The B, Mo treatments was still more effective, it increased the number of filled pods per plant, 1000 pod weight and pod yield by 10.8% in the rainy season and 8.21% in the post rainy season. Increased oil yield by 11.9% in the rainy season and 14.8% post rainy season over the control. The B + Mo treatment gave the better results than control.

Revathy *et al.* (1997) observed that application of fertilizers either by basal or as chelated foliar sprays or received a 0.5% or 1% Zn, Cu, Fe, Mn and Ca recorded highest pod yield in groundnut Cv.Co-2.

Sarkar *et al.* (1998) reported that application of Zn and Mo had the greatest effects in increasing biomass production, leaf area index, crop growth rate and yield attributes resulting in 61 and 41 per cent greater pod yields than the control.

Ashokan and Raj (1974) observed that the application of boron increased the yield of groundnut. Subrahmaniyan *et al*. (2001) reported that application of zinc sulphate, borax and ferrous sulphate either alone or in combination registered significant higher yields. Among the different treatments combined application of zinc sulphate + borax + ferrous sulphate recorded the highest pod yield 2209 kg ha^{-1} as compared to control.

Zinc as soil application supported higher pod yield of groundnut due to better nodulation and nitrogen fixation. However, pod yield increased only marginally with application of iron to both soil and foliage (Kulkarni, 1989b). Channabasavanna and Setty (1993) observed that application of 10 kg $ZnSO_4$ per hectare at sowing gave significantly highest kernel yield in groundnut over control. The higher pod yield (2.12 t/ha) of groundnut cultivar JL-24 was obtained with *Rhizobium* + zinc sulphate. Gypsum alone and in combination with zinc sulphate increased the yield significantly (Ram *et al.* 1993).

Soil application of zinc @ 11.2 kg per hectare significantly enhanced the pod yield from 3990 kg per hectare (control) to 4880 kg per hectare. Further, zinc sulphate was more efficient in improving pod yields rather than zinc oxide. Also an extra pod yield of 980 kg per hectare was recorded with the combined application of Zn 5.6 kg per hectare + Mo 2 g per kg seed as against 540 kg per hectare without Mo (Gopala Gowda *et al.* 1995).

The application of trace elements increased the seed yield of groundnut compared to control. The application of Zn + Fe gave the highest seed yield (805 kg ha^{-1}) while the shoot dry matter yield was higher with Fe + Zn + Cu (Mousa *et al.* 1996). Mishra (1996) recorded the maximum pod yield (1285 kg ha^{-1}) with the application of 30 kg S/ha and was significantly superior to control (712 kg ha^{-1}) and 15 kg S/ha (892 kg ha^{-1}) and was on par with the application of 45 kg S/ha (1178 kg ha^{-1}).

Revathy *et al.* (1997) showed that, the soil application of either $ZnSO_4$ or $FeSO_4$ influenced the yield attributes in early stages while at later stages, the foliar spray of chelated micronutrients mixture (Zn EDTA-11.5 % Zn, Cu EDTA-9.5 % Cu, Fe EDTA- 11.0 % Fe, Mn EDTA- 9.5 % Mn, Ca EDTA- 8.5% Ca, Mg EDTA- 5.25 % Mg) @ 0.5 % registered higher values of yield attributes.

Sontakey *et al.* (1999) conducted a field experiment to study the response of sulphur and zinc as soil application in groundnut revealed that the application of sulphur and zinc increased the pod yield significantly. ICGS-44 showed the highest pod yield (2742 kg ha^{-1}) followed by ICGS-11 (2631 kg ha^{-1}).

Chaubey *et al.* (2000) observed that application of 45 kg S/ha recorded significantly higher pod yield (3125.99 kg ha^{-1}), shelling percentage (70.82 %) and 100 kernel weight (44.45 g) over the application of 0, 15 and 30 kg S/ha. Further the application of SSP as sulphur source recorded higher shelling percentage (69.01 %) and 100 kernel weight (42.50 g) and pod yield (2871.68 kg ha^{-1}) compared to the application of elemental S and $ZnSO_{4.}$ Halepyati (2001) indicated that, the application of Zn produced significantly higher pod and haulm yield over 100-kernel weight in groundnut. Zinc application increased the pod yield from 11.3 to 13.1 q ha^{-1}.

Chaube *et al.* (2002) concluded that the soil application of zinc sulphate @ 25 kg $ZnSO_4 .7H_2O$/ha significantly increased the pod yield by 15.5% over control. Soil application of 12.5 and 25.0 kg ha^{-1} $ZnSO_4 .7H_2O$ significantly increased the seed yield by 31.9 and 30.6 % over seed treatment with 24.0 g $ZnSO_4 .7H_2O$ kg^{-1} seed, respectively.

Chitdeshwari and Poongothai (2003) reported the response of groundnut to the application of multi micronutrients to soil and also as seed treatment indicated that the soil application of Zn 5 kg ha^{-1} + B 1.5 kg ha^{-1} + S 40 kg ha^{-1} significantly increased the pod yield to the tune of 24.2% for TMV-7 and 14.8 % for JL- 24 over control.

Saren and Sarkar (2007) conducted a field experiment during summer 2003 and 2004 to study the growth and yield of groundnut under different levels of irrigation and zinc.

The crop receiving three irrigations, (branching, peg development and pod development) recorded significantly higher pod yield (18 q ha^{-1}), kernel yield (13 q ha^{-1}) and oil yield (620.1 kg ha^{-1}) than under two irrigations. Zinc @ 20 kg ha^{-1} significantly increased the pod, kernel and oil yields as compared to 15 and 25 kg ha^{-1}. Irrigation applied only at branching and no zinc application recorded the lowest yield and yield attributes. Zinc @ 25 kg ha^{-1} significantly lowered the crop productivity might be due to toxicity of zinc.

A field experiment was conducted by Patel *et al.* (2007) during *kharif* and *Rabi* seasons of 1999-2000, 2000-01 and 2001-02 to study the effect of sulphur and micronutrients with and without FYM on yield of *kharif* groundnut and residual effect on succeeding wheat crop. Application of 10 tonnes FYM/ha to groundnut considerably increased the pod and haulm yields, uptake of Fe and Zn in pod and available Fe and Zn in soil over no FYM. Groundnut crop fertilized with 20 kg S/ha increased the pod and haulm yields as well as uptake of Fe and Zn in pod and haulm over control. Application of $FeSO_4$ and $ZnSO_4$ each @ 25 kg ha^{-1} resulted in significantly higher pod and haulm yields, DTPA-FE and Zn in post harvest soil and their uptakes than other treatments. Similar trend followed in wheat crop.

Ramani *et al.* (2007) evaluated the different method of micronutrient application in groundnut. The seed treatment with ZnO @ 16 ml kg^{-1} seeds containing 30% Zn was also comparable in increasing yield of groundnut with soil application of $ZnSO_4$ @ 5 Kg Zn/ha. The seed treatment @ 12 ml kg^{-1} seeds containing 25% Mn through MnO_2 increased the groundnut pod yield by about 2 q ha^{-1} over control. Similarly, the seed treatment with ammonium molybdate @ 6 ml kg^{-1} seeds of 12.5 % Mo concentration was also found superior over other Mo treatments to increase pod, haulm and total yields. The uptake of micronutrient was significantly higher over control.

Kuligod *et al.* (2007) studied the nutrient management for sustainable groundnut productivity in Black soils of Upper Krishna Canal Commands. The higher pod yield of 23.9 q ha^{-1} due to addition of 10 kg /ha each of $ZnSO_4$ and $FeSO_4$ along with recommended dose of fertilizers. However, pod yield that was obtained by micronutrient application (10 kg /ha each of $ZnSO_4$ and $FeSO_4$) along with fertilizer was on par with that of 150 per cent recommended dose of fertilizers. But, net return and B: C ratio were higher for the treatment that received 100 per cent RDF along with 10 kg each of $ZnSO_4$ and $FeSO_4$. Sonawane *et al*. (2010) reported significantly highest pod yield in treatment 20 kg $ZnSO_4$ and 5 kg borax as soil application and three foliar sprays of 1.0 % Fe in addition to RDF followed by 20 kg Zn + 5 kg Borax + RDF. The % increase in yield by these two treatment combinations were 49.94 and 33.76 % over RDF only.

2.2.2.3 Combined application of major, secondary and micronutrients

Lakshmamma and Raj (1997) reported that the combination of 60kg P_2O_5/ha, 40kg K_2O/ha and Co applied to seed (500mg kg^{-1}) followed by 2 foliar sprays at 45 and 85 days after sowing, recorded highest seed yield in TMV-2 with application of Co, P and K. Dilip Singh and Singh (2000) conducted an experiment at Udaipur on groundnut and revealed that fertilization of 60 kg S/ha gave significantly higher pod yield (2.84 t/ha) over 30 and 0 kg S/ha. And phosphorus application up to 50 kg ha^{-1} had recorded significantly higher pod yield (2.84 t/ha) over no P. Mahakulkar *et al*. (1992) reported that, individual nutrient elements of B, S or $MnSO_4$ did not significantly increase the pod yield compared with N + P alone, but combinations of nutrients, particularly combination with S, increased the yield of groundnut.

Krishnappa (1993) obtained a mean pod yield of groundnut (1.4 t/ha) without fertilizer and 1.8-2.0 tonnes in treatments receiving NPK with Ca, S, Cu, Fe, B, Mo and Zn or with all trace elements. Janakiraman *et al.* (2004) observed that three consecutive seasons during *kharif* 1998, 1999 and 2000 revealed that groundnut growth and yield were significantly higher when Fe, Zn and B were applied with recommended dose of NPK fertilizers. Combined application of 50kg N/ha, 25 kg P_2O_5/ha, 25kg K_2O/ha, $FeSo_4$ at 10 kg ha^{-1} $ZnSO_4$ at 5.0 kg ha^{-1} and borax at 1.0 kg ha^{-1} maximized the groundnut yield and net returns. There was a response both from sole application of each of the above mentioned micronutrients and from their combined application. Dimree and Dwivedi (1994) reported that significantly higher kernel yield (169 kg ha^{-1}) and shell yield (720 kg ha^{-1}) of groundnut was obtained with the application of 45 kg S/ha. Similar results was reported with application of 60 kg P_2O_5/ha.

The results of experiment by Christopher Lourduraj *et al.* (1997) for three consecutive seasons during summer 1990, 1991 and 1992 reveled that groundnut yields were significantly more if applied with iron, zinc, boron and gypsum. When basal application of NPK was combined with application of borax @ 5 kg ha^{-1} + $ZnSO_4$ 25 kg ha^{-1} along with application of gypsum @ 500 kg ha^{-1} and 1 % $FeSO_4$ spray on 45^{th} day after sowing resulted in maximum yield of the crop. The application of recommended rate of N: P_2O_5: K_2O fertilizers (17: 34: 54 kg ha^{-1}) + trace elements (Fe, Mn, Zn, B and Mo) produced the higher groundnut pod yield (2.05 t/ha) which was not significantly differ when compared to application of recommended NPK + 250 kg gypsum (2.03 t/ha). The pod yield was lowest with untreated control (1.66 t) (Lourdaraj *et al.* 1998b).

Kathmale *et al.* (2000) recorded a maximum and significantly higher dry pod (5178 kg ha^{-1}) and haulm (8448 kg ha^{-1}) yields due to application of recommended dose fertilizer (25 kg N + 50 kg P_2O_5) and 250 kg gypsum + zinc sulphate @ 25 kg ha^{-1}. Mohapatra and Dixit (2010) conducted a field experiment during *kharif* of 2003 and 2004 on loamy sand soil to study the effect of integrated use of FYM, recommended dose of fertilizer (RDF) i.e., 20-17.4-33.3 kg NPK/ha, *Rhizobium,* gypsum (250kg ha^{-1}) and boron (1 kg ha^{-1}) on performance of groundnut and soil fertility. Results revealed that application of FYM + 75% RDF + Rhizobium + gypsum + boron recorded significantly higher pod per plant, 100 pod weight resulting in higher pod (2.66 tonnes/ha), kernel yield (1.92 tonnes/ha) and nutrient uptake (151.4-17.0—58.6-0.8-0.07 kg N-P-K-S-B/ha.

2.2.3 Quality parameters

2.2.3.1 Major nutrients

Yakadri *et al.* (1992) revealed that in a red sandy loam soil, the protein content was higher (22.71 %) with 30 kg N/ha than N, but was not affected by the increasing level of P and K. Barik and Mukharjee (1995) observed higher oil content of 49.33 percent in groundnut with the application of 40 kg N per hectare as compared to the lower and higher levels of N application during summer season. Higher protein content (21.58 %), oil content (51.70 %) and oil yield (15.82 q ha^{-1}) were recorded due to 100 percent RDF (Shinde *et al.* 2000). Deshmukh and Atre (1993) recorded significantly higher oil content of 47.93 percent with the application of 50-75 PK kg per hectare as compared to control.

Choudhery *et al.* (1991) reported that application of P_2O_5 @ 60 kg ha^{-1} resulted in higher oil content (50.9 %) over no P application. Oil content was increased from 48.4 percent in control to 49.7 percent at 60 kg S/ha. Ved Singh *et al.* (1994) observed that the groundnut applied with 60 kg P_2O_5 per hectare recorded the highest oil content of 51 percent as compared to the application of 30 kg P_2O_5 per hectare at Sriganganagar during *kharif* season. Asha *et al.* (1996) recorded numerically higher oil content of 46.98 percent in groundnut kernels with the application of 50 kg P_2O_5 per hectare when compared to the application of 25 kg P_2O_5 per hectare.

Bhalerao *et al.* (1993) observed higher oil content of 48.93 percent in groundnut kernels with the application of 37.5-75-45 NPK kg per hectare when compared to 47.2 percent with the application of 25-50-30 NPK kg per hectare. Thimmegouda (1993) obtained significantly higher oil yield ofn1606 kg per hectare with the application of 25-72-37.5 NPK kg per hectare as compared to control.

2.2.3.2 Secondary and micronutrients

Dongale and Zende (1976) reported that application of boron and sulphur increased the oil content in groundnut seed from 47.16 to 52.26 percent and protein content from 23 to 27 percent over control. Krishnappa *et al.* (1992) found that the application of 5 kg Zn/ha enhanced the protein content of groundnut significantly over control. Application of zinc sulphate has significantly enhanced the crude protein content of groundnut seeds but the oil content was found to be non significant (Gopala Gowda *et al.* 1995). Gopal gowda *et al* (1994) observed that groundnut grown in Zn deficient light textured soils of Karnataka responded to Zn when applied as ZnSo4 @ 1g kg^{-1} of seeds increases the crude protein (25.81%) than control (21.81%).

Survase *et al*. (1986) observed that application of calcium, sulphur, boron along with FYM produced maximum dry pod yield (22.5 q/ ha). The oil content and protein content also increased due to different treatments from 44.71 to 47.61 per cent and from 24.46 to 27.24 per cent, respectively. Application of trace elements slightly increased the seed oil content of groundnut and the higher oil content was obtained with the application of Fe + Mn + Zn was reported by Mousa *et al.* (1996). Application of Mo and B significantly increased oil content (%) of groundnut as compared to Mo and B control treatment (Noor *et al.* 1997).

2.2.3.3 Combined application of major, secondary and micronutrients

Shahjahan *et al* (1989) reported that application of 60:40:60 NPK kg ha^{-1} with 40 kg Zn increased the 100 kernel weight, oil content, protein per cent and germination in groundnut. The protein content of groundnut seeds from plants fertilized with sodium borate @ 7.5 kg ha^{-1} along with NPK fertilizers was 1% higher than in the control (26.8 %) and fat content was 1.2% lower than in the control (Luo *et al.* 1993). Dimree and Dwivedi (1994) opined that application of sulphur @ 45 kg ha^{-1} increased oil content (53.5 %) and protein content (25.4 %) over the control. Similar results was reported with application of 60 kg P_2O_5/ha. Fertilization of groundnut with boron + sulphur along with nitrogen and phosphorus did not record any significant effect on oil percentage. Protein percentage was significantly influenced by application of N @ 25 kg ha^{-1}, P @ 50 kg ha^{-1} with B @ 10 kg ha^{-1} and S @ 20 kg ha^{-1} (Mahakulkar *et al.,* 1992).

Hegde and Babu (2004) noticed that profitable oil seeds cultivation is possible with integrated use of nutrient sources to improve the productivity and quality oil and protein. The nutritional balance, mainly of secondary and micronutrients has contributed to losses in oil seed yield and quality. The quality responses due to fertilizer (N, P, K, S and trace elements) use of different oil seeds like groundnut etc.

2.3 Nutrient uptake

2.3.1 Major nutrients

Singh and Ahuja (1985) observed higher uptake of N (124.45 kg ha^{-1}) and P (23.2 kg ha^{-1}) with the application of 90 kg P_2O_5 per hectare as compared to the application of 60 kg P_2O_5 per hectare. An average crop of groundnut yielding 19 q ha^{-1} removed about 170 kg N, 30 kg P_2O_5, 100 kg K_2O, 15 kg S and 39 kg Ca (Aulakh *et al.,* 1985). Kaushik and Jain (1991) recorded significantly higher uptake of N (157.1 kg ha^{-1}) and P (26.7 kg ha^{-1}) with the application of 60 kg P_2O_5 per hectare as compared to the application of 40 kg P_2O_5 per hectare. Significantly higher P uptake by groundnut pods was found with the application of 50 kg P_2O_5 (33.26 kg/plot) over 25 kg P_2O_5 (30.80 kg/plot) but was on par with 75 kg P_2O_5 (34.90 kg/plot). Similar trend of P uptake was observed in haulm (Sathone and Babulkar, 1991).

Thimmegowda (1993) while studying the nutrient uptake pattern in groundnut observed that the concentration and uptake of nutrients (N, P and K) was maximum with application of recommended fertilizer (25 N, 75 P_2O_5 and K_2O kg ha^{-1}) and minimum with no fertilizer. Ved singh *et al.* (1994) observed that the groundnut higher P uptake (37.79 kg ha^{-1}) with application of 60 kg P_2O_5 per hectare as compared to the application of 30 kg P_2O_5 per hectare. Asha *et al.* (1996) reported that the groundnut kernel recorded highest uptake of N (30.31 kg ha^{-1}) and P (4.39 kg ha^{-1}) with the application of 25 kg P_2O_5 per hectare as compared to the control at Junagadh during *kharif* season. Vali *et al.* (1978) found that N and P content of dry matter at peg formation and pod development stages of groundnut were positively correlated with pod yields.

Loganathan and Krishnamurthy (1977a) observed that uptake of N, P and K concentration in groundnut kernels was markedly increased due to calcium application. Vinod Kumar *et al.* (2000) recorded the maximum uptake of NPK (121.15, 10.14, 34.89 kg ha^{-1}) with the application of 30: 60: 30 kg NPK/ha compared to the application of 10: 40: 10 kg NPK/ha and 20: 40: 20 kg NPK/ha. Deka *et al*. (2001) stated that significant increase in N, P and K uptake was noted upto application of 50 P_2O_5/ha in groundnut, which was on par with 75 and 100 kg P_2O_5/ha. Balasubramanaiyan (1997) reported that combined application of NK in equal split doses at basal and 45 DAS increased the uptake of N, P and K (131.1, 25.5 and 58.4 kg ha^{-1}, respectively) by groundnut compared to the application of N basal, K basal and NK basal.

The residual effect of different organic and inorganic nutrient sources on yield and nutrient uptake of succeeding summer groundnut was studied by Badole *et al.* (2003). Integrated nutrient supply system showed significant residual effect on groundnut. It recorded maximum dry pod (2537 kg ha^{-1}) and haulm yield (4388 kg ha^{-1}) of groundnut. The organic nutrient sources along with biofertilizers produced higher dry pod and haulm yield as compared to untreated. Among the organic treatments (combination of different organic materials) was found superior. Similar trend was observed with respect to N, P and K uptake by kernel haulm and hull by groundnut.

2.3.2 Secondary and micronutrients

Dongale and Zende (1976) reported that the application of sulphur alone or in combination with FYM or boron helped not only in checking the excessive vegetative growth of the crop but also helped in absorbing more nutrients to produce more pod yield of groundnut crop. Sammireddy *et al.* (1992) reported that application of nitrogen, phosphorus and sulphur increased concentration of nutrients and lowest in Ca, Mg and K concentration, while Ca, Mg and K concentrations were highest in haulms. Significant correlation was observed between pod yield and uptake of nutrients by groundnut.

Tripathy *et al.* (1999b) observed that, the application of micronutrients (Zn, B and Mo) to groundnut cv. JL-24 and TGS 1 increased their nutrient uptake. Latha *et al.* (2002) observed that, DTPA-Zn was markedly influenced by the residual effect of zinc and manure application with on par with values recorded for 12.5 and 25 kg $ZnSO_4$ per hectare application in maize sunflower cropping system. De and Chatterjee (1976) indicated that Mn and Zn application reduced the P content in groundnut kernel whereas the Zn application increased appreciably Zn content in kernels. B increased Ca content in haulms. Yadav *et al.* (1991) observed that, zinc composition in groundnut plant parts increased with zinc application.

Tripathi and Singh (1984) identified that, boron uptake by gram as well as groundnut increased markedly with increasing concentrations of boron in soil solution. For both the crops, boron content in plants grown on 7.2 ppm of boron level was approximately 11 times higher than that of plants grown on 0.6 ppm. There existed a positive correlation between soil and plant boron. Luo *et al.* (1993) demonstrated that, the average B content of B fertilized plants at four different stages (seedling, flowering, pod setting and harvesting) was 37.2 ppm (49.4 % higher than that of the control) in stems, 38.0 ppm (13.8 %) in leaves, 13.0 ppm (9.2 %) in shells and 14.9 ppm (27.4 %) in seeds.

Mousa *et al.* (1996) reported that, the plant concentrations and uptake of micronutrients varied widely among the treatments consisting of micronutrients. The higher concentrations of Fe + Mn + Cu, Fe + Zn + Cu and Mn + Cu, respectively, with some exceptions. The chemically extractable trace elements in soil at the end of the experiment varied widely with treatments and some antagonistic relationships between Fe and Mn and Zn and Cu were found. Bell *et al.* (1990) reported that, a high proportion of legume crops are deficient in one or more of nutrients like B, Mo, P, K, S and N. whereas, the B deficiency affected about 33 % of all groundnut crops. Foliar spray of chelated mixtures of micronutrients increased the respective micronutrient concentrations in seeds of groundnut besides their nutrient uptake (Revathy *et al.* 1997).

3. MATERIAL AND METHODS

The particulars relating to the geographical set up of the micro-watershed, collection and preparation of the soil samples and the analytical methods adopted in the investigation are briefly presented in this chapter. Under this investigation groundnut was the test crop.

3.1 Location of micro-watershed

The watershed area belongs to the Kotur and Agsanhalli villages of Dharwad district (Fig. 1). The micro-watershed is located between; 15°32'8.35''N and 15°31'46.42''N latitudes and 74°54'37.08'' E and 74°53'42.01'' E longitudes.

3.2 Climate

The Kotur village is situated in the Northern Transitional Zone (Zone-8) of Karnataka state. The mean monthly meteorological data during the period of experimentation (2011) and for the past 60 years (1950-2010) are presented in Appendix 1.

The rainfall received in all the months during the crop growth period except August and September was lower than the average of past 60 years. The mean maximum temperature during the period of experimentation was ranged from 26.2°C (August) to 29.9°C (October), while the minimum temperature was ranged from 19.5°C (October) to 21.3°C (June). The mean relative humidity varied from 73 per cent in the month of October to 87 per cent in the month of August 2011.

3.3 Identification of soil fertility constraints

3.3.1 Collection of soil samples

For identification of soil fertility constraints in the study area, eighty (80) surface soil samples (0-20 cm) at 10" (second) grid interval were collected during May 2011. Exact geographical locations of surface soil samples were recorded using a GPS device (Table 1). Processed soil samples were analyzed for available nutrients.

3.3.2 Preparation and storing of soil samples

Soil samples collected were dried in shade. The air dried samples were ground with a wooden pestle and mortar and passed through a 2 mm sieve to separate the coarse fragments (>2 mm). The fine earth samples were stored in separate containers and used for various analysis.

3.3.3 Methods of soil analysis

3.3.3.1 Soil reaction

Soil pH was determined in 1:2.5 soil-water suspension by potentiometric method (Sparks, 1996).

3.3.3.2 Electrical conductivity

Electrical conductivity was determined in 1:2.5 soil-water extract using conductivity bridge and expressed as dSm^{-1} (Sparks, 1996).

3.3.3.3 Organic carbon

The organic carbon content of a finely ground (0.2mm) soil sample was determined by Walkley and Black's wet oxidation method as described by Sparks (1996) and expressed in g kg^{-1} soil.

3.3.3.4 Available nitrogen

Available nitrogen in the soil was estimated by modified alkaline permanganate method (Sharawat and Buford 1982). The organic matter present in the soil was oxidized by the nascent oxygen liberated by $KMnO_4$ in the presence of NaOH. After cooling distillation was confirmed by adding Devardas alloy to include NO_3-N and thus, the ammonia released was distilled and absorbed in boric acid mixed indicator. The quantity NH_3 distilled was estimated by titration against a standard acid.

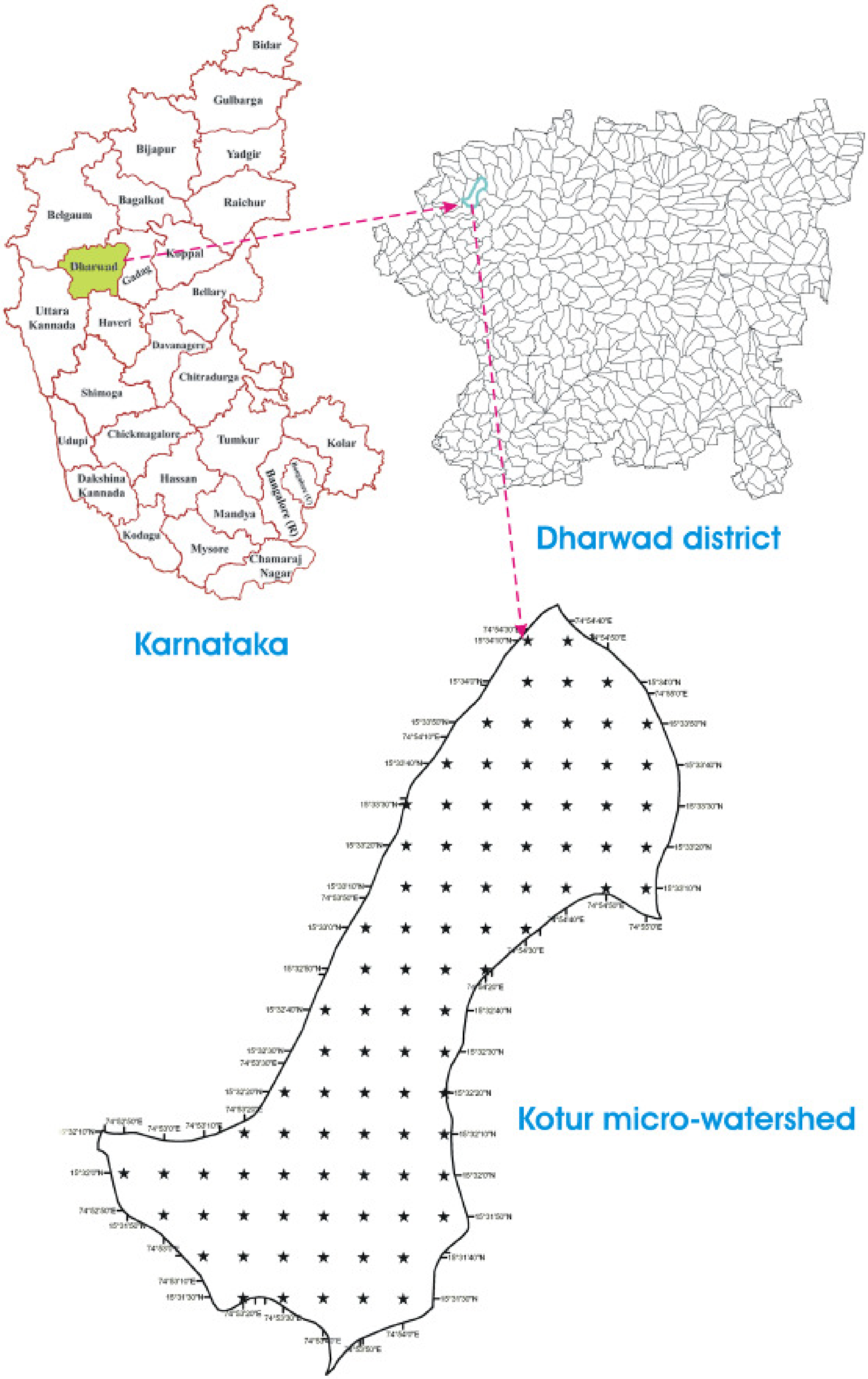


Fig 1.Location of study area with sample points

Table 1: Geographical locations of soil samples of Kotur micro-watershed

Sample No.	Latitude (N)	Longitude (E)	Sample No.	Latitude	Longitude
1	15^0 32' 0"	74^0 54' 0"	41	15^0 33' 30"	74^0 54' 10"
2	15^0 32' 0"	74^0 53' 50"	42	15^0 33' 30"	74^0 54' 20"
3	15^0 32' 10"	74^0 53' 30"	43	15^0 33' 30"	74^0 54' 30"
4	15^0 32' 10"	74^0 53' 40"	44	15^0 33' 30"	74^0 54' 40"
5	15^0 32' 10"	74^0 53' 50"	45	15^0 33' 30"	74^0 54' 50"
6	15^0 32' 10"	74^0 54' 0"	46	15^0 33' 30"	74^0 55' 0"
7	15^0 32' 20"	74^0 54' 0"	47	15^0 33' 40"	74^0 55' 0"
8	15^0 32' 20"	74^0 53' 50"	48	15^0 33' 40"	74^0 54' 50"
9	15^0 32' 20"	74^0 53' 40"	49	15^0 33' 40"	74^0 54' 40"
10	15^0 32' 20"	74^0 53' 30"	50	15^0 33' 40"	74^0 54' 30"
11	15^0 32' 30"	74^0 53' 40"	51	15^0 33' 40"	74^0 54' 20"
12	15^0 32' 30"	74^0 53' 50"	52	15^0 33' 40"	74^0 54' 10"
13	15^0 32' 30"	74^0 54' 0"	53	15^0 33' 50"	74^0 54' 20"
14	15^0 32' 40"	74^0 54' 10"	54	15^0 33' 50"	74^0 54' 30"
15	15^0 32' 40"	74^0 54' 0"	55	15^0 33' 50"	74^0 54' 40"
16	15^0 32' 40"	74^0 53' 50"	56	15^0 33' 50"	74^0 54' 50"
17	15^0 32' 40"	74^0 53' 40"	57	15^0 33' 50"	74^0 55' 0"
18	15^0 32' 50"	74^0 53' 50"	58	15^0 34' 0"	74^0 54' 50"
19	15^0 32' 50"	74^0 54' 0"	59	15^0 34' 0"	74^0 54' 40"
20	15^0 32' 50"	74^0 54' 10"	60	15^0 34' 0"	74^0 54' 30"
21	15^0 32' 50"	74^0 54' 20"	61	15^0 34' 10"	74^0 54' 30"
22	15^0 33' 0"	74^0 54' 30"	62	15^0 32' 0"	74^0 53' 20"
23	15^0 33' 0"	74^0 54' 20"	63	15^0 32' 0"	74^0 53' 10"
24	15^0 33' 0"	74^0 54' 10"	64	15^0 32' 0"	74^0 53' 0"
25	15^0 33' 0"	74^0 54' 0"	65	15^0 32' 0"	74^0 52' 50"
26	15^0 33' 10"	74^0 54' 0"	66	15^0 31' 50"	74^0 53' 0"
27	15^0 33' 10"	74^0 54' 10"	67	15^0 31' 50"	74^0 53' 10"
28	15^0 33' 10"	74^0 54' 20"	68	15^0 31' 50"	74^0 53' 20"
29	15^0 33' 10"	74^0 54' 30"	69	15^0 31' 50"	74^0 53' 30"
30	15^0 33' 10"	74^0 54' 40"	70	15^0 31' 40"	74^0 53' 10"
31	15^0 33' 10"	74^0 54' 50"	71	15^0 31' 40"	74^0 53' 20"
32	15^0 33' 10"	74^0 55' 0"	72	15^0 31' 40"	74^0 53' 30"
33	15^0 33' 20"	74^0 55' 0"	73	15^0 31' 40"	74^0 53' 40"
34	15^0 33' 20"	74^0 54' 50"	74	15^0 31' 40"	74^0 53' 50"
35	15^0 33' 20"	74^0 54' 40"	75	15^0 31' 40"	74^0 54' 0"
36	15^0 33' 20"	74^0 54' 30"	76	15^0 31' 30"	74^0 53' 20"
37	15^0 33' 20"	74^0 54' 20"	77	15^0 31' 30"	74^0 53' 30"
38	15^0 33' 20"	74^0 54' 10"	78	15^0 31' 30"	74^0 53' 40"
39	15^0 33' 20"	74^0 54' 0"	79	15^0 31' 30"	74^0 53' 50"
40	15^0 33' 30"	74^0 54' 0"	80	15^0 31' 30"	74^0 54' 0"

3.3.3.5 Available phosphorus

Available phosphorus in soil samples (pH < 6.5) was extracted by Bray and Kurtz No.1 extracting solution (0.03 N NH_4F in 0.025 N HCl) (Sparks, 1996).

The available phosphorus in the remaining soil samples (pH> 6.5) was extracted with Olsen's reagent ($NaHCO_3$). In the extracts phosphorus was determined by ascorbic acid reductant method using spectrophotometer at 780 nm (Singh *et al.*, 2010).

3.3.3.6 Available potassium

Available potassium in soil was extracted by neutral normal ammonium acetate and subsequent estimation was by flame photometer (Sparks, 1996).

3.3.3.7 Available sulphur

Available sulphur was extracted from the soil using 0.15 per cent calcium chloride solution and sulphur in the extract was determined by turbidimetry as outlined by Sparks (1996) using spectrophotometer at 420 nm.

3.3.3.8 Exchangeable calcium and magnesium

Exchangeable calcium and magnesium in soil were determined in neutral normal ammonium acetate extract by Versanate Titration as described by Sparks (1996).

3.3.3.9 Available micronutrients

Available zinc, copper, iron and manganese were extracted by using DTPA extractant as explained by Lindsay and Norvell (1978). The concentration of zinc, copper, iron and manganese in the extract was estimated using atomic absorption spectrophotometer (AAS Shimadzu model).

3.3.3.10 Available boron

Available boron was extracted by Hot distilled water as an extractant as explained by Gupta (1967). Boron was determined in the extract by azomethane-H method using spectrophotometer at 420 nm (Singh *et al.*, 2010).

3.3.4 Preparation of soil fertility maps using GIS techniques

A *dbf* file consisting of data for X and Y co-ordinates in respect of sampling site location was created. A shape file (Vector data) showing the outline of Kotur micro-watershed area was created in *Arc GIS 10.0*.

The *dbf* file was opened in the project window and in X-field, ``longitudes`` and in Y-field, ``lattitudes`` were selected. The Z field was used for different nutrients. The Kotur microwatershed file was also opened and from the ``Surface menu`` of Arc GIS geo statistical Analyst "geo statistical wizard`` option was selected.

On the output "grid specification dialogue", output grid extend chosen was same as Kotur micro-watershed and the interpolation method employed was krigging. Then map was reclassified based on ratings of the respective nutrients.

3.4 Field experiment

As a part of the present investigation, a field experiment was carried out in the farmer's field at Kotur village to study the response of groundnut to identified nutrient constraints and over all view of the experimental field is given in Plate 1. The physical and chemical properties of the experimental soil are given in Table 2. The plan of layout is given in Fig. 2.

3.4.1 Treatment details

Available N, P_2O_5, sulphur, zinc and boron were found deficient whereas potassium was high in available status at the selected site for the field experiment. Based on these results the following modification in RDF was made to study the response of groundnut.

T_1- RDF,

T_2-Fertilizer recommendation by Bhoochetana project.

Table 2: Characteristic properties of the soil of experimental site

Sl. No.	Particulars	Value	Method adopted	Reference
1.	**Particle size analysis (oven dry basis)**			
	Coarse sand (%)	20.6	Hydrometer method	Piper, 2002
	Silt (%)	19.6		
	Clay (%)	58.8		
	Textural class	Clay		
2.	**Chemical properties**			
	Soil reaction (1:2.5)	6.42	Potentiometric method	Sparks, 1996
	Electrical conductivity (dS m^{-1})	0.18	Conductometry	Sparks, 1996
	Organic carbon (g kg^{-1})	5.8	Wet oxidation method	Sparks, 1996
	Free calcium carbonate (%)	4.6	Rapid acid titration method	Piper, 2002
	Cation exchange capacity (cmol (p+) kg^{-1})	38.2	Ammonium acetate saturation method	Piper, 2002
3.	**Available Nutrients**			
	Available N (kg ha^{-1})	224	Alkaline permanganate method	Sharawat and Burford 1982
	Available P_2O_5 (kg ha^{-1})	21	Brays method	Sparks, 1996
	Available K_2O (kg ha^{-1})	380	Flame photometer method	Sparks, 1996
	Available S (mg kg^{-1})	8.4	Turbidimetric method	Sparks, 1996
4.	**Exchangeable cations**			
	Exchangeable Ca (cmol (p+) kg^{-1})	9.5	Versanate Titration method	Sparks, 1996
	Exchangeable Mg (cmol (p+) kg^{-1})	1.3	Versanate titration method	Sparks, 1996
5.	**Available micronutrients (mg kg^{-1})**			
	Zn	0.48	DTPA extractant	Lindsay and Norvell, 1978
	Fe	3.68		
	Mn	2.69		
	Cu	4.41		
	Hot water soluble B	0.36	Azomethane-H method	Singh *et al.* 2010

T_3- RDF modification based on soil test; According to recommended package of practice, UAS, Dharwad, N and K_2O were not modified from RDF. Because of low available P_2O_5 status, 12.5 kg P_2O_5 was added to RDP_2O_5. Hence, modifiedP_2O_5 in this treatment is 62.5 kg P_2O_5/ha. In addition to these nutrients, recommended Zn and Fe was applied.

In T_4 and T_5 RD N and RD P_2O_5 were increased to 20 and 40 per cent, respectively, whereas, RDK_2O was reduced to 20 and 40 per cent, respectively. In addition to these nutrients, 5 kg zinc and 0.2 kg B was included in the treatments.

In T_6 and T_7 N, P_2O_5 and K_2O levels were same as in T_4 and T_5, respectively. But zinc and boron level was increased to 7.5 kg and 0.3 kg, respectively.

In T_8 and T_9 N, P_2O_5 and K_2O levels were same as in T_4 and T_5, respectively. But zinc and boron level was increased to 10 kg and 0.4 kg, respectively.

The treatments details are given below;

T_1 = RDF

T_2= RDF-Bhoochetana

T_3 = RDF modification by Soil test (RPP)

T_4= 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum

T_5 = 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum

T_6 = 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum

T_7 = 140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum

T_8 = 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum

T_9 = 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum

Based on the above treatments following are the quantity of nutrient applied in the field experiment

Treatments	Nutrient Doses
T_1	25: 50: 25: 5: 5: 500 :: N: P_2O_5: K_2O: Zn: Fe: Gypsum kg ha^{-1}
T_2	10: 25: 12: 5: 0.25: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}
T_3	25: 62.5: 25: 5: 5: 500 :: N: P_2O_5: K_2O: Zn: Fe: Gypsum kg ha^{-1}
T_4	30: 60: 20: 5: 0.2: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}
T_5	35: 70: 15: 5: 0.2: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}
T_6	30: 60: 20: 7.5: 0.3: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}
T_7	35: 70: 15: 7.5: 0.3: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}
T_8	30: 60: 20: 10: 0.4: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}
T_9	35: 70: 15: 10: 0.4: 200 :: N: P_2O_5: K_2O: Zn: B: Gypsum kg ha^{-1}

3.4.1.1 Micronutrients incubation

The micronutrients $ZnSO_4$, $FeSO_4$ and B were mixed with vermicompost at 1:1 ratio, cured for 2 weeks, air dried and applied to field at the time of sowing for treatment 3-9.

3.4.2 Experimental details:

Season / Year	: *Kharif*, 2011
Crop	: Groundnut
Situation	: Rainfed
Spacing	: 30 × 10 cm
Replications	: 3
Design	: Randomized Block Design (RBD)

3.4.3 Cultural operations

3.4.3.1 Land preparation

The land was ploughed once and harrowed twice to get fine tilth before sowing of crop. Stubbles and weeds were removed and then plots were laid out as per plan of layout.

3.4.3.2 Seed rate, seed treatment and sowing

The Rhizobium and PSB were treated to the seeds one day before the sowing, kept in shade air dried and taken up the sowing. The seeds were sown @ 125 kg ha^{-1} on 15^{th} June, 2011.

3.4.3.3 Fertilizer application

Fertilizers were applied as per treatment details. Fertilizers were given in the form of urea, diammonium phosphate, muriate of potash, $ZnSO_4$, $FeSO_4$, B and chelated micronutrient formulations were applied in the respective treatments as per the recommendation. Gypsum was applied at peg initiation stage as per the recommendation for each plot.

3.4.3.4 After care operation

Plant protection measures were taken as per UAS package of practice during the crop growth.

3.4.3.5 Harvesting

The crop was harvested on 18^{th} October 2011, on attaining physiological maturity (123 days after sowing) and kept separately for drying. The pods were separated and later dried to constant moisture of approximately 8-9 per cent. From the net plot, pod and haulm yields per ha were calculated.

3.5 Collection of experimental data

Five plants per plot were selected randomly in the net plot area and tagged for recording observations at four stages (30^{th}, 60^{th}, 90^{th} day after sowing and at harvest).

3.5.1 Observations on growth components

3.5.1.1Plant height and number of branches

The plant height (cm) was measured at 30, 60, 90 DAS and at harvest by taking five plants in net plot area randomly in each plot. Similarly, the number of branches at 30, 60, 90 DAS and at harvest was recorded by taking five plants in random in each plot.

3.5.1.2 Dry matter production

Dry matter production of both haulm and pods were recorded at harvest. The haulm and pod samples were first washed with 0.1 *N* HCl and distilled water and then dried in shade and weighed. These were dried in an oven at 70°C to constant weight and the oven dry weight was recorded. Based on the moisture content dry matter production was calculated and expressed in quintals per hectare.

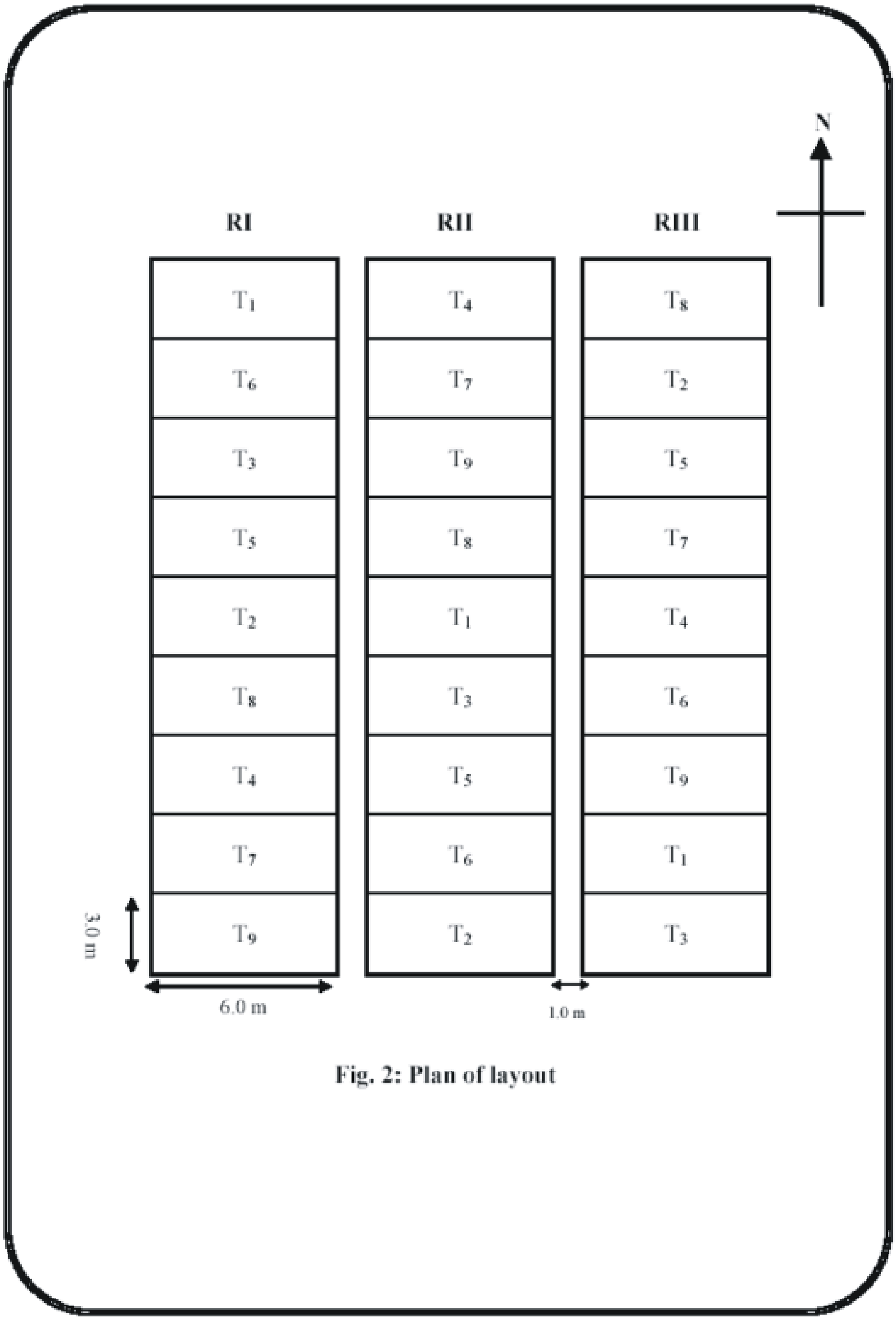


Fig 2. Plan of layout

Plate 1. General view of experimental plot

3.5.2 Observations on yield and yield attributes

The pods from the randomly selected and tagged five plants for taking biometric observations at harvest were used and the following observations on yield components and yield were recorded.

3.5.2.1 Number of pods per plants

At harvest selected five plants randomly from each treatment for recording observation on growth parameters were uprooted separately and counted number of pods and the average was taken as the number of pods per plant.

3.5.2.2 Pod weight

Weight of the pods per plant was recorded after air-drying .The values of five plants are averaged and presented as pod weight per plant.

3.5.2.3 Shelling percentage

From each net plot produce 100 g of cleaned pods were weighed and the kernels obtained after shelling were also weighed .The shelling percentage was worked out by using formula.

$$\text{Shelling percentage (\%)} = \frac{\text{Kernel weight}}{\text{Pod weight}} \times 100$$

3.5.2.4 Test weight (100 grain weight)

One hundred seeds were counted from randomly selected five plants per each treatment and their weight was recorded and expressed in grams.

3.5.2.5 Pod yield

After harvest, pods were separated from the plants then the pods were dried, cleaned and weighed .Using net plot yield, pod yield in quintal per hectare was computed and presented.

3.5.2.6 Haulm yield

The yield of dry matter from the net plot area at harvest was recorded after complete sun drying and haulm yield was worked out as quintals per hectare.

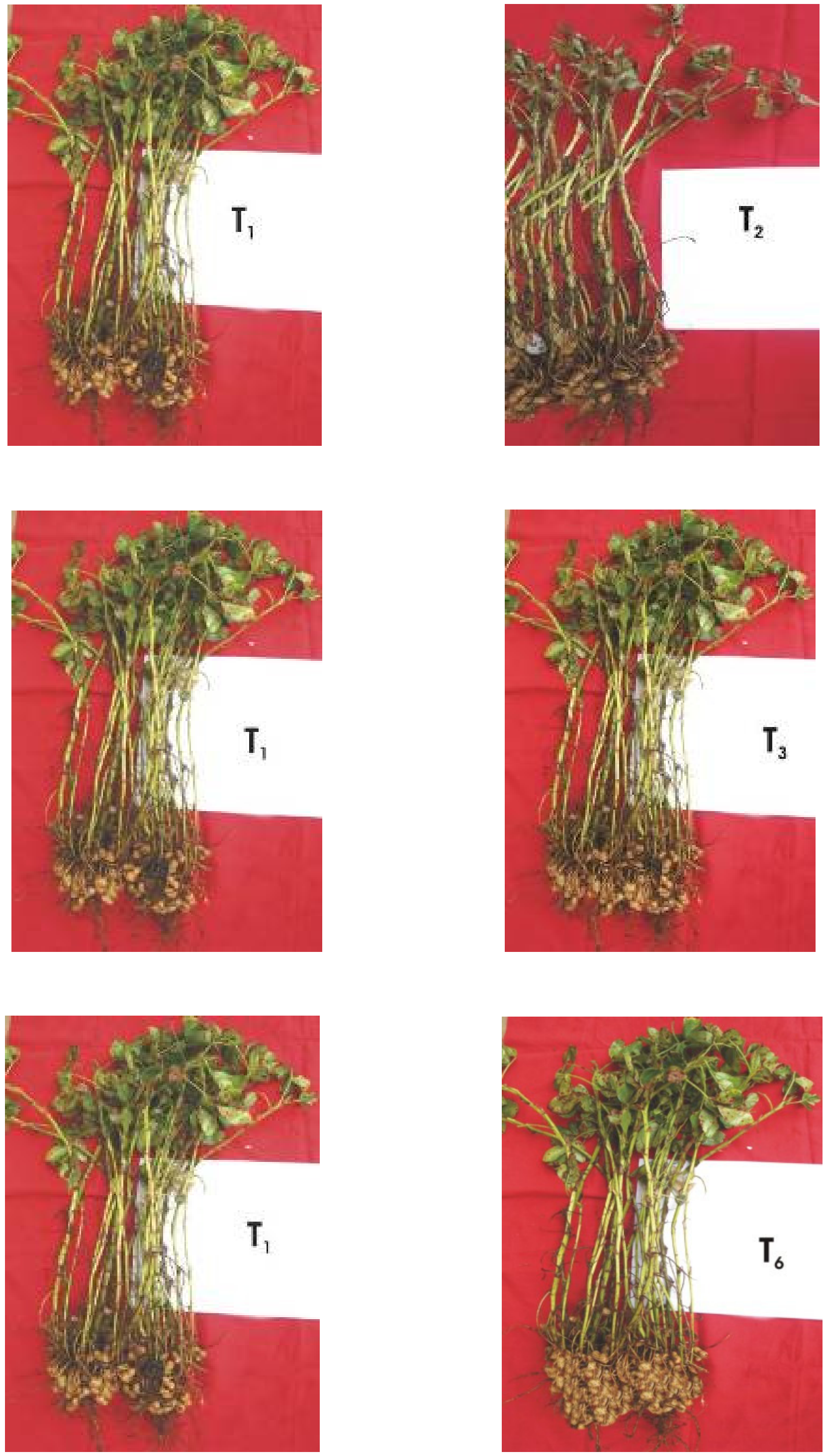


Plate 2.Comparison between different treatments

3.5.3 Observations on quality parameters

3.5.3.1 Crude protein content

The protein content in the pod was analyzed by indirect method. First, the percent nitrogen content of the sample was estimated by micro Kjeldahl method (Jackson, 1967). Then the nitrogen value was multiplied by a factor 6.25 to get the crude protein content of the sample and expressed in percentage. The oven dried pod was finely ground and used to analyze the crude protein content.

3.5.3.2 Oil content

Approximately 15 g of kernels drawn randomly from each treatment was oven dried at 50 ± 5^0 C and oil content was estimated by nuclear magnetic resonance (NMR, Oxford 4000)

3.5.3.3 Oil yield (kg ha^{-1})

Oil yield per hectare was worked out by the formula given below and expressed in kg /ha.

$$\text{Oil yield (Kg ha}^{-1}\text{)} = \frac{\text{Oil content (\%)}}{100} \times \frac{\text{Shelling (\%)}}{100} \times \text{Pod yield (kg ha}^{-1}\text{)}$$

3.6 Economic analysis

The cost of cultivation for each treatment was worked out by taking into consideration the price of inputs prevailing in the market. The grain/seed and straw yield of crops were considered to work out the gross returns from each treatment. Benefit cost ratio was calculated using the formulae.

$$\text{BC (ratio)} = \frac{\text{Gross returns (`/ha)}}{\text{Cost of cultivation (`/ha)}}$$

The prices of inputs and outputs are given in appendix II.

3.7 Chemical analysis of plant and pod samples

3.7.1 Preparation of plant and pod sample

The five plants were sampled for estimating the dry matter production and nutrient uptake from each field at harvest were thoroughly washed with distilled water and dried in hot air oven at 65℃. Dried samples were powdered in a Willey mill to considerable fineness before storing them in polythene bags for further analysis.

3.7.2 Digestion of plant and pod samples

Powdered whole plant and pod samples were separately treated with concentrated HNO_3 overnight for pre digestion. Then, the pre digested samples were treated with diacid mixture (HNO_3:$HClO_4$) (10:4 ratio) and digested on sand bath at low temperature till colourless white precipitate was obtained. The residue was dissolved in 6N HCl, filtered then the content was made to known volume by using 6N HCl. This was used for further nutrient analysis.

The following analysis were carried out from the diacid digested samples of whole plant and pod.

3.7.2.1 Phosphorus

Phosphorus in digested samples was determined by Vanadomolybdophosphoric yellow colour method (Tandon, 1998) by using spectrophotometer at 420 nm wavelength.

3.7.2.2 Potassium

Potassium in the aliquot was estimated with the help of flame photometer after appropriate dilution Tandon (1998).

3.7.2.3 Sulphur

Sulphur in aliquot was estimated by turbidometric method as explained by Sparks (1996)

3.7.2.4 Calcium and Magnesium

Calcium and Magnesium in the diacid extract were determined by versanate titration as described by Black (1965).

3.7.2.5 Micronutrients

Zinc, copper, iron and manganese were estimated in the aliquot of plant extract using atomic absorption spectrophotometer (Shimodzu model) as described by Tandon (1998).

3.7.2.6 Boron

The boron in plant sample was estimated by dry ashing which extracted with 0.5 *M* HCl. The boron in the aliquot was determined by azomethane-H method using spectrophotometer at 420 nm (Singh *et al.,* 2010).

3.7.2.7 Nitrogen estimation of whole plant and pod samples

Nitrogen was estimated in a microkjeldhal unit as described by Tandon (1998). For the estimation of nitrogen in plant samples, 0.5 g of powdered sample was digested with concentrated sulphuric acid in the presence of digestion mixture ($CuSO_4$ + K_2SO_4 + Selenium powder) till it turned blue. The digested sample was distilled with excess of 40 per cent sodium hydroxide and the ammonia released was trapped in 2 per cent of boric acid and ammonium tetra borate thus formed was titrated against 0.1*N* H_2SO_4.

3.8 Nutrient uptake studies

3.8.1 Nutrient uptake (kg ha^{-1})

The nutrient uptake by groundnut at harvest was worked out using the following equation.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{dry matter yield (kg ha}^{-1}\text{)}}{100}$$

3.9 Chemical analysis of post harvest soils

After harvest of crop soil samples were collected from the field and processed and analyzed for available nitrogen, available phosphorus, available potassium, available sulphur, exchangeable calcium and magnesium, available zinc, copper, iron and manganese and available boron by procedure as described in section 3.3.3.4 to 3.3.3.10.

3.10 Statistical analysis

The experimental data obtained was subjected to statistical analysis adopting Fischer’s method of analysis of variance as outlined by Gomez and Gomez (1984). Critical Difference (C.D.) values were given in the table at 5 per cent level of significance, whenever the F test was significant at 5 per cent level.

4. EXPERIMENTAL RESULTS

A study was undertaken during *kharif* 2011 to identify the nutrient constraints of a micro-watershed in northern transition zone of Karnataka and response of groundnut to identified nutrient constraints. The representative study area selected was Kotur micro-watershed in Dharwad district.

Fertility status of the study area, growth and yield parameters, nutrient content and uptake of groundnut, available nitrogen, phosphorus, potassium, sulphur, zinc and boron in soil at harvest stage were studied and the results are presented in this chapter under the following headings.

4.1 Identification of soil fertility constraints

4.2 Response of groundnut to nutrients

4.3 Nutrient content of groundnut at harvest

4.4 Nutrient uptake of groundnut at harvest

4.5 Available N, P, K, S, Zn and B status in soil at post harvest stage and

4.6 Economic analysis

4.1 Identification of soil fertility constraints

The results of the investigations carried out to identify the soil fertility constraints in Kotur village are presented in this chapter. A total of 80 soil samples in the micro-watershed was collected and analyzed. The results are presented here under.

4.1.1 Soil reaction (cf. Table 3)

The pH of surface soil samples ranged from 6.1 to 8.9 with an average value of 7.23 and standard deviation of 0.81. Soil samples at higher elevation had lower pH compared to those at valley in the micro-watershed. It is estimated that, 27.5 per cent of the samples in slightly acidic range (6.1−6.4), 30 per cent in neutral range (6.5−7.5) and remaining 42.5 per cent samples were alkaline in reaction (7.6−8.9).

4.1.2 Electrical conductivity (cf. Table 3)

The EC in surface samples ranged from 0.03 to 0.48 dSm^{-1} with an average of 0.19 dSm^{-1}. Standard deviation was 0.07 dSm^{-1} showing a spatial variability in EC of soils of the micro-watershed.

4.1.3 Organic carbon (cf. Table 3)

Organic carbon in the soils of the study area ranged from 0.3 to 10.8 g kg^{-1}. The average organic carbon content of the micro-watershed was 6.03 g kg^{-1} with a standard deviation of 2.39 g kg^{-1}. 36.25 per cent of samples were low in organic carbon status followed by 33.75 per cent in medium range and 30 per cent in high range of organic carbon. Organic carbon status was higher in low-lying valley area of the micro-watershed as compared to that of the hilly zone.

4.1.4 Available nitrogen (cf. Table 3)

Available N content varied from 62.0 kg ha^{-1} to 384.0 kg ha^{-1} with average of 174.35 kg ha^{-1}. The standard deviation was of 39.01 kg ha^{-1} nitrogen. The entire micro-watershed was low in available nitrogen status.

4.1.5 Available phosphorus (cf. Table 3)

Available P_2O_5 varied from 1.0 kg ha^{-1} to 76.0 kg ha^{-1} showing high degree spatial variation in available P. The average and standard deviation were 23.38 and 13.10 kg ha^{-1}, respectively. 67.5 per cent samples were low in available phosphorus, 32.5 per cent samples in medium range of P_2O_5 availability.

4.1.6 Available potassium (cf. Table 3)

The micro-watershed was rich in available potassium. The available K ranged from 200 to 520 kg K_2O ha^{-1} with an average of 315.88 kg K_2O ha^{-1} and standard deviation of 61.21 kg K_2O ha^{-1}. The 71.25 per cent samples were lying in medium range of K availability and remaining 28.75 per cent samples were high in available potassium status.

4.1.7 Available sulphur (cf. Table 3)

Available S in soils ranged from 4.9 to 19.6 mg kg^{-1}. The mean was 9.11 mg kg^{-1} with a standard deviation of 2.80 mg kg^{-1} showing high spatial variation in available S. The 66.25 percent samples were lying in low range and remaining 33.75 percent were in medium range of available sulphur status.

4.1.8 Exchangeable cations (cf. Table 4)

4.1.8.1 Calcium

Exchangeable calcium in soil samples of the study area ranged from 2.1 to 27 cmol (p^+) kg^{-1} with mean of 10.28 cmol (p^+) kg^{-1} and standard deviation of 6.88 cmol (p^+) kg^{-1}. The micro-watershed is dominated by exchangeable calcium compared to other exchangeable cations.

4.1.8.2 Magnesium

Exchangeable magnesium in the soil samples ranged from the 0.6 to 8.6 cmol (p^+) kg^{-1}. The mean was 2.75 cmol (p^+) $kg^{-1}$with a standard deviation of 1.97 cmol (p^+) kg^{-1}. The micro-watershed is sufficient in exchangeable magnesium for most of the crops.

4.1.9 Available micronutrients (cf. Table 4)

4.1.9.1 Available zinc

Available Zn of the study area ranged from 0.32 to 1.41 mg kg^{-1}. The average and standard deviation were 0.62 mg kg^{-1} and 0.26 mg kg^{-1}, respectively. It may be observed that, 67.5 per cent of the samples were below the critical range of Zn (0.6 mg kg^{-1}).

4.1.9.2 Available iron

Available iron content in micro-watershed soil samples was ranged from 0.9 mg kg^{-1} to 28.9 mg kg^{-1}. The average was 6.22 mg kg^{-1} with a standard deviation of 7.31 mg kg^{-1}. The 51.25 percent of samples were below critical limit of available Fe (2.5 mg kg^{-1}).

4.1.9.3 Available copper

Available copper was in the range of 0.73 to 4.47 mg kg^{-1} with mean and standard deviation of 2.18 mg kg^{-1} and 1.11 mg kg^{-1}, respectively. The available Cu status of the micro-watershed was above the critical limit of 0.2 mg kg^{-1}.

4.1.9.4 Available manganese

Available manganese content in the soil samples of the study area was ranged from 2.3 to 25.8 mg kg^{-1}. The mean and standard deviation were 11.44 mg $kg^{-1}$and 6.92 mg kg^{-1}, respectively. Available Mn in the entire area was above the critical limit of 1.0 mg kg^{-1} soil.

4.1.10 Hot water soluble boron (cf. Table 4)

Hot water soluble boron of the study area ranged from 0.12 to 1.19 mg kg^{-1}. The mean and standard deviation were 0.49 mg $kg^{-1}$and 0.16 mg kg^{-1}, respectively. Among the samples studied, 47.5 percent of the samples were below the critical limit (0.5 mg kg^{-1}).

4.2 Response of groundnut to nutrients

4.2.1 Growth parameters

The effect of nutrients on plant height, number of branches at different growth stages and dry matter production at harvest of groundnut were studied and presented in table 5 through Table 7.

Table 3: Chemical properties and available major nutrient status of Kotur micro-watershed

Sl. No	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
1.	6.4	0.35	4.8	209	17	290
2.	6.9	0.32	9	185	20	260
3.	6.2	0.29	10.2	191	38	320
4.	7.0	0.29	9	172	30	280
5.	7.3	0.15	8.4	154	54	260
6.	6.4	0.28	7.8	185	46	240
7.	7.4	0.27	6.6	62	42	240
8.	6.3	0.23	9	105	12	280
9.	6.7	0.24	10.8	216	16	280
10.	6.6	0.16	3.3	172	7	280
11.	6.1	0.12	5.6	189	14	200
12.	7.0	0.26	9.3	179	22	340
13.	6.5	0.09	7.5	142	21	420
14.	6.2	0.17	8.7	209	16	420
15.	8.2	0.48	5.1	166	15	280
16.	6.9	0.33	9	136	18	320
17.	6.6	0.36	3.3	197	19	280
18.	6.3	0.36	5.4	179	22	250
19.	8.0	0.35	5.1	179	21	360
20.	6.8	0.19	6.3	191	17	340
21.	7.6	0.17	4.2	179	19	340
22.	7.8	0.17	6	154	16	340
23.	6.6	0.16	6	197	20	300
24.	7.8	0.14	7.2	166	22	340
25.	7.7	0.14	6.6	160	16	300
26.	6.3	0.15	3.6	190	15	280
27.	7.8	0.18	3.6	160	17	300
28.	7.9	0.12	4.8	179	14	320
29.	7.8	0.12	5.1	185	14	300
30.	8.1	0.14	3.3	197	17	380
31.	7.0	0.19	6.6	203	22	480
32.	7.3	0.15	2.4	203	24	480
33.	7.9	0.18	6	216	34	280
34.	7.5	0.14	7.8	209	52	520
35.	7.9	0.19	5.1	172	24	320
36.	7.8	0.13	4.2	148	38	320
37.	7.8	0.16	2.4	160	13	300
38.	8.1	0.11	2.7	154	28	320
39.	6.8	0.15	3.3	191	12	300
40.	7.6	0.15	4.8	185	21	320
41.	7.3	0.19	2.4	179	38	320

Contd…

Sl. No	pH	EC (dS m^{-1})	Organic carbon (g kg^{-1})	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
42.	7.6	0.15	5.1	172	17	300
43.	8.7	0.18	6.6	160	33	300
44.	8.3	0.16	1.8	185	10	320
45.	7.6	0.2	4.8	172	7	380
46.	7.0	0.17	6.3	216	42	280
47.	8.4	0.18	5.7	234	18	340
48.	8.1	0.13	3	154	15	440
49.	8.0	0.14	7.2	191	18	320
50.	8.3	0.19	2.1	264	11	300
51.	8.5	0.16	7.5	233	11	320
52.	8.4	0.14	0.3	234	17	480
53.	8.0	0.13	4.5	197	27	420
54.	8.7	0.11	5.4	197	56	300
55.	8.5	0.12	3.9	203	52	320
56.	8.0	0.18	5.4	129	15	320
57.	7.0	0.15	4.5	179	14	280
58.	8.2	0.18	4.5	203	9	360
59.	8.3	0.17	4.5	179	5	340
60.	8.9	0.12	5.1	123	1	320
61.	8.4	0.13	1.5	185	9	300
62.	6.2	0.29	10.2	384	38	320
63.	6.3	0.12	9	172	30	300
64.	6.4	0.15	8.4	154	54	300
65.	6.8	0.28	7.8	185	76	340
66.	6.7	0.17	6.6	62	42	440
67.	6.9	0.23	9	105	12	280
68.	6.8	0.15	4.8	209	17	260
69.	6.2	0.13	9	185	20	290
70.	6.4	0.17	6.6	62	42	260
71.	6.3	0.23	9	105	12	320
72.	6.4	0.15	4.8	209	17	280
73.	6.4	0.23	9	185	20	260
74.	6.2	0.29	10.2	346	38	240
75.	6.3	0.12	9	172	20	240
76.	6.5	0.21	7.8	185	48	280
77.	6.2	0.17	6.6	62	42	280
78.	6.3	0.23	9	105	12	280
79.	6.4	0.15	4.8	209	17	200
80.	6.2	0.13	9	185	20	260
Range	**6.1-8.9**	**0.09-0.48**	**0.3^{-1} 0.8**	**62-384**	**1.0-76**	**200-520**
Mean	**7.23**	**0.19**	**6.03**	**174.35**	**23.38**	**315.88**
SD	**0.81**	**0.07**	**2.39**	**39.01**	**13.10**	**61.21**

Table 4: Secondary nutrients and available micronutrients status of Kotur micro-watershed

Sl. No	S	Ca	Mg	Zn	Fe	Cu	Mn	B
	($mg\ kg^{-1}$)	($cmol\ (p+)\ kg^{-1}$)		($mg\ kg^{-1}$)				
1.	6.2	2.4	0.9	0.41	1.3	2.48	19.8	0.45
2.	5.6	2.8	0.8	0.50	1.5	2.12	21.8	0.51
3.	9.2	6.2	2.2	0.35	1.1	4.16	8.8	0.44
4.	8.6	6.2	0.6	0.51	2.6	3.04	12.4	0.58
5.	6.2	4.6	0.8	0.60	2.1	2.04	18.2	0.62
6.	9.2	5.6	3	0.60	2.4	2.81	6.2	0.46
7.	10.2	6.9	2.4	0.92	2.0	3.51	14.5	0.51
8.	11.9	5.1	1.6	1.10	1.3	4.47	14.2	0.39
9.	8.7	5.9	2.6	0.73	0.9	3.76	24	0.31
10.	7.7	2.1	0.8	0.65	1.4	1.73	25.8	0.27
11.	10.2	2.9	0.9	0.96	1.4	2.92	12.9	0.34
12.	12.5	8.1	1.9	0.50	10.2	3.56	13.4	0.34
13.	6.7	2.4	1.1	0.32	11.7	2.23	20.8	0.42
14.	6.4	6.7	1.9	0.42	2.6	3.52	21.3	0.34
15.	19.6	23.3	4.3	0.64	6.4	2.45	4.8	0.12
16.	12.6	8	1.6	0.58	10.4	4.09	11.9	0.15
17.	7.7	2.9	1	0.59	8.9	2.55	20.7	0.36
18.	6.8	3.6	0.6	0.56	2.9	2.42	23.1	0.44
19.	16.6	11.8	2	0.60	6.4	3.04	2.9	0.58
20.	6.0	7.9	1.2	0.53	2.8	2.77	19.9	0.65
21.	8.4	9.3	1.5	0.55	1.5	2.1	7.2	0.45
22.	7.0	13.7	3.3	0.48	9.4	1.61	4.4	0.47
23.	6.2	4.9	2.1	0.50	2.2	2.26	20.8	0.59
24.	10.1	10.5	7.7	0.55	2.2	1.91	4.5	0.6
25.	6.4	10.7	2.1	0.55	2.9	2.09	7.7	0.49
26.	5.5	2.2	1.6	0.60	10.4	1.83	20	0.61
27.	9.8	7.6	6	0.37	1.3	1.38	4.4	0.6
28.	6.8	10.7	8.6	0.59	1.5	1.17	4	0.65
29.	7.8	18.1	3.7	0.78	1.1	0.92	4.1	0.65
30.	5.8	20.5	4	1.00	2.6	0.87	3.9	0.58
31.	8.2	11.2	1.9	0.66	2.1	1.24	11.6	0.66
32.	6.0	10.4	4.2	1.31	2.4	1.39	9.7	0.51
33.	7.3	4.4	1.9	0.85	2.0	1.34	6.5	0.5
34.	5.2	7.1	3.8	0.72	1.3	1.64	10.5	0.45
35.	4.9	15.1	6.6	0.41	0.9	0.96	3.9	0.55
36.	5.2	20.4	4.2	0.53	1.4	0.79	3.2	0.61
37.	8.7	16.7	5	0.38	1.4	0.91	4.5	0.51
38.	14.7	11.2	5	0.41	9.5	1.09	3.9	1.19
39.	12.4	2.4	1.1	0.85	1.7	1.82	21.9	0.63
40.	15.6	10.5	2.9	0.52	3.7	1.12	5.5	0.55
41.	12.7	14.6	1.5	0.50	1.7	1.84	14.4	0.49

Contd…

Sl. No	S	Ca	Mg	Zn	Fe	Cu	Mn	B
	(mg kg^{-1})	(cmol (p+) kg^{-1})		(mg kg^{-1})				
42.	11.6	15.4	6.8	0.37	1.0	1.18	6.9	0.51
43.	11.3	27	4	0.35	1.0	0.94	2.7	0.59
44.	10.0	19.8	6.1	0.35	1.5	0.94	2.3	0.41
45.	9.1	16.5	6.8	0.45	7.3	1.28	6.2	0.91
46.	8.1	4.8	2.4	0.84	2.4	3.8	25	0.47
47.	11.3	11.2	3.9	1.33	1.3	2.25	8.8	0.51
48.	10.2	18.9	4.1	0.87	1.3	1.05	7.1	0.51
49.	13.1	19.3	6.2	1.15	0.9	0.73	4.2	0.65
50.	8.2	25.2	1.4	0.34	2.2	0.75	2.6	0.46
51.	9.5	16.1	7.7	0.44	3.7	1.11	5.6	0.51
52.	9.7	18.5	3.5	0.54	1.8	0.96	2.3	0.39
53.	9.3	17.8	4.3	0.73	1.5	1.14	4.9	0.31
54.	11.8	23.2	1.6	0.49	1.9	0.88	4.8	0.27
55.	9.6	21.8	4.1	0.43	2.4	0.91	5.1	0.34
56.	11.1	20.2	5.6	0.49	2.6	0.91	6.5	0.34
57.	11.0	21.7	2.2	0.44	2.6	1.29	17.7	0.42
58.	8.9	20	5	0.55	1.6	1.17	6.2	0.34
59.	9.2	22.2	1.6	0.38	1.3	0.81	4.7	0.12
60.	10.5	18.5	0.9	0.44	1.8	1.09	5.8	0.15
61.	9.5	14.8	0.8	0.56	2.0	1.11	7.7	0.36
62.	9.2	6.2	2.2	0.35	26.2	4.16	8.8	0.44
63.	8.6	6.2	0.8	0.81	27.0	3.04	12.4	0.58
64.	6.2	4.6	0.8	0.60	22.0	2.04	18.2	0.62
65.	9.2	5.6	3	0.60	19.8	2.81	6.2	0.62
66.	10.2	6.9	2.4	0.55	11.6	3.51	14.5	0.54
67.	11.9	5.1	1.6	0.41	12.9	4.47	14.2	0.59
68.	6.2	2.4	0.9	0.41	7.3	2.48	19.8	0.45
69.	5.6	2.8	0.8	0.18	5.1	2.12	21.8	0.51
70.	10.2	6.9	2.4	0.60	6.4	3.51	14.5	0.54
71.	11.9	5.1	1.6	0.51	10.4	4.47	14.2	0.59
72.	6.2	2.4	0.9	0.41	8.9	2.48	19.8	0.45
73.	5.6	2.8	0.8	0.28	25.9	2.12	21.8	0.51
74.	9.2	6.2	2.2	1.04	28.9	4.16	8.8	0.44
75.	8.6	6.2	0.7	0.81	26.2	3.04	12.4	0.58
76.	9.2	5.6	3	0.69	22.0	2.81	6.2	0.62
77.	10.2	6.9	2.4	0.92	19.8	3.51	14.5	0.54
78.	11.9	5.1	1.6	1.10	11.6	4.47	14.2	0.59
79.	6.2	2.4	0.9	1.41	12.9	2.48	19.8	0.45
80.	5.6	2.8	0.8	1.18	7.3	2.12	21.8	0.51
Range	**4.9^{-1} 9.6**	**2.1-27**	**0.6-8.6**	**0.32^{-1} .41**	**0.9-28.9**	**0.73-4.47**	**2.3-25.8**	**0.12^{-1} .19**
Mean	**9.11**	**10.28**	**2.75**	**0.62**	**6.22**	**2.18**	**11.44**	**0.49**
SD	**2.80**	**6.88**	**1.96**	**0.26**	**7.31**	**1.11**	**6.92**	**0.16**

Table 5: Effect of nutrients on plant height (cm) at different growth stages of groundnut

Treatments	30 DAS	60 DAS	At harvest
T_1 - RDF	17.1	25.40	36.30
T_2 - RDF-Bhoochetana	15.3	23.30	28.87
T_3 - RDF modification by Soil test (RPP)	16.9	27.03	38.80
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	19.2	28.10	38.30
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	19.8	28.80	38.80
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	22.7	33.23	42.90
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	22.1	32.30	40.97
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	20.6	32.13	40.80
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	22.8	32.80	41.80
S. Em±	**1.75**	**0.42**	**0.71**
CD (0.05)	**NS**	**1.58**	**2.14**

4.2.1.1 Plant height (cm) (cf. Table 5)

Plant height at 30 DAS, was not significantly influenced by different nutrients. Treatment T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) recorded the highest plant height (22.8 cm) followed by T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) and T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum) (22.7 and 22.1 cm, respectively) whereas, the lowest plant height (15.3 cm) was recorded with treatment T_2 (RDF-Bhoochetana).

At 60 DAS, plant height was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the significantly highest plant height (33.23 cm) and was on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [32.30, 32.13 and 32.80 cm , respectively].

The lowest plant height (23.30 cm) was recorded with treatment T_2 (RDF-Bhoochetana). However it is significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [25.40, 27.03, 28.10 and 28.80 cm , respectively].

At 90 DAS and harvest, plant height was significantly influenced by different nutrients and the response trend followed was the same as that at 60 DAS.

Treatment T_6 recorded the highest plant height (42.9 cm) which was on par with treatment T_7 , T_8 and T_9 [40.97, 40.80 and 41.80 cm , respectively], whereas, the lowest plant height (28.87 cm) was recorded with treatment T_2. However, it is significantly superior over treatment $T_{1,}$ $T_{3,}$ T_4 and T_5 [36.30, 38.80, 38.30 and 38.80 cm , respectively].

4.2.1.2 Number of branches (cf. Table 6)

Number of branches at 30 DAS was not significantly influenced by different nutrients. Treatment T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) recorded the highest number of branches (5.5) followed by T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) and T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum) (5.3 and 5.2, respectively) whereas, the lowest number of branches (3.6) was recorded with treatment T_2 (RDF-Bhoochetana).

At 60 DAS, number of branches was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest number of branches (7.66) which is on par with T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [7.37, 7.39 and 7.50 , respectively], whereas, the lowest number of branches (4.91) was recorded with treatment T_2 (RDF-Bhoochetana).

However it is significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [6.32, 6.98, 6.47 and 6.80 , respectively].

At 90 DAS and harvest, number of branches was significantly influenced by different nutrients. Treatment T_6 recorded the highest number of branches (9.6) which was on par with treatment $T_{7,}$ T_8 and T_9 [9.26, 9.22 and 9.27 , respectively], whereas, the lowest number of branches (5.6) was recorded with treatment T_2. However it was significantly superior over treatment $T_{1,}$ $T_{3,}$ T_4 and T_5 [7.20, 8.43, 7.80 and 8.20 , respectively].

4.2.1.3 Dry matter production (q ha^{-1}) (cf. Table 7)

The data pertaining to dry matter production at harvest revealed that, it was significantly influenced by different nutrients.

Table 6: Effect of nutrients on number of branches at different growth stages of groundnut

Treatments	30 DAS	60 DAS	At harvest
T_1- RDF	4.9	6.32	7.20
T_2- RDF-Bhoochetana	3.6	4.91	5.60
T_3- RDF modification by Soil test (RPP)	4.2	6.98	8.43
T_4- 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	4.8	6.47	7.80
T_5- 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	5.1	6.80	8.20
T_6- 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	5.3	7.66	9.60
T_7-140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	5.2	7.37	9.26
T_8- 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	5.2	7.39	9.22
T_9- 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	5.5	7.50	9.27
S. Em±	**0.47**	**0.22**	**0.39**
CD (0.05)	**NS**	**0.65**	**1.18**

Table 7: Effect of nutrients on dry matter production (q ha^{-1}) of groundnut

Treatments	At harvest		
	Haulm	**Pod**	**Total**
T_1 - RDF	26.89	23.11	50.00
T_2 - RDF-Bhoochetana	21.20	18.63	39.83
T_3 - RDF modification by Soil test (RPP)	28.57	26.63	55.20
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	27.87	25.79	53.66
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	28.67	26.84	55.51
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	32.58	29.72	62.30
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	31.18	27.32	58.50
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	30.55	27.64	59.19
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	31.54	28.35	59.89
S. Em±	**0.53**	**0.91**	**1.21**
CD (0.05)	**1.60**	**2.74**	**3.62**

Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest dry matter production in haulm (32.58 q ha^{-1}) which was on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [31.18, 30.55 and 31.54 q ha^{-1} , respectively], whereas, the lowest dry matter production (21.20 q ha^{-1}) was recorded with treatment T_2 (RDF-Bhoochetana). However it is significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [26.89, 28.57, 27.87 and 28.67 q ha^{-1} , respectively].

In pod also, the treatment T_6 recorded the highest dry matter production (29.72 q ha^{-1}) which is on par with treatment $T_{7,}$ T_8 and T_9 [27.32, 27.64 and 28.35 q ha^{-1} , respectively], whereas, the lowest dry matter production (18.63 q ha^{-1}) was recorded with treatment T_2. However, it is significantly superior over treatment $T_{1,}$ $T_{3,}$ T_4 and T_5 [23.11, 26.63, 25.79 and 26.84 q ha^{-1} , respectively].

Similarly, with respect to total dry matter production same trend was followed as in haulm and pod. The treatment T_6 recorded the highest dry matter production (62.30 q ha^{-1}) which is on par with treatment $T_{7,}$ T_8 and T_9 [58.50, 59.19 and 59.89 q ha^{-1} , respectively], whereas, the lowest dry matter production (39.83 q ha^{-1}) was recorded with T_2. However, it was significantly superior over treatment $T_{1,}$ $T_{3,}$ T_4 and T_5 [50.00, 55.20, 53.66 and 55.51 q ha^{-1} , respectively].

4.2.2 Yield and yield attributes

4.2.2.1 Haulm yield (q ha^{-1}) (cf. Table 8)

Haulm yield at harvest was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest haulm yield (37.81 q ha^{-1}) which was on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [36.68, 36.43 and 36.91 q ha^{-1} , respectively], whereas, the lowest haulm yield (27.18 q ha^{-1}) was recorded with treatment T_2 (RDF-Bhoochetana). However, it is significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [33.27, 35.67, 34.00 and 35.58 q ha^{-1} , respectively].

4.2.2.2 Pod yield (q ha^{-1}) (cf. Table 8)

Pod yield at harvest was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest pod yield (33.93 q ha^{-1}) which is on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [32.53, 33.27 and 33.53 q ha^{-1} , respectively], whereas, the lowest pod yield (22.40 q ha^{-1}) was recorded with treatment T_2 (RDF-Bhoochetana). However, it was significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [26.23, 28.50, 28.03and 29.77 q ha^{-1} , respectively].

4.2.2.3 Number of pods per plant (cf. Table 9)

Number of pods per plant at harvest was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest number of pods per plant (28.80 g) which is on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [27.70, 27.10 and 28.43 g respectively].

Table 8: Effect of nutrients on haulm yield and pod yield (q ha^{-1}) of groundnut

Treatments	Haulm yield (q ha^{-1})	Pod yield (q ha^{-1})
T_1 - RDF	33.27	26.23
T_2 - RDF-Bhoochetana	27.18	22.40
T_3 - RDF modification by Soil test (RPP)	35.67	28.50
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	34.00	28.03
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	35.58	29.77
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	37.81	33.93
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	36.68	32.53
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	36.43	33.27
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	36.91	33.53
S. Em±	**0.70**	**0.72**
CD (0.05)	**2.11**	**2.16**

Table 9: Effect of nutrients on yield attributes of groundnut

Treatments	Number of pods/plant (g)	Pod weight/ plant (g)	Shelling percentage (%)	Test weight (g)
T_1 - RDF	23.23	23.47	63.54	32.37
T_2 - RDF-Bhoochetana	16.67	17.18	61.07	30.33
T_3 - RDF modification by Soil test (RPP)	22.53	20.79	64.90	33.77
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	22.70	22.88	65.07	34.53
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	23.03	23.91	65.64	34.80
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	28.80	29.19	68.83	36.47
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	27.70	28.03	68.06	35.25
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	27.10	28.74	67.95	35.29
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	28.43	28.61	67.46	35.85
S. Em±	**1.08**	**1.17**	**0.79**	**0.54**
CD (0.05)	**3.23**	**3.49**	**2.36**	**1.61**

Whereas, the lowest number of pods per plant (16.67 g) was recorded with treatment T_2 (RDF-Bhoochetana). However it is significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [23.23, 22.53, 22.70 and 23.03 , respectively].

4.2.2.4 Pod weight per plant (cf. Table 9)

Pod weight per plant at harvest was recorded and significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest number of pods per plant (29.19 g) which is on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [28.03, 28.74 and 28.61 g , respectively], whereas, the lowest number of pods per plant (17.18 g) was recorded with treatment T_2 (RDF-Bhoochetana). However, it was significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [23.47, 20.97, 22.88 and 23.91 , respectively].

4.2.2.5 Shelling percentage (cf. Table 9)

Shelling percentage at harvest was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest shelling percentage (68.83 %) which is on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [68.06, 67.95 and 67.46 % , respectively], whereas, the lowest shelling percentage (61.07 %) was recorded with treatment T_2 (RDF-Bhoochetana). However it is significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [63.54, 64.90, 65.07 and 65.64 , respectively].

4.2.2.6 Test weight (cf. Table 9)

Test weight (100 seed weight) at harvest was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P2O5 + 80% RD K2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest test weight (36.47 g) which was on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [35.25, 35.29 and 35.85 g , respectively], whereas, the lowest test weight (30.33) was recorded with treatment T_2 (RDF-Bhoochetana). However, it was significantly superior over treatment T_1 (RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [32.37, 33.77, 34.53 and 34.80 , respectively].

4.2.3 Quality parameters (cf. Table 10)

4.2.3.1 Crude protein content (%)

Crude protein content of kernels was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest crude protein content (31.44 %) which was on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [29.48, 29.38 and 29.73 % , respectively], whereas, the lowest crude protein content (20.10 %) was recorded with treatment T_2 (RDF-Bhoochetana). However, it was significantly superior over treatment T_1(RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [25.79, 26.04, 27.04 and 29.73 % , respectively].

Table 10: Effect of nutrients on quality parameters of groundnut

Treatments	Crude Protein content (%)	Oil content (%)	Oil yield (kg ha^{-1})
T_1 - RDF	25.79	47.67	794.43
T_2 - RDF-Bhoochetana	20.10	46.87	640.77
T_3 - RDF modification by Soil test (RPP)	26.04	47.27	874.62
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	27.02	47.17	860.25
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	27.19	47.53	928.50
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	31.44	47.93	1119.51
T_7 -140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	29.48	47.50	1051.99
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	29.38	47.47	1071.90
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	29.73	47.83	1082.64
S. Em±	**0.94**	**0.20**	**23.62**
CD (0.05)	**2.83**	**0.60**	**70.81**

4.2.3.2 Oil content

Oil content of kernels was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P2O5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest oil content (47.93 %) which is on par with treatment T_1 , T_3 , T_4 , T_5 , T_7 , T_8 and T_9 [47.67, 47.27, 47.17, 47.53, 47.50, 47.47 and 47.83 % , respectively], whereas, the lowest oil content (46.87 %) was recorded with treatment T_2 (RDF-Bhoochetana).

4.2.3.3 Oil yield (kg ha^{-1})

Oil yield of kernels was significantly influenced by different nutrients. Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) recorded the highest oil yield (1119.51) which is on par with treatment T_7 (140% RD N and P_2O_5 + 60% RD K_2O +7.5 kg Zn + 0.3 kg B + 200 kg gypsum), T_8 (120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) and T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) [1051.99, 1071.90 and 1082 kg ha^{-1} , respectively], whereas, the lowest oil yield (640.77) was recorded with treatment T_2 (RDF-Bhoochetana). However, it was significantly superior over treatment T_1(RDF), T_3 (RDF modification by Soil test (RPP)), T_4 (120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) and T_5 (140% RD N and P_2O_5 + 60% RD K2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) [794.43, 874.62, 860.25 and 928.50 kg ha^{-1} , respectively].

4.3 Nutrient concentration of groundnut at harvest

4.3.1 Nitrogen (%)

The concentration of nitrogen recorded at harvest stage revealed that, nitrogen concentration in pod was higher than that in haulm and it was significantly influenced by the nutrients. The N content in haulm ranged from 1.28 per cent (T_2) to 1.39 per cent (T_6) which was on par with T_1, T_4, T_5, T_7, T_8 and T_9 (1.33, 1.35, 1.39, 1.39, 1.37 and 1.38 %) and it was significantly superior over the T_3 (1.30 %) (cf. Table 11). The N content in pod ranged from 3.22 per cent (T_2) to 3.45 per cent (T_9) and it was not significantly influenced by nutrients. (cf. Table 12).

4.3.2 Phosphorus (%)

The concentration of phosphorus in pod at harvest stage was higher than that in haulm and significantly influenced by the nutrients. The P_2O_5 concentration in haulm ranged from 0.30 per cent (T_2) to 0.41 per cent (T_6). Treatment T_6 was on par with T_1, T_3, T_5, T_7, T_8 and T_9 (0.37, 0.38, 0.37, 0.40, 0.38 and 0.40 % , respectively). It was significantly superior over T_4 (0.35 %) (cf. Table 11). The P_2O_5 concentration in pod varied from 0.75 per cent (T_2) to 0.89 per cent (T_6). Treatment T_6 was significantly superior over the treatments; T_3, T_4, T_5, T_8 and T_9 (0.82, 0.79, 0.83, 0.82 and 0.83 % , respectively) which was on par with T_7 (0.85 %) (cf. Table 12).

4.3.3 Potassium (%)

The concentration of potassium in pod at harvest stage was higher than that in haulm. However, K concentration was not significantly influenced by the nutrients. The K_2O concentration in haulm ranged from 1.23 per cent (T_4) to 1.33 per cent (T_6) (cf. Table 11) and in pod ranged from 2.41 per cent (T_2) to 2.69 per cent (T_6) (cf. Table 12).

4.3.4 Sulphur (%)

The concentration of sulphur at harvest stage was recorded and sulphur concentration in pod was higher than that in haulm. It was significantly influenced by the nutrients. The sulphur concentration in haulm ranged from 0.26 per cent (T_2) to 0.36 per cent (T_1). However treatment T_1 was significantly superior over all the treatments except T_6 (0.34 %) (cf. Table 11). The sulphur concentration in pod ranged from 0.60 per cent (T_2) to 0.82 per cent (T_1). Treatment T_1 was on par with T_5, T_6, T7, T8 and T_9 (0.79, 0.80, 0.78, 0.76 and 0.78 % , respectively). It was significantly superior over the treatments T_3 and T_4 (0.61 and 0.68%) (cf. Table 12).

Table 11: Nutrient concentration in groundnut haulm at harvest

Treatments	N	P_2O_5	K_2O	S	Zn	B
	%				mg/kg	
T_1 - RDF	1.33	0.37	1.30	0.36	62.73	13.60
T_2 - RDF-Bhoochetana	1.28	0.30	1.27	0.26	60.33	16.54
T_3 - RDF modification by Soil test (RPP)	1.30	0.38	1.29	0.34	61.32	13.81
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	1.35	0.35	1.23	0.29	62.50	16.97
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	1.39	0.37	1.25	0.32	64.87	17.06
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	1.39	0.41	1.33	0.34	78.20	22.20
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	1.39	0.40	1.25	0.33	77.70	21.72
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	1.37	0.38	1.30	0.32	79.87	21.93
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	1.38	0.40	1.26	0.33	80.17	22.37
S. Em±	**0.02**	**0.01**	**0.03**	**0.02**	**0.97**	**0.65**
CD (0.05)	**0.07**	**0.04**	**0.10**	**0.02**	**2.91**	**1.95**

Table 12: Nutrient concentration in groundnut pod at harvest

Treatments	N	P_2O_5	K_2O	S	Zn	B
	%				mg/kg	
T_1 - RDF	3.30	0.84	2.59	0.82	214.67	25.43
T_2 - RDF-Bhoochetana	3.22	0.75	2.41	0.60	203.93	37.47
T_3 - RDF modification by Soil test (RPP)	3.26	0.82	2.67	0.80	213.57	25.46
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	3.36	0.79	2.66	0.68	210.60	38.34
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	3.43	0.83	2.53	0.79	216.47	38.64
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	3.43	0.89	2.69	0.80	241.17	42.64
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	3.45	0.85	2.53	0.78	239.70	42.22
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	3.39	0.82	2.61	0.76	240.03	42.36
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	3.45	0.83	2.58	0.78	242.60	42.48
S. Em±	**0.15**	**0.02**	**0.17**	**0.04**	**1.08**	**2.26**
CD (0.05)	**NS**	**0.05**	**NS**	**0.11**	**3.24**	**6.78**

4.3.5 Zinc (mg kg^{-1})

The concentration of zinc at harvest stage was recorded and zinc concentration in pod was higher than that in haulm. It was significantly influenced by the nutrients. The zinc concentration in haulm ranged from 60.33 mg kg^{-1} (T_2) to 80.17 mg kg^{-1} (T_9). Treatment T_9 was on par with T_6, T_7 and T_8 (78.20, 77.70 and 79.87 mg kg^{-1} , respectively). It was significantly superior over T_1, T_3, T_4 and T_5 (62.73, 61.32, 62.50 and 64.87 mg kg^{-1} , respectively) (cf. Table 11). The zinc concentration in pod varied from 203.93 mg kg^{-1} (T_2) to 242.60 mg kg^{-1} (T_9). Treatment T_9 was on par with T_6, T_7 and T_8 (241.17, 239.70 and 240.03 mg kg^{-1} , respectively). It was significantly superior over T_1, T_3, T_4 and T_5 (214.67, 213.57 210.60 and 216.47 mg kg^{-1} , respectively) (cf. Table 12).

4.3.6 Boron (mg kg^{-1})

The concentration of boron at harvest stage was recorded and boron concentration in pod was higher than that in haulm. It was significantly influenced by the nutrients. The boron concentration in haulm ranged from 13.60 mg kg^{-1} (T_1) to 22.37 mg kg^{-1} (T_9). Treatment T_9 was on par with T_6, T_7 and T_8 (22.20, 21.72 and 21.93 mg kg^{-1} , respectively). It was significantly superior over T_2, T_3, T_4 and T_5 (16.54, 13.81, 16.97 and 17.06 mg kg^{-1} , respectively) (cf. Table 11). The boron concentration in pod ranged from 25.43 mg kg^{-1} (T_1) to 42.48 mg kg^{-1} (T_9). Treatment T_9 on par with T_2, T_4, T_5, T_6, T_7 and T_8 (37.47, 38.34, 38.64, 42.64, 42.22 and 42.36 mg kg^{-1} , respectively). It was significantly superior over T_3 (25.46 mg kg^{-1}) (cf. Table 12).

4.4 Nutrient uptake by groundnut at harvest

4.4.1 Nitrogen (kg ha^{-1})

The nitrogen uptake at harvest was recorded and uptake was more in pod than haulm. It was significantly influenced by nutrients. Treatment T_6 recorded the maximum N uptake In haulm (45.27 kg ha^{-1}), whereas, the treatment T_2 accounted for the lowest uptake (27.21 kg ha^{-1}). Treatment T_6 was on par with T_7 and T_9 (43.20 and 43.43 kg ha^{-1}). However, it was significantly superior over T_1, T_3, T_4, T_5 and T_8 (35.73, 37.13, 37.69, 39.74 and 41.77 kg ha^{-1} , respectively) (cf. Table 13). Treatment T_6 recorded the maximum N uptake in pod (101.97 kg ha^{-1}). The treatment T_2 accounted for the lowest N uptake (59.94 kg ha^{-1}). Treatment T_6 was on par with T_5, T_7, T_8 and T_9 (91.91, 94.39, 97.08 and 98.10 kg ha^{-1} , respectively). However, it was significantly superior over T_1, T_3 and T_4 (76.34, 86.74 and 86.46 kg ha^{-1} , respectively) (cf. Table 14). Treatment T_6 also recorded the maximum total N uptake (147.25 kg ha^{-1}) and treatment T_2 accounted for the lowest uptake (87.15 kg ha^{-1}). Treatment T_6 was on par with T_5, T_7, T_8 and T_9 (131.65, 137.59, 138.85 and 141.53 kg ha^{-1} , respectively). However, it was significantly superior over T_1, T_3 and T_4 (112.07, 123.88 and 124.47 kg ha^{-1} , respectively) (cf. Table 15).

4.4.2 Phosphorus (kg ha^{-1})

The phosphorus uptake at harvest was more in pod than in haulm. It was significantly influenced by nutrients. Treatment T_6 recorded the maximum phosphorus uptake in haulm (13.28 kg ha^{-1}). The treatment T_2 accounted for the lowest P uptake (6.29 kg ha^{-1}). Treatment T_6 was on par with T_7 and T_9 in P uptake (12.48 and 12.76 kg ha^{-1}). However, it was significantly superior over T_1, T_3, T_4, T_5 and T_8 (10.03, 10.76, 9.87 and 10.71 kg ha^{-1} , respectively) (cf. Table 13). Treatment T_6 recorded the maximum uptake in pod (26.41 kg ha^{-1}). The treatment T_2 accounted for the lowest P uptake (13.98 kg ha^{-1}). Treatment T_6 was significantly superior over all other treatments (cf. Table 14). The total P uptake also followed the same trend as in pod uptake with the maximum uptake in T_6 (39.69 kg ha^{-1}). The treatment T_2 accounted for the lowest P uptake (20.27 kg ha^{-1}). Treatment T_6 was on par with T_9 (36.39 kg ha^{-1}). However, it was significantly superior over other treatments (cf. Table 15).

4.4.3 Potassium uptake (kg ha^{-1})

The potassium uptake at harvest was more in pod than in haulm and significantly influenced by nutrients. Treatment T_6 recorded the maximum K uptake in haulm (43.41 kg ha^{-1}). The treatment T_2 accounted for the lowest K uptake (26.92 kg ha^{-1}). Treatment T_6 was on par with T_8 and T_9 (39.82 and 39.87 kg ha^{-1}).

However, it was significantly superior over T_1, T_3, T_4, T_5 and T_7 (35.04, 36.96, 34.34, 35.90 and 38.99 kg ha^{-1} , respectively) (cf. Table 13). Similarly, treatment T_6 recorded the maximum K uptake in pod (79.89 kg ha^{-1}). The treatment T_2 accounted for the lowest K uptake (44.83 kg ha^{-1}). Treatment T_6 was on par with other treatment (cf. Table 14). The total potassium uptake in treatment T_6 recorded was the maximum (123.30 kg ha^{-1}). The treatment T_2 accounted for the lowest K uptake (71.75 kg ha^{-1}). Treatment T_6 was on par with T_8 and T_9 (114.86 and 113.11 kg ha^{-1} , respectively). However, it was significantly superior over T_1, T_3, T_4, T_5 and T_7 (94.97, 107.93, 102.54 and 103.62 kg ha^{-1}, respectively) (cf. Table 15).

4.4.4 Sulphur (kg ha^{-1})

The sulphur uptake at harvest was also more in pod than haulm and it was significantly influenced by nutrients. In haulm, treatment T_6 recorded the maximum S uptake (10.97 kg ha^{-1}). The treatment T_2 accounted for the lowest S uptake (5.59 kg ha^{-1}). Treatment T_6 was on par with T_1, T_7, T_8 and T_9 (9.66, 10.43, 9.73 and 10.30 kg ha^{-1} , respectively). However, it was significantly superior over T_3, T_4, T_5 and (9.20, 7.99 and 9.26 kg ha^{-1} , respectively) (cf. Table 13). In pod, treatment T_6 recorded the maximum S uptake (23.91 kg ha^{-1}). The treatment T_2 accounted for the lowest uptake (11.13 kg ha^{-1}). Treatment T_6 was on par with T_5, T_7, T_8 and T_9 (21.21, 21.36, 21.92 and 22.02 kg ha^{-1} , respectively). However, it was significantly superior over T_1, T_3 and T_4 (18.89, 17.25 and 16.45 kg ha^{-1} , respectively) (cf. Table 14). The total S uptake also followed the same trend as in pod and haulm. Treatment T_6 recorded the maximum S uptake (34.87 kg ha^{-1}), whereas, the treatment T_2 accounted for the lowest S uptake (16.72 kg ha^{-1}). Treatment T_6 was on par with T_7, T_8 and T_9 (31.78, 31.65 and 32.32 kg ha^{-1} , respectively). However, it was significantly superior over T_1, T_3, T_4 and T_5 (28.54, 27.45, 25.54 and 30.47 kg ha^{-1} , respectively) (cf. Table 15).

4.4.5 Zinc (g/ha)

The zinc uptake at harvest was more in pod than haulm and significantly influenced by nutrients. In haulm, treatment T_6 recorded the maximum Zn uptake (254.96 g/ha). The treatment T_2 accounted for the lowest uptake (127.89 g/ha). Treatment T_6 was on par with T_7, T_8 and T_9 (242.28, 244.14 and 252.83 g/ha , respectively). However, it was significantly superior over T_1, T_3, T_4 and T_5 (168.72, 175.10, 174.10 and 186.10 g/ha , respectively) (cf. Table 13). In pod, treatment T_6 recorded the maximum Zn uptake (716.73 g/ha). The treatment T_2 accounted for the lowest uptake (379.98 g/ha). Treatment T_6 was on par with T_8 and T_9 (687.59 and 688.02 g/ha , respectively). However, it was significantly superior over T_1, T_3, T_4, T_5 and T_7 (496.09, 568.58, 542.66, 580.82 and 654.88 g/ha , respectively) (cf. Table 14). The total uptake also followed the same trend as in haulm and pod uptake. Treatment T_6 recorded the maximum uptake (971.69 g/ha). The treatment T_2 accounted for the lowest uptake (507.87 g/ha). Treatment T_6 was on par with T_8 and T_9 (931.73 and 940.85 g/ha , respectively). However, it was significantly superior over T_1, T_3, T_4, T_5 and T_7 (664.81, 743.77, 716.76, 766.92 and 897.17 g/ha , respectively) (cf. Table 15).

4.4.6 Boron (g/ha)

Treatment T_6 recorded the maximum boron uptake in haulm (72.43 g/ha), whereas, the treatment T_2 accounted for the lowest B uptake (35.07 g/ha). Treatment T_6 was on par with T_7, T_8 and T_9 (67.68, 66.91 and 70.62 g/ha , respectively). However, it was significantly superior over T_1, T_3, T_4 and T_5 (36.56, 39.48, 47.23 and 48.92 g/ha , respectively) (Table 13). Treatment T_6 recorded the maximum B uptake in pod (126.70 g/ha), whereas, the treatment T_1 accounted for the lowest uptake (58.77 g/ha). Treatment T_6 was on par with T_7, T_8 and T_9 (115.43, 121.29 and 120.53 g/ha , respectively). However, it was significantly superior over T_2, T_3, T_4 and T_5 (69.28, 67.77, 98.73 and 103.51 g/ha , respectively) (Table 14). The total uptake also followed the same trend as in haulm and pod. Treatment T_6 recorded the maximum B uptake (199.13 g/ha), whereas, the treatment T_1 accounted for the lowest B uptake (95.33 g/ha).

Treatment T_6 was on par with T_7, T_8 and T_9 (183.11, 188.20 and 191.15 g/ha , respectively). However, it was significantly superior over T_2, T_3, T_4 and T_5 (104.34, 107.25, 145.96 and 152.43 g/ha , respectively) (Table 15). The boron uptake at harvest was more in pod than in haulm. It was significantly influenced by nutrients.

Table 13: Nutrient uptake by groundnut haulm at harvest

Treatments	N	P_2O_5	K_2O	S	Zn	B
	Kg ha^{-1}				g/ha	
T_1 - RDF	35.73	10.03	35.04	9.66	168.72	36.56
T_2 - RDF-Bhoochetana	27.21	6.29	26.92	5.59	127.89	35.07
T_3 - RDF modification by Soil test (RPP)	37.13	10.76	36.96	9.29	175.10	39.48
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	37.69	9.87	34.34	7.99	174.10	47.23
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	39.74	10.71	35.90	9.26	186.10	48.92
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	45.27	13.28	43.41	10.97	254.96	72.43
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	43.20	12.48	38.99	10.43	242.28	67.68
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	41.77	11.61	39.82	9.73	244.14	66.91
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	43.43	12.76	39.87	10.30	252.83	70.62
S. Em±	**1.03**	**0.52**	**1.28**	**0.50**	**5.91**	**2.14**
CD (0.05)	**3.10**	**1.57**	**3.85**	**1.50**	**17.73**	**6.41**

Table 14: Nutrient uptake by groundnut pod at harvest

Treatments	N	P_2O_5	K_2O	S	Zn	B
	Kg ha^{-1}				g/ha	
T_1 - RDF	76.34	19.34	59.93	18.89	496.09	58.77
T_2 - RDF-Bhoochetana	59.94	13.98	44.83	11.13	379.98	69.28
T_3 - RDF modification by Soil test (RPP)	86.74	21.80	70.96	17.25	568.58	67.77
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	86.46	20.59	68.20	17.55	542.66	98.73
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	91.91	22.48	67.72	21.21	580.82	103.51
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	101.97	26.41	79.89	23.91	716.73	126.70
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	94.39	23.17	69.16	21.36	654.88	115.43
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	97.08	23.55	75.04	21.92	687.59	121.29
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	98.10	23.63	73.24	22.02	688.02	120.53
S. Em±	**5.07**	**0.86**	**5.24**	**1.01**	**19.98**	**5.37**
CD (0.05)	**15.19**	**2.57**	**15.70**	**3.02**	**59.91**	**16.10**

Table 15: Total uptake of nutrients in groundnut at harvest

Treatments	N	P_2O_5	K_2O	S	Zn	B
	Kg ha^{-1}				g/ha	
T_1 - RDF	112.07	29.37	94.97	28.54	664.81	95.33
T_2 - RDF-Bhoochetana	87.15	20.27	71.75	16.72	507.87	104.34
T_3 - RDF modification by Soil test (RPP)	123.88	32.56	107.93	27.45	743.77	107.25
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	124.15	30.46	102.54	25.54	716.76	145.96
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	131.65	33.19	103.62	30.47	766.92	152.43
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	147.25	39.69	123.30	34.87	971.69	199.13
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	137.59	35.64	108.15	31.78	897.17	183.11
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	138.85	35.16	114.86	31.65	931.73	188.20
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	141.53	36.39	113.11	32.32	940.85	191.15
S. Em±	**5.35**	**1.11**	**4.52**	**1.15**	**22.65**	**5.89**
CD (0.05)	**16.05**	**3.33**	**13.56**	**3.46**	**67.89**	**17.67**

4.5 Available nutrient status in soil after harvest of crop

The data on nutrient status at post harvest stage is presented through Table 16.

4.5.1 Nitrogen (kg ha^{-1})

Available nitrogen content in soil after harvest of groundnut crop did not differ significantly due to nutrients. However, the maximum available nitrogen noticed in treatment T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) (230.27 kg ha^{-1}). Lowest available nitrogen was recorded with T_2 (RDF-Bhoochetana) (223.27 kg ha^{-1})

4.5.2 Phosphorus (kg ha^{-1})

Available phosphorus content in soil after harvest of groundnut crop differed significantly due to nutrients. The available P_2O_5 content was maximum in treatment T_5 (140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum) (26.89) and which is on par with all the treatments (T_3, T_4, T_6, T_7, T_8 and T_9) except T_1 (RDF) (22.42 kg ha^{-1}). Lowest P_2O_5 content was with T_2 (RDF-Bhoochetana) (20.95 kg ha^{-1}).

4.5.3 Potassium (kg ha^{-1})

The available potassium content of soil after harvest was not significantly influenced by nutrients. However, the maximum available potassium was observed in treatment T_3 (RDF modification by Soil test (RPP)) (387.00 kg ha^{-1}). Lowest available nitrogen was recorded with T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) (381.33 kg ha^{-1}).

4.5.4 Sulphur (mg kg^{-1})

Available sulphur content in soil after harvest of groundnut crop differed significantly due to nutrients. The available sulphur content was maximum in treatment T_3 (RDF modification by Soil test (RPP)) (10.40 mg kg^{-1}). Lowest sulphur content was with T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) (8.43 mg kg^{-1}).

4.5.5 Zinc (mg kg^{-1})

Available zinc content in soil after harvest of groundnut crop differed significantly due to nutrients. The available zinc status at post harvest stage was maximum in treatment T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) (0.99 mg kg^{-1}) which is significantly superior over other treatments except T_8. The lowest available zinc status was observed in treatment T_2 (RDF-Bhoochetana) (0.55 mg kg^{-1}).

4.5.6 Boron (mg kg^{-1})

Available boron content in soil after harvest of groundnut crop differed significantly due to nutrients. The available boron content was maximum in treatment T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum) (0.79 mg kg^{-1}) and which is on par with all the treatments (T_7 and T_8). Lowest available boron content was with T_1 (RDF) (0.31 mg kg^{-1}).

4.6 Economic analysis

Treatment T_6 (120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum) + 200 kg Gypsum/ha) which recorded the maximum gross returns and cost cultivation (Rs.113054 per ha and Rs.29536 per ha, respectively). Treatment T_2 (RDF-Bhoochetana) which recorded the lowest gross returns and cost of cultivation (Rs.74942 per ha and Rs.27795 per ha , respectively). The treatment T_6 recorded the highest benefit: cost ratio of 3.83, whereas treatment T_2 recorded the lowest benefit: cost ratio of 2.70 (Table 17).

Table 16: Available nutrient status at harvest

Treatments	N	P_2O_5	K_2O	S	Zn	B
	Kg ha^{-1}			mg/kg		
T_1 - RDF	226.53	22.42	386.53	10.16	0.56	0.31
T_2 - RDF-Bhoochetana	223.27	20.95	386.00	9.40	0.55	0.50
T_3 - RDF modification by Soil test (RPP)	225.60	25.58	387.00	10.40	0.69	0.32
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	228.80	25.87	384.33	8.90	0.66	0.47
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	229.80	26.85	382.00	8.78	0.63	0.45
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	228.40	25.14	382.33	8.13	0.72	0.59
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	230.17	26.31	383.33	8.53	0.75	0.64
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	228.08	25.55	382.93	8.6	0.98	0.77
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	230.27	26.89	381.33	8.33	0.99	0.79
S. Em±	**3.88**	**1.12**	**10.71**	**0.31**	**0.05**	**0.05**
CD (0.05)	**NS**	**3.37**	**NS**	**0.93**	**0.16**	**0.13**

Table 17: Effect of nutrients on economics of groundnut

Treatments	Cost of cultivation (Rs./ha)	Gross returns (Rs./ha)	Net returns (Rs./ha)	Benefit cost ratio
T_1 - RDF	30093	87928	57835	2.92
T_2 - RDF-Bhoochetana	27795	74942	47147	2.70
T_3 - RDF modification by Soil test (RPP)	29685	90935	61250	2.97
T_4 - 120% RD N and P_2O_5 + 80% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	29128	93776	64648	3.22
T_5 - 140% RD N and P_2O_5 + 60% RD K_2O + 5 kg Zn + 0.2 kg B + 200 kg gypsum	29430	99454	70025	3.38
T_6 - 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	29536	113054	83518	3.83
T_7 - 140% RD N and P_2O_5 + 60% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum	29838	108498	78660	3.64
T_8 - 120% RD N and P_2O_5 + 80% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	30067	110836	80768	3.69
T_9 - 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum	30369	111725	81356	3.68

5. DISCUSSION

Soil fertility is one of the major properties in maintaining soil quality. Nutrient mapping of an area will give the quantity and distribution of nutrients spatially. To know the fertility status of soil eighty (80) soil samples were collected from Kotur village of Dharwad district to identify the soil fertility constraints and based on that information groundnut was grown as test crop to study the response to identified nutrient constraints. The results of the investigation are discussed in this chapter.

5.1 Identification of soil fertility constraints in Kotur micro-watershed

5.1.1 Soil reaction (cf. Table 18)

The soil reaction was neutral (6.5–7.5) in 348.4 ha of area and it was acidic in about 223.4 ha of area. The acidic nature of red soils was due to leaching of bases. High rainfall in this area induces leaching of soluble salts. Similar observations were also made by Viswanath *et al*. (1978), Rajaramannan *et al*. (1979) and Badrinath *et al*. (1986) and Mini *et al*. (2004).

The soil reaction was alkaline (7.5 – 8.9) in 298.8 ha of area covering black soils at the valley position in the micro-watershed., (Fig. 3). The higher pH black soils could be attributed to the accumulation of bases. Similar result were reported for black soils by Bhadrapur and Sheshagiri Rao (1979), Thangasamy *et al*. (2005), Ravikumar *et al.,* (2007), Vinay (2007) and Manojkumar (2011)

5.1.2 Electrical conductivity (cf. Table 18)

Entire (870.6 ha) micro-watershed was free of salinity problem because of free drainage condition. Sahu *et al.* (1990) also observed very low soluble salts in red soils. The black soils were also relatively free from salts. Similar findings have also been reported by Pulakeshi (2010) in black soils of Northern transition zone of Karnataka.

5.1.3 Organic carbon (cf. Table 18)

The organic carbon content of the soil was in the range of 0.3 to 10.8 g kg^{-1} at the surface, (Fig. 4). An area of (277.1 ha) was low in micro-watershed because of less organic matter addition to the soil and intensive cultivation. The reason for low organic carbon content in these soils may be attributed to the prevalence of tropical condition, where the degradation of organic matter occur at a faster rate coupled with little or no addition of organic manures and low vegetative cover on the fields, thereby leaving less chances of accumulation of organic carbon in the soils. Major portion of the (357.7 ha) micro-watershed in valley area was high in organic carbon content. This can be attributed to luxuriant vegetative growth and consequent addition of organic matter to soil in this heavy rainfall area and removal of organic matter from higher elevation and accumulation in valley region (Mahalingam and Durairaj, 1968 and Powar and Mehta, 1999).

5.1.4 Available major nutrients

5.1.4.1 Nitrogen (cf. Table 18)

The available nitrogen content was low (Fig. 5) in entire part of the study area (870.6 ha). The variation in N content may be related to soil management, application of FYM and fertilizer to previous crop. (Ashok Kumar, 2000). The low available nitrogen content in the area could be attributed to low OC status of soil coupled with low nitrogen fertilization leading to nitrogen deficiency. The results obtained in the present study are in agreement with the findings of Mathews *et al*. (2009) and Ravikumar *et al*. (2007)

5.1.4.2 Phosphorus (cf. Table 18)

The available phosphorus content was medium in major parts of the watershed (513.3 ha), but it was low in 355.3 ha (Fig. 6). The red soils showed low values of available phosphorus, which may be due to low CEC, clay content and acidic soil reaction (Anon, 1989; Krishnamurthy, 1993 and Bopathi and Sharma, 2006).

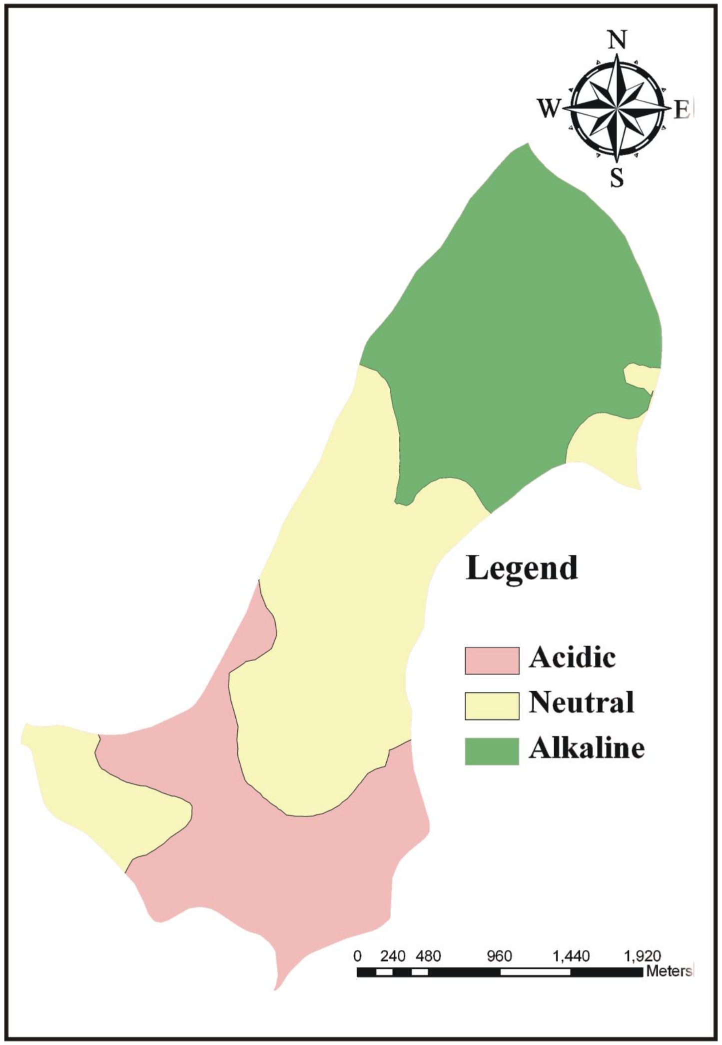


Fig 3. pH status in soils of Kotur micro-watershed

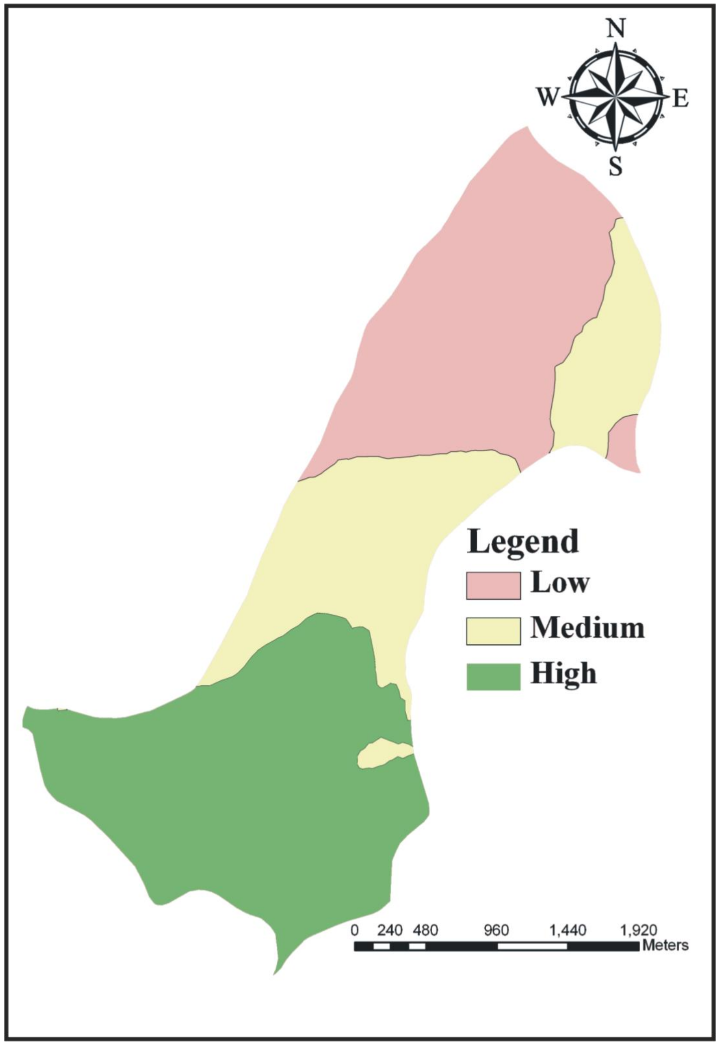
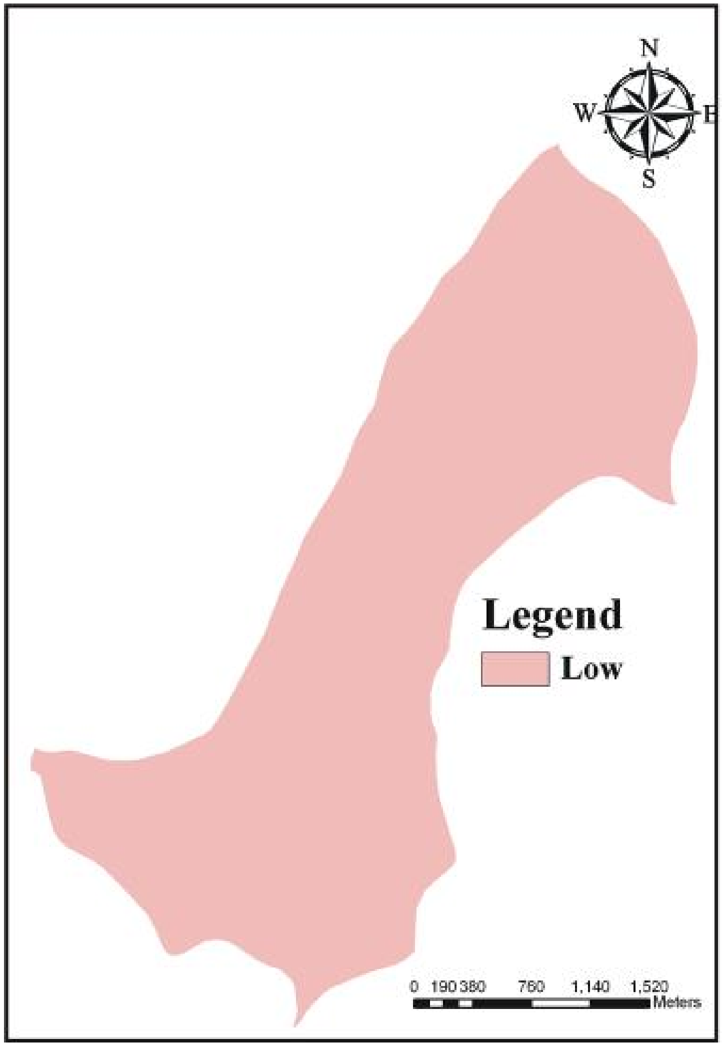


Fig 4. Organic carbon status in soils of Kotur micro-watershed



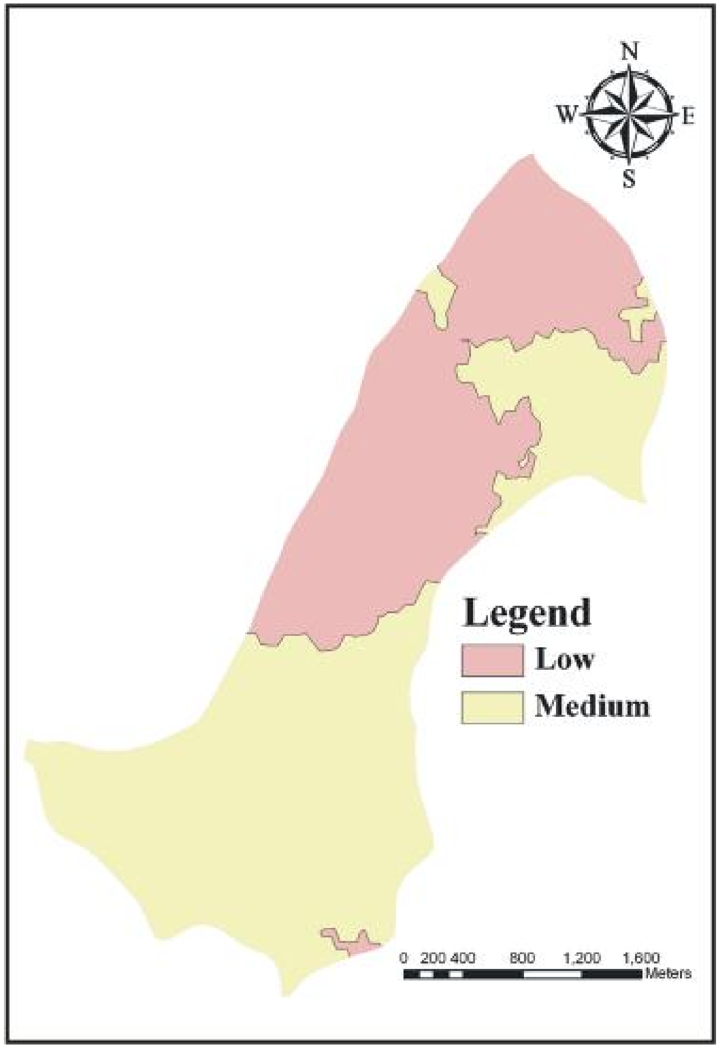


Fig 5. Available nitrogen status in soils of Kotur micro-watershed

Fig 6. Available phosphorus status in soils of Kotur micro-watershed

The present findings are in line with those of Sahu and Mishra (1997) and (Shiva Prasad *et al.,* 1998) who reported that majority of the soils in Karnataka were medium in phosphorus content (Table 3).

5.1.4.3 Potassium (cf. Table 18)

The available potassium content in major portion of the study area was under medium (191.4 ha) and high (679.2 ha) category (Fig. 7), respectively. Black soils showned higher values than red soils due to predominance of K rich micaceous and feldspars minerals in parent material. Similar results were observed by Ravikumar *et al*. (2007). Jaffee and Levine (1939) reported that increase in pH and CEC increase the number of sites for K adsorption. Similar findings were made by Vara Prasad Rao (2008), Shiva Prasad *et al.* (1998) and Srikant *et al* (2008).

5.1.5 Available secondary nutrients

5.1.5.1 Sulphur (cf. Table 18)

The area under low and medium category for sulphur was 669.0 ha and 201.6 ha (Fig. 8), respectively. Low and medium level of available sulphur was recorded due to lack of sulphur addition and continuous removal of S by crops. Black soils were comparatively higher in organic carbon status as a result they were higher in available S status. Conversely, red soils were poor in organic carbon and hence, exhibited low available S status. Thus soil type also influenced available S status of soils. In addition, low status of sulphur can be attributed to low EC of soils. Sharma and Gangwar (1997) reported negative correlation between total sulphur and electrical conductivity.

5.1.5.2 Calcium and magnesium (cf. Table 18)

Entire (870.6 ha) study area was high in exchangeable Ca and Mg status. Ananthanarayana (1986) reported higher exchangeable Ca and Mg contents in black soils than red soils. Availability of calcium and magnesium to the crops do not generally present problems in black soils, as these soils are calcareous in nature. The exchangeable Ca and Mg are attributed to the type and amount of clay present in these soils. These results are in confirmation with the findings of Krishnamurthy (1993) and Alur (1994). It was clear that Mg was present in low amount than Ca because of its higher mobility. These results are in conformity with findings of Pulakeshi (2010) and Manojkumar (2011), in the soils of Northern transition zone of Karnataka.

5.1.6 Available micronutrients

5.1.6.1 Available zinc (cf. Table 18)

In black and red soils, the available zinc was deficient in the major part of the study area (454.3 ha) and sufficient in 416.3 ha (Fig. 9). The content of Zn increased with low pH and high organic carbon content but decreased with increase in pH as also reported by Satyavathi and Suryanarayana Reddy (2004). Since, the most of the soils are alkaline and dominated by $CaCO_3$, zinc may be precipitated as hydroxides and carbonates as a result and their solubility and mobility may be decreased and reduced availability (Patil *et al*. 2006).

5.1.6.2 Iron (cf. Table 18)

Black soils fall under deficient (242.6 ha) and sufficient category (628.0 ha) in Fe status (Fig. 10). Red soils are sufficient and excess in Fe status. In black soils, low Fe content may be due to precipitation of Fe by $CaCO_3$ and decrease its availability. Similar results were also observed by Ravikumar *et al.,* (2007) and Patil *et al*., (2006). The available iron in surface soils has no regular pattern of distribution as reported by Nayak *et al.* (2002). This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

5.1.6.3 Copper (cf. Table 18)

Entire portion of the study area (870.6 ha) was under sufficient rating for available copper status (Fig. 11). Raghupathi (1989) reported that available copper content in North Karnataka soils ranged from 0.4 to 1.2 ppm.

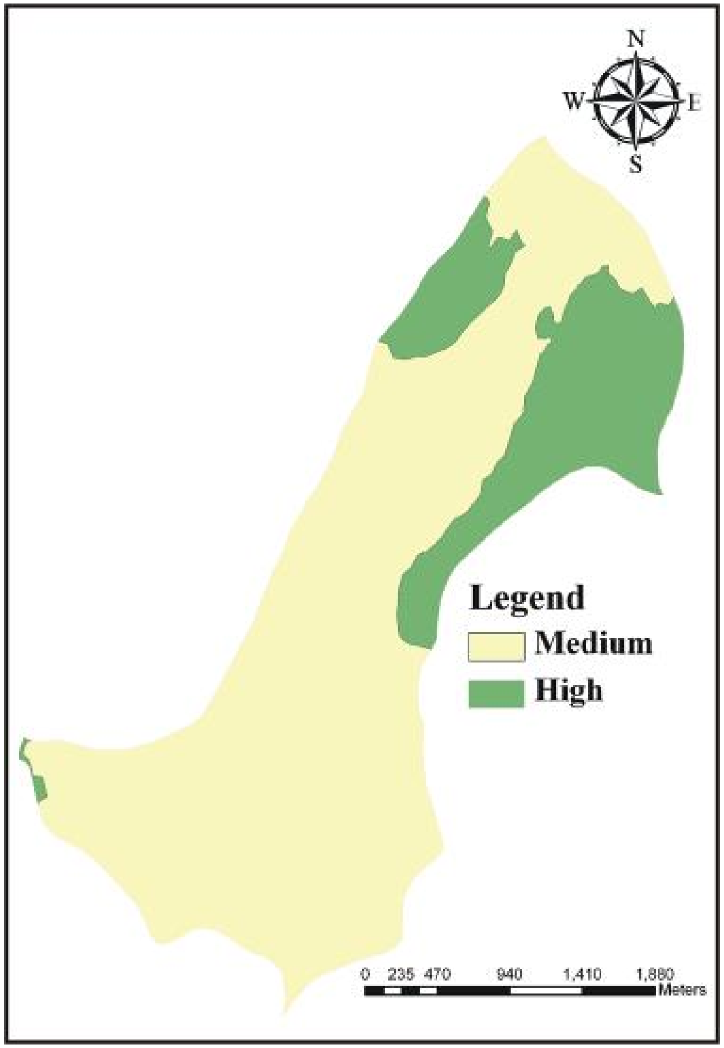


Fig 7. Available potassium status in soils of Kotur micro-watershed

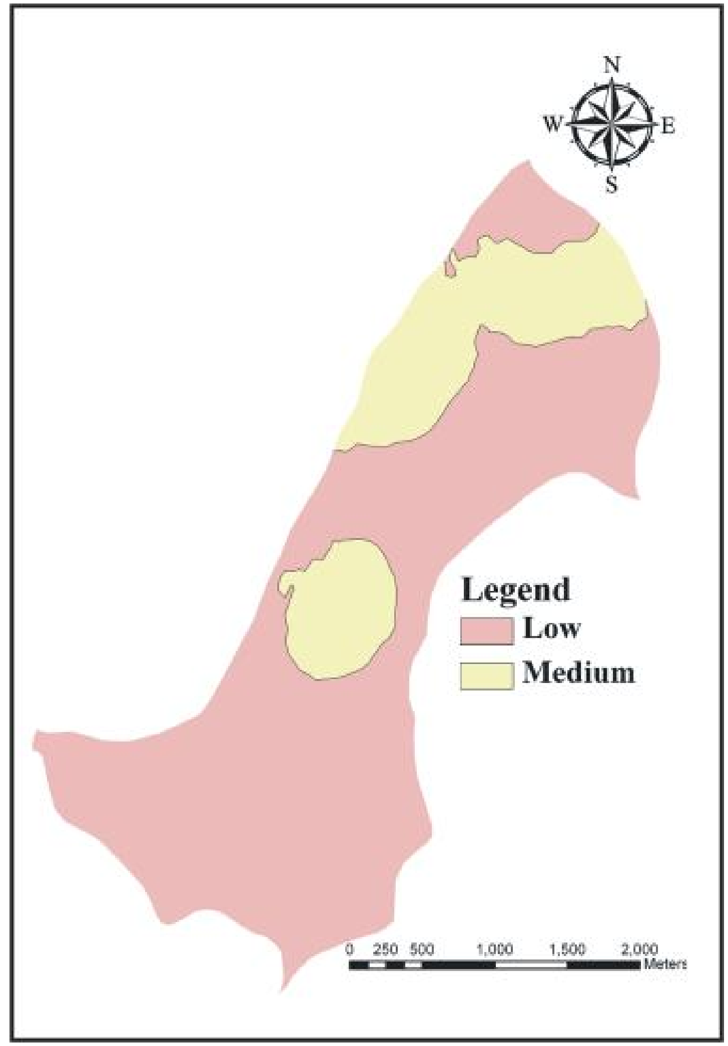


Fig 8. Available sulphur status in soils of Kotur micro-watershed

Similar results were also observed by Ravikumar *et al*. (2007), Pulakeshi (2010) and Manojkumar (2011) that sufficient status of available copper in Northern transition zone of Karnataka.

5.1.6.4 Manganese (cf. Table 18)

In black and red soils, the available manganese was found to be sufficient in entire study area (Fig. 12), which may be due to neutral to low pH and nature of the parent material as reported by Prasad and Sahi (1989). Sufficient content of manganese was observed by Ravikumar *et al*. (2007) in Vertisols of Malaprabha command area, Pulakeshi (2010) in the soils of northern transition zone of Karnataka derived from chlorite schist and Manojkumar (2011) in the soils of northern transition zone of Karnataka derived from basalt.

5.1.6.5 Boron (cf. Table 18)

The study area was found to be deficient in 501.5 ha and sufficient in 369.1 ha (Fig. 13). The boron deficiency in most part of the micro-watershed was due to low organic carbon status of the soils. Similar observation made by Satyavathi and Suryanarayana Reddy (2004) that available boron showed positive relation with organic carbon.

Based on the nutrients maps prepared after the analysis of surface soil samples from Kotur micro-watershed, N, P, S, Zn and B were found deficient in major portion of the area. Hence, they identified as soil fertility constraints in the soils of Kotur micro-watershed.

5.2 Effect of soil test based nutrients application on growth, dry matter production and yield in groundnut

5.2.1 Dry matter production

The results revealed that, application of nutrients based on soil test significantly influenced dry matter production in haulm and pod. RDF modification according to *Bhoochetana* project of ICRISAT caused significant reduction in dry matter production indicating that modified recommendation is not enough to produce higher dry matter, whereas, RDF modification according to RPP, UAS, Dharwad (T_3) resulted in significantly superior dry matter production (55.20 q ha^{-1}) compared to application of RDF (50.00 q ha^{-1}).

The increase in dry matter due to modification of RDF was related to higher level of P application. The increase in dry matter at higher level of P was mainly because, phosphorus being an essential constituent of cellular proteins and nucleic acids encouraged the meristematic activities of groundnut and increased uptake of all the nutrients which in turn helped in better plant growth and dry matter production.

Increase in RD N and P_2O_5 to 120% and 140% with application of 5 kg Zn/ha and 0.2 kg B/ha (T_4 and T_5) increased total dry matter production but was non significant compared to T_3. Significant increase in total dry matter yield compared to RDF was obtained at 120% and 140% RD N and P_2O_5 with application of 7.5 kg Zn/ha and 0.3 kg B/ha. Further increase in Zn and B level did not increase the dry matter yield.

The highest total dry matter yield of 62.30 q ha^{-1} (Fig. 14) was obtained due to 20% RD N and P_2O_5 increase with application of 7.5 kg Zn and 0.3 kg B (T_6). The results are in confirmation with those obtained by Patel *et al*. (1983), Newase *et al.* (1990), Nimje (1992) and Thorave and Dhonde (2005) who observed that groundnut recorded higher plant height, number of branches per plant, number of leaves per plant and haulm and pod yield per hectare with application of higher levels of N and P per hectare,respectively when compared to the lower doses (12.5 and 25 kg N and P per hectare,respectively).

Significant response of groundnut to Zn might be due to its presence in the various enzymes and hormones, it favoured increased synthesis of enzymes and hormones along with the metabolisation of major nutrients, which in turn promoted the growth components. Sarkar *et al*. (1998) reported that the use of increased dose of Zn increased the shoot dry matter production in wheat. This might be due to the favourable effects of these elements in nitrogen assimilation and carbohydrate metabolism.

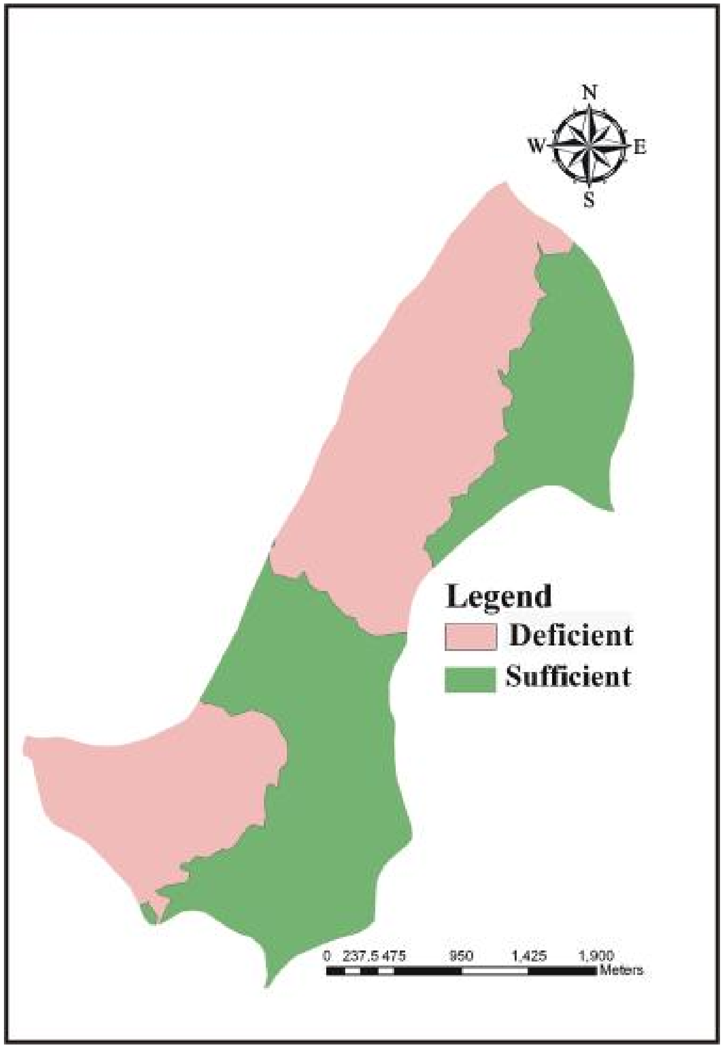


Fig 9. Available zinc status in soils of Kotur micro-watershed

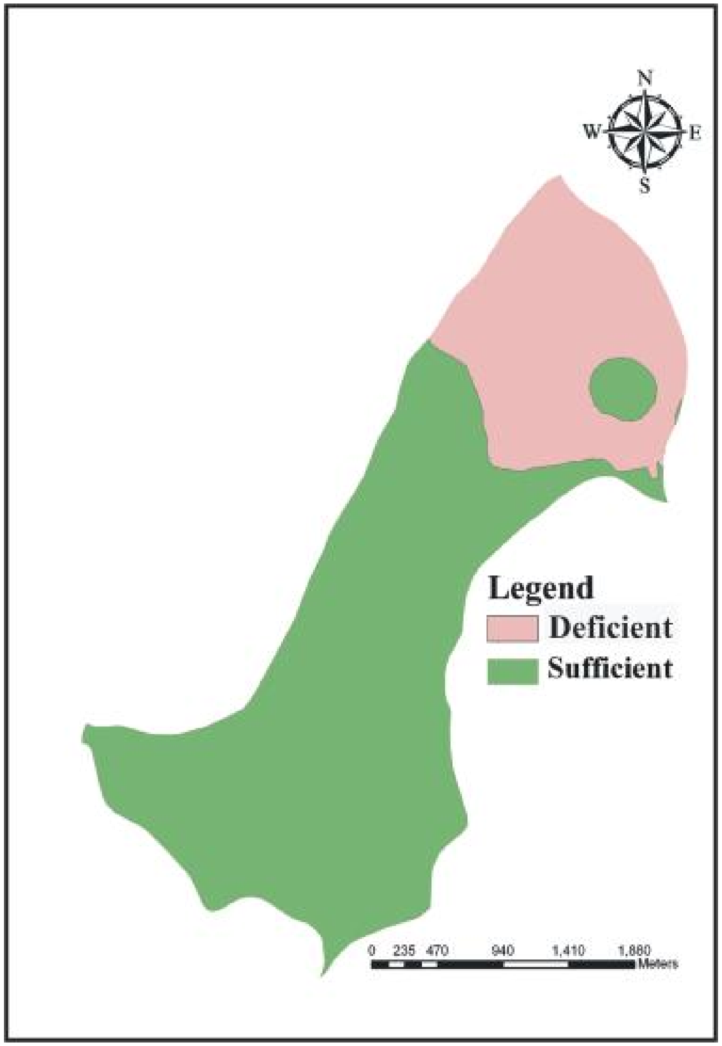


Fig 10. Available iron status in soils of Kotur micro-watershed

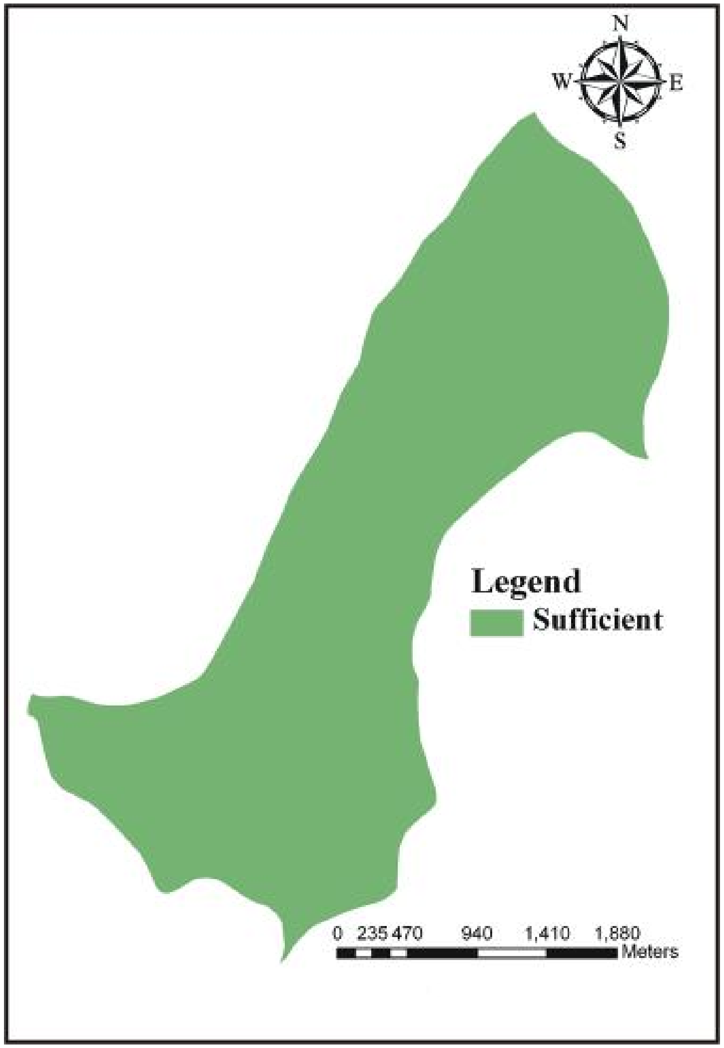


Fig 11. Available copper status in soils of Kotur micro-watershed

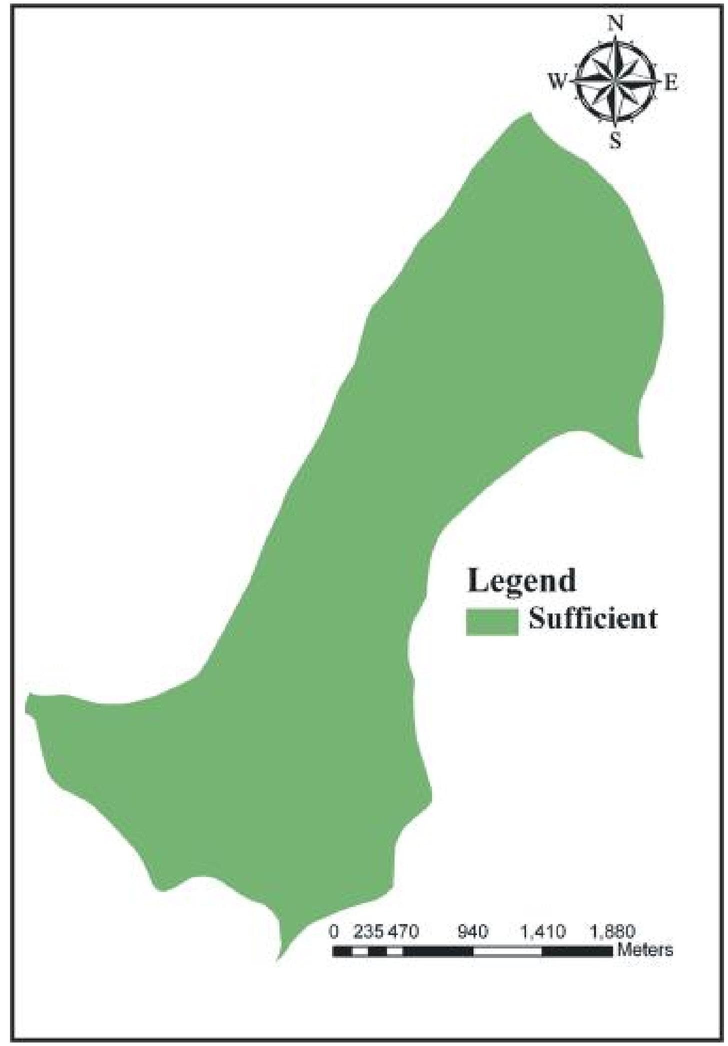


Fig 12. Available manganese status in soils of Kotur micro-watershed

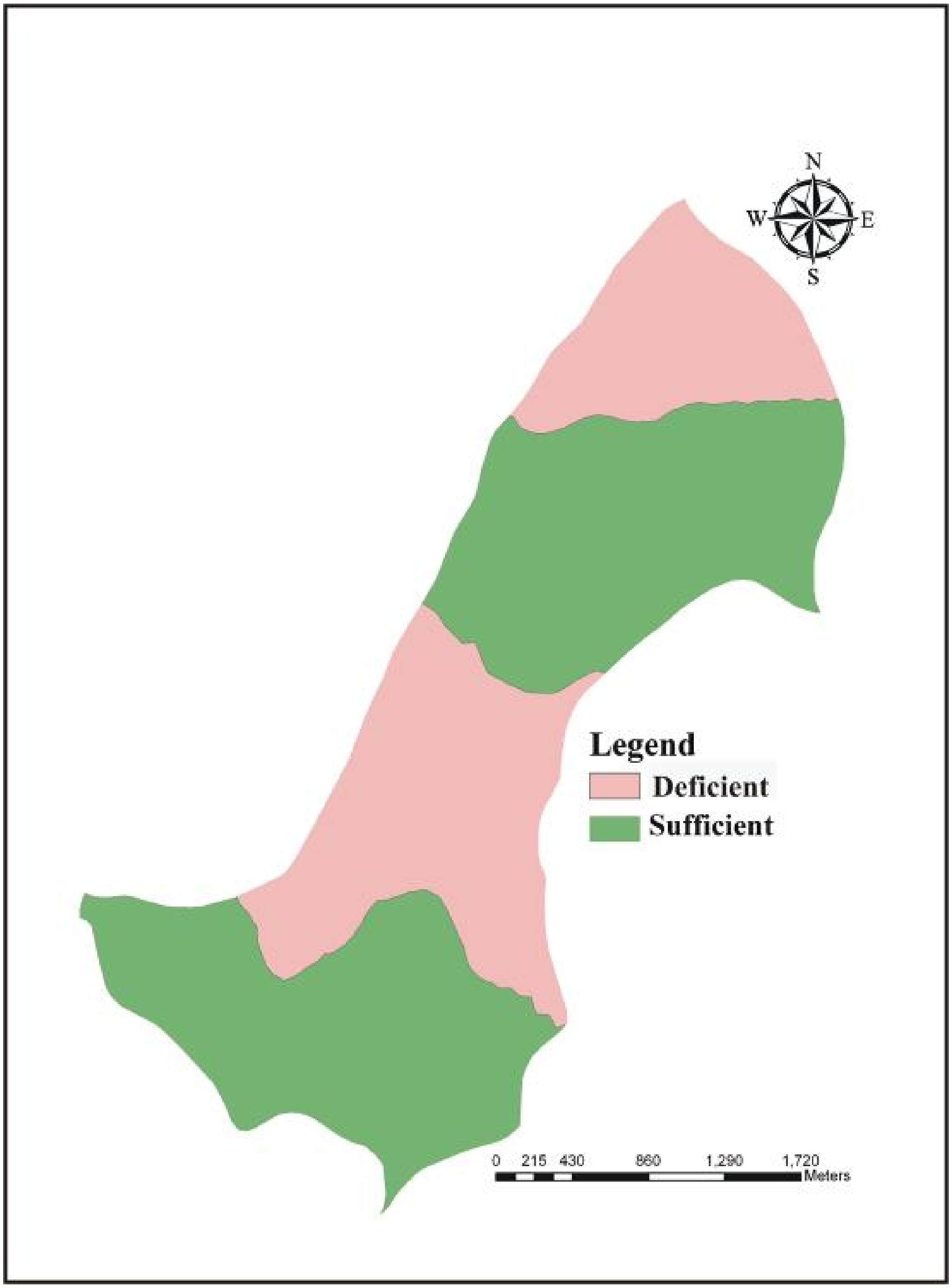


Fig 13. Available boron status in soils of Kotur micro-watershed

Table 18: Area indicating available nutrient status of Kotur micro-watershed

Property/Nutrient	Status	Area (ha)	Percentage of total area
pH	Acidic	223.4	25.66
	Neutral	348.4	40.01
	Alkaline	298.8	34.33
Organic carbon	Low	277.1	31.82
	Medium	235.8	27.09
	High	357.7	41.09
Nitrogen	Low	870.6	100
Phosphorus	Low	355.3	40.81
	Medium	513.3	59.19
Potassium	Medium	191.4	21.98
	High	679.2	78.02
Sulphur	Low	669.0	76.84
	Medium	201.6	23.16
Calcium	Sufficient	870.6	100
Magnesium	Sufficient	870.6	100
Zinc	Deficient	454.3	52.18
	Sufficient	416.3	47.82
Iron	Deficient	242.6	27.86
	Sufficient	628.0	72.14
Copper	Sufficient	870.6	100
Manganese	Sufficient	870.6	100
Boron	Deficient	501.5	57.6
	Sufficient	369.1	42.4

The highest dry matter production in T_6 was also related to significantly higher plant height, number of branches and number of pods per plant compared to other treatments. The increase in dry matter production due to increased application of N, P, Zn and B was related to their low available status in soil. This clearly showed that, RDF level of nutrients were not sufficient for production of higher total dry matter in groundnut at low soil fertility status. It was also observed that, 20 to 40 % reduction in recommended potassium application due to its high available status in soil did not affect the total dry matter production in groundnut.

The results on response of groundnut are in conformity with the findings of Janakiraman *et al* (2004) their results on experiments conducted for three consecutive seasons during kharif 1998, 1999 and 2000 revealed that, groundnut growth and yield were significantly higher when Fe, Zn and B were applied with recommended dose of NPK fertilizers. The work of Vishwakarma *et al.* (2008) revealed that maximum plant height (60.33 cm) and number of branches (5.83 per plant) in groundnut were recorded with soil application of borax. Khanda and Dixit (1995) also reported favourable effect of combined application of N and Zn on yield components due to the increased vigour, photosynthate accumulation and better translocation of photosynthates to the sink.

5.2.2 Haulm and pod yield

Significantly higher haulm (37.81 q ha^{-1}) and pod yield (33.93 q ha^{-1}) compared to RDF (33.27 and 26.23 q ha^{-1}, respectively) (Fig. 15) was obtained in the treatment which received 20% RDF increase with 7.5 kg Zn and 0.3 kg B/ha (T_6). It may be noted that, RDF modification by *Bhoochetana* project of ICRISAT caused significant reduction in groundnut haulm and pod yield indicating that modified recommendation was not enough to produce higher pod yield. RDF modification according to RPP, UAS, Dharwad resulted in significantly superior haulm and pod yield compared to application of RDF. The increase in haulm and pod yield due to modification of RDF is related to higher level of P application. Increase in dry matter production due to increased photosynthetic activity and synergistic effect between N and P has further increased the haulm and pod yield. RD N and P_2O_5 application at 120 and 140% with application of 5 kg Zn and 0.2 kg B (T_4 and T_5) significantly increased total pod yield compared to RDF. Further increase in N, P, Zn and B level did not increase the haulm and pod yield of groundnut. The Significantly highest increase in pod yield in T_6 was mainly due to significantly higher number of pods per plant and pod weight per plant.

The results on haulm and pod yield of groundnut as influenced by nutrients application was in agreement with the findings of many workers. Chouhan *et al.* (1987) observed higher pod yield (3.74 t/ha) with the application of 60 kg P_2O_5 per ha when compared to the lower levels of P_2O_5 at Gwalior during *kharif* season. Angadi *et al.* (1990), Gnanamurthy and Balasubramanaian (1992), Bhalerao *et al.* (1993) and Vinod Kumar *et al.* (2000) also obtained significantly higher haulm and pod yield with the application of higher level of recommended NPK compared to 100 percent recommended dose. Further, they reported higher pods per plant, 100-kernel weight, sound mature kernel and shelling percentage with the application of more than 100 percent recommended dose of N, P and K.

The sulphur application through gypsum helped in the enhanced uptake of N, P, K and S that might have influenced the synthesis and translocation of carbohydrates. The application of sulphur increased yield also due to early flowering and greater pod setting. Reduction in gypsum application from 500 to 200 kg ha^{-1} did not affect the yield and yield attributes of groundnut in the present study. Similar response for S by groundnut was reported by Mishra (1996) who recorded the maximum pod yield (1285 kg ha^{-1}) with the application of 30 kg S/ha and which was significantly superior to control (712 kg ha^{-1}) and 15 kg S/ha (892 kg ha^{-1}) and was on par with the application of 45 kg S/ha (1178 kg ha^{-1}). Agasimani *et al*. (1993) reported that combined application of sulphur and boron (10 and 2.5 kg ha^{-1}, respectively) increased groundnut yield over control in northern transition zone of Karnataka. Halepyati (2001) and Chaube *et al.* (2002) indicated that, the application of Zn produced significantly higher pod and haulm yield and100-kernel weight in groundnut. Increase in haulm and pod yield due to application of micronutrients exerted a beneficial effect on chlorophyll content in the leaves, nodulation and dry matter in plant which increased the productivity (Kulkarni *et al*., 1986)

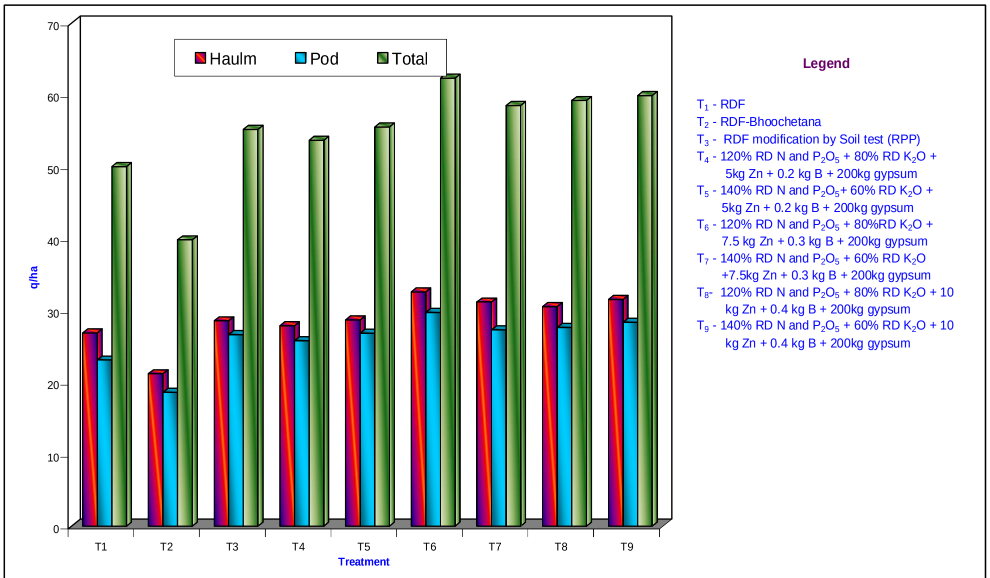


Fig. 14: Effect of nutrients on dry matter production (q/ha) of groundnut

Fig. 14: Effect of nutrients on dry matter production (q/ha) of groundnut

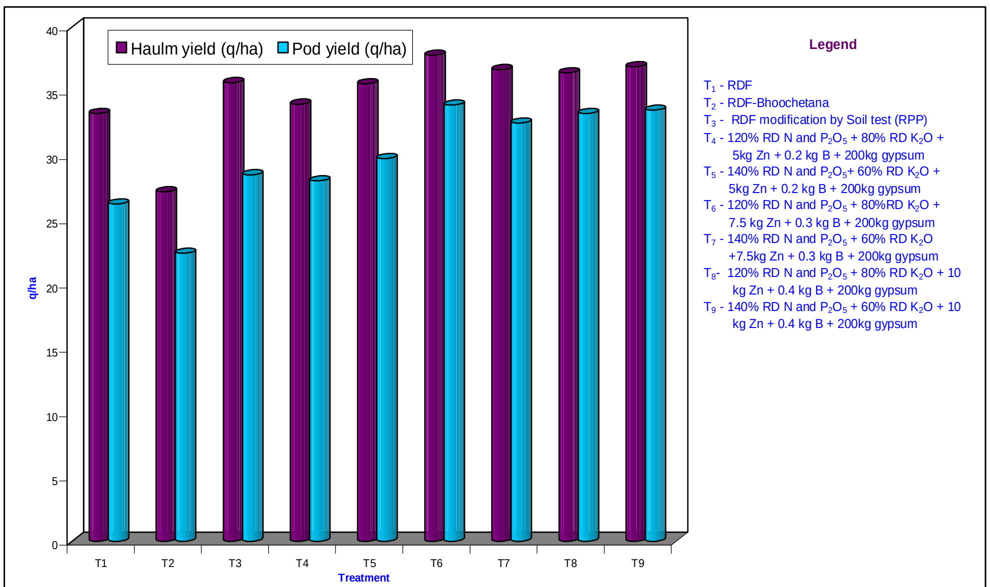


Fig. 15: Effect of nutrients on haulm yield and pod yield (q/ha) of groundnut

Fig. 15: Effect of nutrients on haulm yield and pod yield (q/ha) of groundnut

Based on the haulm and pod yield and yield attributes, the optimum nutrient levels 30-60-20-7.5-1.5- 200 kg ha^{-1} N, P_2O_5, K_2O, Zn, B and Gypsum may be required for higher yield of groundnut at low availability status of N, P_2O_5, Zn and B and at high availability of K_2O and Fe. The findings are in line with Prabakaran *et al.* (1998) who observed that, application of recommended dose fertilizers along with gypsum (250 kg ha^{-1}) and micronutrient mixture as basal application enhanced the pod yield significantly and increase in yield was 17 percent over RDF alone. Sudarsan and Ramaswamy (1993), Tripathy *et al.* (1999a) Chitdeshwari and Poongothai (2003) also reported the response of groundnut to the application of multi micronutrients to soil and also as seed treatment indicating significant increase in the pod yield over control.

5.3 Effect of soil test based nutrient application on quality parameters in groundnut

The results on quality parameters revealed that, application of nutrients based on soil test significantly influenced them. RDF modification according to *Bhoochetana* project of ICRISAT caused significant reduction in quality parameters indicating that modified recommendation is not enough to produce higher quality, whereas, RDF modification according to RPP, UAS, Dharwad resulted in at par quality parameters compared to application of RDF. Significant increase in protein content, oil content and oil yield compared to RDF was obtained at 120% and 140% RD N and P_2O_5 with application of 7.5 kg Zn and 0.3 kg B per ha. Further increase in Zn and B level did not increase the quality parameters. The highest protein content (31.44 %), oil content (47.93 %) and oil yield (1119.51 kg ha^{-1}) was obtained due to 20% RDF increase with application of 7.5 kg Zn and 0.3 kg B per ha (T_6). The increase in quality parameters due to increased application of N, P, Zn and B was related to their low available status in soil. This clearly showed that, RDF level of nutrients was not sufficient for production of higher quality in groundnut at low soil fertility status. It was also observed that, 20 to 40 % reduction in recommended potassium application due to its high available status in soil did not affect the quality in groundnut.

The results are in conformity with those obtained by Dongale and Zende (1976), Survase *et al*. (1986) and Agasimani *et al* (1993) who reported that application of calcium, boron and sulphur along with FYM increased the oil content in groundnut seed over control. Choudhery *et al.* (1991), Deshmukh and Atre (1993), Thimmegouda (1993), Bhalerao *et al.* (1993) Ved Singh *et al.* (1994) and Asha *et al.* (1996) reported significant increase in oil content in groundnut kernels with the application of higher level of NPK. Protein percentage was significantly influenced by application of N @ 25 kg ha^{-1}, P @ 50 kg ha^{-1} and S @ 20 kg ha^{-1} (Mahakulkar *et al.* 1992).

Reduction in gypsum application from 500 kg ha^{-1} in T_1 to 200 kg ha^{-1} in all the other treatments did not affect test weight, shelling percent, oil content and oil yield. The total sulphur uptake by groundnut under the study ranged from 16.72 to 34.34 kg ha^{-1}. This clearly shows that sulphur contained in 200 kg gypsum (30-35 kg) may be sufficient for producing optimum oil content and oil yield for the soils under study. Significant increase in oil content was reported by many scientists due to application of 45-60 kg S depending on initial soil S status. Choudhery *et al.* (1991) reported that oil content was increased from 48.4 percent in control to 49.7 percent at 60 kg S/ha. Dimree and Dwivedi (1994) opined that application of sulphur @ 45 kg ha^{-1} increased oil content (53.5 %) and protein content (25.4 %) over the control. Application of zinc sulphate has significantly enhanced the crude protein content of groundnut seeds but the oil content was found to be non significant (Gopala Gowda *et al.* 1995). Application of trace elements slightly increased the seed oil content of groundnut and the higher oil yield with the application of Fe + Mn + Zn, Mo and B was reported by Gopala Gowda *et al.* (1995), Mousa *et al.* (1996) and Noor *et al.* (1997).

5.4 Effect of soil test based nutrient application on N, P, K, S, Zn and B concentration in groundnut

The nitrogen concentration in haulm and pod was not significantly influenced due to higher level of N application. The phosphorus content in haulm and pod increased with higher application of P.

This was in agreement with Singh *et al*. (2000) who reported that, content of phosphorus in plants appeared to be related to the initial available phosphorus content of the soil and its application. The concentration of nutrients in pod was more than that in the haulm; the concentration did not vary much in haulm and pod at lower levels. However, the absorption of nutrients was more with the higher dose of nutrients i.e. 20% and 40% increase in RDF. This was in agreement with Kuligod (2007); who reported that treatment which received 150% RDF and 150% RDF + FYM recorded more nutrient content in tissue. Rao and Gangakishan (1993) also reported that many groundnut cultivars recorded higher uptake and accumulation of N and P due to application of higher doses of N and P. The concentration of zinc varied much due to higher application rate Yadav *et al.* (1991) observed that, zinc composition in groundnut plant parts increased with zinc application.

5.5 Effect of soil test based nutrient application on N, P, K, S, Zn and B uptake by groundnut

5.5.1 Nitrogen (kg ha^{-1})

The nitrogen uptake in groundnut haulm was less than that in the pod. Significantly higher nitrogen uptake was recorded in treatment T_6 (Fig. 16). The significant increase in nitrogen uptake at T_6 was mainly due to increase in P, Zn and B level. Further, increased N, P, Zn and B level did not increase N uptake by groundnut. The increased uptake may also be accounted for synergistic effect between N and P. Higher level of phosphorus must have enhanced the root growth which help in better absorption of nitrogen through symbiotic nitrogen fixation process (Veerabhadrappa *et al.,* 2003). The combined application of nitrogen and zinc at higher level may also increase the yield and yield attributes. Ram *et al*. (1993) reported that the beneficial effect of N + Zn could be attributed to the synergistic effect between these nutrients and continuous and enhanced nitrogen supply.

The studies made by Dongale and Zende (1976) indicated, that the application of sulphur alone or in combination with FYM or boron helped not only in checking the excessive vegetative growth of the crop but also helped in absorbing more nutrients to produce higher pod yield of groundnut crop. Thimmegowda (1993) while studying the nutrient uptake pattern in groundnut observed that, the concentration and uptake of nutrients (N, P and K) was maximum with application of recommended fertilizer (25 N, 75 P_2O_5 and K_2O kg ha^{-1}) and minimum with no fertilizer. Vinod Kumar *et al.* (2000) recorded the maximum uptake of NPK (121.15, 10.14, 34.89 kg ha^{-1}) with the application of 30: 60: 30 kg NPK/ha compared to the application of 10: 40: 10 kg NPK/ha and 20: 40: 20 kg NPK/ha.

5.5.2 Phosphorus (kg ha^{-1})

Application of higher doses of phosphate fertilizer increased the P-uptake. Treatment T_6 recorded the highest 'P' uptake in both pod and haulm (Fig. 17). This increased P uptake may be due to the increased dry mater production and synergistic effect between N and P. Synergistic effect between N and P was reported by Singh and Ahuja (1985), Kaushik and Jain (1991), Sathone and Babulkar (1991) and Ved Singh *et al.* (1994) who recorded significantly higher uptake of N (157.1 kg ha^{-1}) and P (26.7 kg ha^{-1}) with the application of 50-90 kg P_2O_5 per hectare as compared to the application of 25-60 kg P_2O_5 per hectare. Application of chelated Zn might have also enhanced the phosphorus uptake than the non chelated application of Zn to the soil which otherwise precipitated P.

5.5.3 Potassium (kg ha^{-1})

Potassium uptake by haulm and pod did not follow the trend in its application (Fig. 18) as the soils of the experimental site are rich in available potassium status. The highest potassium uptake was recorded in treatment T_6. This may be attributed to significantly higher dry matter accumulation as a result of application of higher doses of other deficient nutrients such as; N, P, Zn and B. The results confirm that, micronutrients application enhanced the potassium uptake. Balasubramanaiyan (1997) reported that combined application of NK in equal split doses at basal and 45 DAS increased the uptake of N, P and K uptake (131.1, 25.5 and 58.4 kg ha^{-1},respectively) by groundnut compared to the application of N basal, K basal and NK basal.

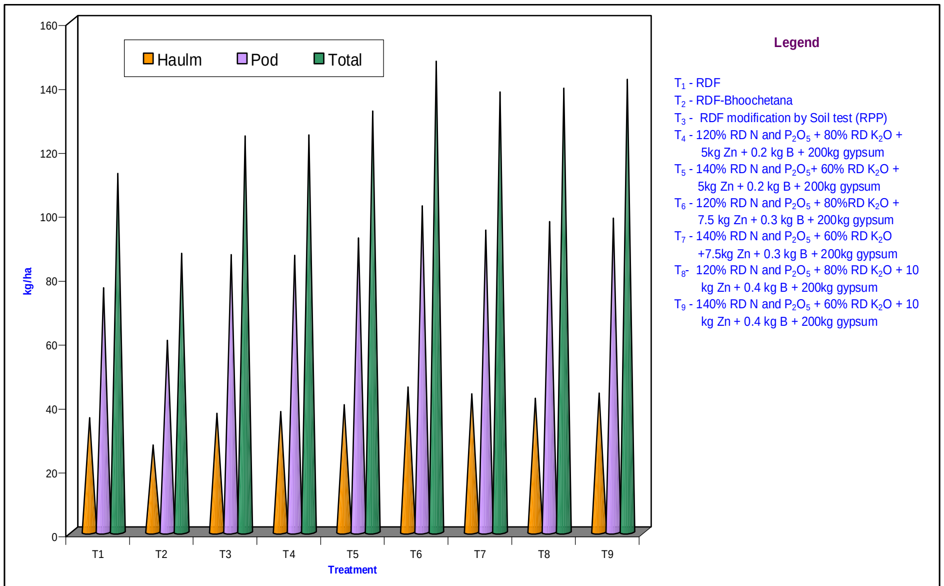


Fig. 16: Nitrogen uptake by groundnut haulm, pod and total at harvest

Fig. 16: Nitrogen uptake by groundnut haulm, pod and total at harvest

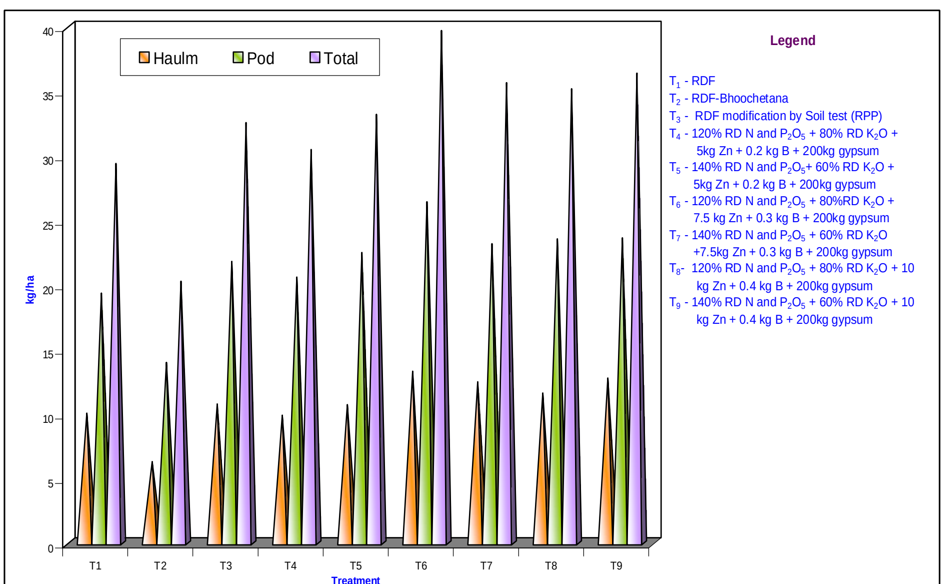


Fig. 17: Phosphorus uptake by groundnut haulm, pod and total at harvest

Fig. 17: Phosphorus uptake by groundnut haulm, pod and total at harvest

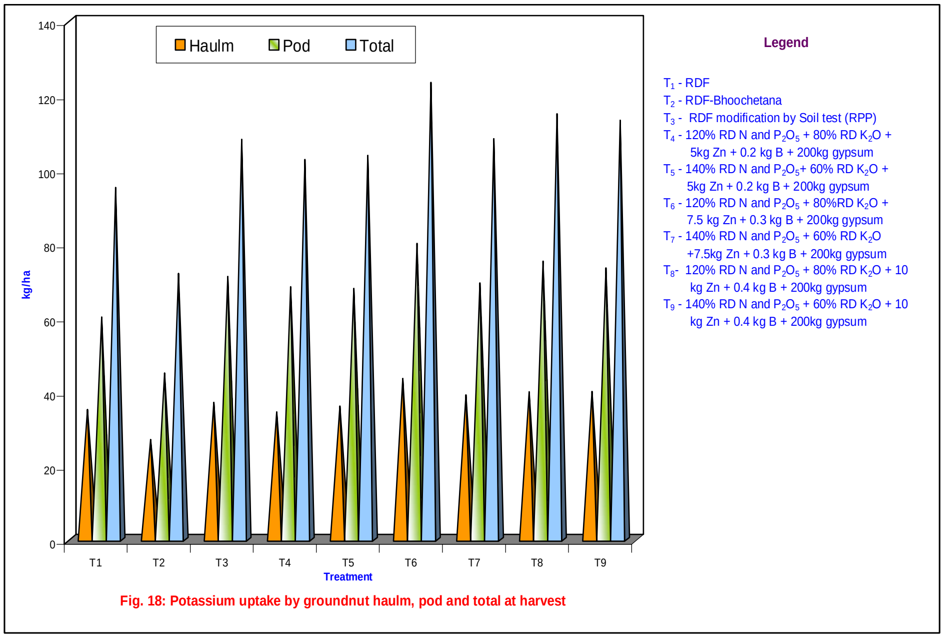


Fig. 18: Potassium uptake by groundnut haulm, pod and total at harvest

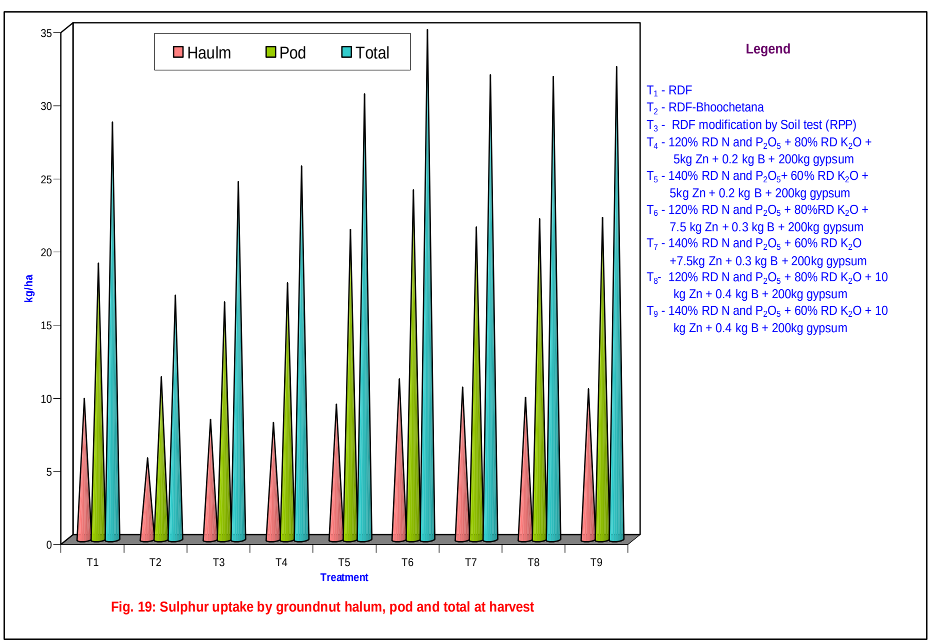


Fig. 19: Sulphur uptake by groundnut halum, pod and total at harvest

5.5.4 Sulphur (kg ha^{-1})

The treatment T_6 recorded the higher S uptake due to application of 200 kg gypsum and higher level of deficient N, P and micronutrients (Fig. 19). This shows that balance of nutrition may be achieved in this treatment (T_6) which resulted higher dry matter production and in turn higher S uptake at lower level of gypsum application. The sulphur application along with N increased sulphur uptake at higher level of N, this would be attributed to the fact that application of nitrogen caused increased requirement for S and accordingly the uptake of S (Srinidhi, 2000). The application of sulphur in the form of gypsum along with higher level of Zn and B might have also enhanced the higher sulphur uptake. The results are in confirmation with Bahl *et al* (1986), Kadam *et al.* (2000) and Chitdeshwari and Poongothai (2003) who reported that, application of S and multi micronutrients to the groundnut significantly increased the sulphur uptake.

5.5.5 Zinc (g/ha)

The Zn uptake was significantly increased with increase in its application from 5 kg ha^{-1} to 7.5 kg ha^{-1} and a highest Zn uptake was recorded in treatment T_6 (Fig. 20). The increase in uptake of zinc was also due to chelation with vermicompost which might have enhanced the supply of zinc to the entire growth period of the crop. Further increase in Zn level up to 10 kg Zn/ha did not significantly increase its uptake. This shows that significant increase in zinc uptake at T_6 was mainly due to increase in Zn and higher dry matter production as a result of application of higher level of N and P. The increased zinc uptake can also be attributed to the sulphur and zinc application at higher level. Singh *et al*. (2004), De and Chatterjee (1976) also indicated that Zn application increased appreciably Zn content in kernels.

5.5.6 Boron (g/ha)

Boron uptake was more in the treatments which received application of B than no B treatments. The boron uptake followed the same trend as that of zinc with higher uptake in T_6 (Fig. 21). The maximum uptake in treatments T_6 was due higher dry matter production and higher B concentration in haulm and pod. The results are in agreement with Chaube *et al.* (2002) who reported that B and Mo application increased nutrients uptake, high nodulation and nitrogenase activity and gave higher pod and oil yields.

Luo *et al.* (1993) demonstrated that, the average B content of B fertilized plants at four different stages (seedling, flowering, pod setting and harvesting) was higher than that of the control. Revathy *et al.* (1997) and Tripathy *et al.* (1999b) observed that, foliar spray and soil application of chelated mixtures of micronutrients increased the respective micronutrient concentrations in seeds of groundnut besides their nutrient uptake in groundnut (cv. JL-24 and TGS 1).

5.6 Effect of soil test based nutrients application on available N, P, K, S, Zn and B in soil after harvest of groundnut

5.6.1 Nitrogen

The available nitrogen content at harvest was more than the initial status in all treatments. Treatment T_9 recorded the highest available N of 230.27 kg ha^{-1} and treatment T_2 recorded the lowest available N of 223.27 kg ha^{-1}. The increase in available N compared to that at the start of the experiment was due to application of recommended dose of N and higher level of N.

5.6.2 Phosphorus

At harvest stage, the available phosphorus content in soil increased from its initial status in all the treatments except T_2 which accounted for a slightly lower P-content than initial status. The available phosphorus content varied form 20.95 kg ha^{-1} in T_2 to 26.89 kg ha^{-1} in T_9. Application of higher doses of phosphate fertilizers along with micronutrients resulted in an increase in available phosphorus in the soil.

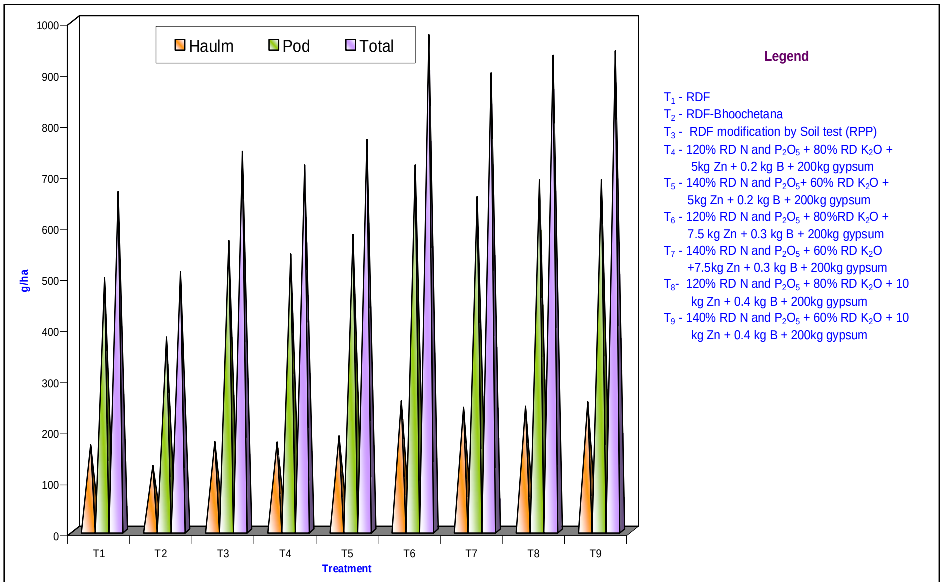


Fig. 20: Zinc uptake by groundnut halum, pod and total at harvest

Fig. 20: Zinc uptake by groundnut halum, pod and total at harvest

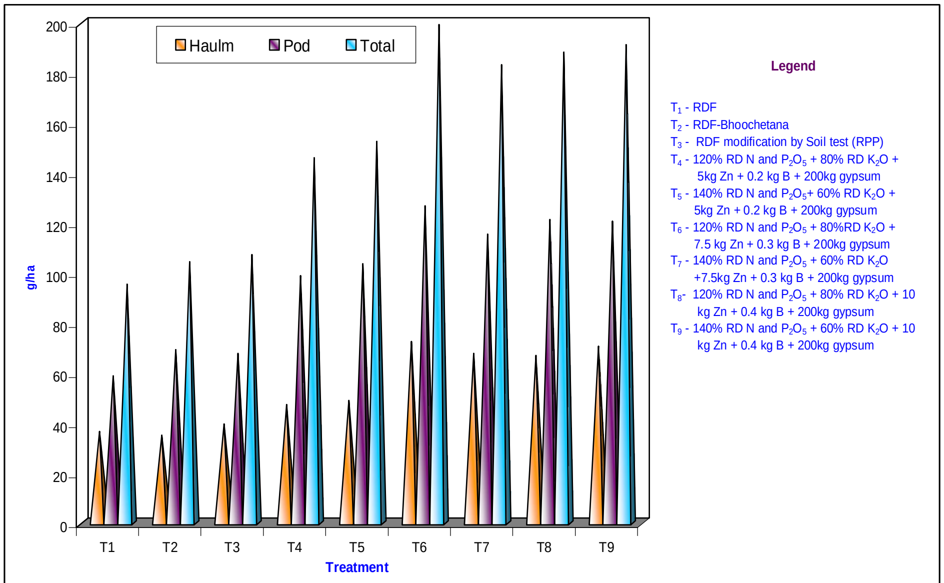


Fig. 21: Boron uptake by groundnut haulm, pod and total at harvest

Fig. 21: Boron uptake by groundnut haulm, pod and total at harvest

5.6.3 Potassium

At harvest stage the available potassium content in soil increased from its initial status in all the treatments. The experimental site was high in available potassium, hence there was not much response to the applied K by crop. The available K content varied from 387 kg ha^{-1} (T_3) to 382.33 kg ha^{-1} (T_9). The increase in available K was due to the application potassium fertilizer which is not a practice by the farmers in the study area.

5.6.4 Sulphur

The available sulphur was increased in all treatments. It ranged from 8.13 mg kg^{-1} (T_6) to 10.40 mg kg^{-1} (T_3). The higher concentration of sulphur in treatment T_3 was due to higher application of gypsum and low dry matter production. Similarly lower, sulphur in treatment T_6 was due to higher dry matter production and lower gypsum application.

5.6.5 Zinc

The available Zn content in soil varied from 0.99 mg kg^{-1} (T_9) to 0.55 mg kg^{-1} (T_2). At harvest stage, the available zinc content in soil increased from its initial status in all the treatments. It was found that increase in the Zn concentration in treatments due to higher application rate. Zinc removal was more in T_6 due to higher dry matter production and resulted in comparatively low residual Zn status.

5.6.6 Boron

The available boron content increased from the initial status due to application of B except in T_1 and $T_{3.}$ The Available boron ranged from 0.79 mg kg^{-1} (T_9) to 0.31 (T_1). This decrease in the available boron was due to higher dry matter production and uptake. The higher level of residual available B was due to higher rate of application of B.

The present experiment was conducted in the farmer's field and farmers usually do not apply recommended dose of fertilizer and micronutrients to the crops as a result, the initial fertility status except K was low. Hence, the increase in available nutrients compared to at the start of the experiment was high due to application of RDF and higher level of nutrients. The increase in available K after the harvest of the crop was due to the application of potassium fertilizer which is not a practice by the farmers in the study area.

5.7 Economic analysis

The cost benefit analysis of groundnut cultivation showed that the treatment T_6 i.e. 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum per ha recorded the highest benefit cost ratio (3.83). This was because, T_6 recorded maximum gross and net returns due to higher pod yield and haulm yield due to application of vermicompost chelated zinc and boron along with higher dose of nitrogen and phosphorus. Since the experiment was conducted in the farmers' field, the treatment T_6 can be considered for higher yields. Further, the proposed treatment may be test on large scale trials under multi-locations before recommendation.

Results of Practical utility

1. Mapping of nutrients by GIS techniques revealed that soils of major portion of the study area were deficient in available N, P, S, Zn and B indicating the need for soil test based application of nutrients for the crop to avoid nutrient mining from soil.

2. The higher yield of GPBD-4 and benefit cost ratio (3.83) can be achieved with the application of 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg gypsum kg per ha in nutrients deficient areas of farmer's field.

Future line of work

Response of groundnut and other crops at different levels of RDF modification based on soil test may be studied separately at different soil fertility status (low, medium, high) in the present micro-watershed as well as in the other micro-watersheds of similar soil properties.

6. SUMMARY AND CONCLUSIONS

A survey was undertaken in Kotur micro-watershed in Dharwad district, Northern transition zone of Karnataka with an objective of identifying soil fertility constraints of a by GIS technique and to study the response of groundnut to identified soil fertility constraints.

Surface soil samples at 10" (second) grid interval were collected from the study area for the assessment of soil fertility constraints. The sampling location was recorded by using GPS. After processing, the samples were analyzed for pH, EC, OC, N, P, K, S, Ca, Mg, Zn, Fe, Cu, Mn and B. Soil fertility maps were prepared for each of the nutrients by GIS technique using Arc GIS 10.0 software.

Available nitrogen content of the entire micro-watershed was low (870.6 ha) which ranged from 62 to 264 kg ha^{-1}. Available phosphorous in the soil ranged from 1.0 to 56.0 kg ha^{-1} with 355.3 ha in low and 513.3 ha in medium category available phosphorus. The lowest value of available potassium recorded was 200 kg ha^{-1} and the highest 520 kg ha^{-1}. Available K_2O was medium in 191.4 ha area and high in 679.2 ha. Available sulphur ranged from 4.9 to 19.6 mg kg^{-1} with 669.0 ha low and 201.6 ha medium category. Available zinc content in soil ranged from 0.32 mg kg^{-1} to 1.41 mg kg^{-1}. Zinc was deficient in 454.3 ha and sufficient 416.3 ha. Available iron content in soil ranged from 0.9 mg kg^{-1} to 28.9 mg kg^{-1}. In the study area iron was deficient in 242.6 ha, while 628.0 ha area was sufficient in iron. The entire watershed was found to be sufficient in available copper and manganese. Available boron content in the micro-watershed ranged from 0.12 mg kg^{-1} to 1.19 mg kg^{-1} with 501.5 ha deficient in boron, while 369.1 ha area sufficient in boron.

Mapping of nutrients by GIS techniques revealed that major portion of the study area was deficient in available N, P, S, Zn and B.

After identifying fertility constraints, a field experiment was conducted during the *kharif* season of 2011 in the farmer's field at Kotur village of Dharwad district. Various treatments imposed were RDF, Soil test based RDF (RPP), Soil Test Nutrient Application 120% RD N and P_2O_5 + 80% RD K_2O and 40% RD140% RD N and P_2O_5 + 60% RD K_2O increase in N and P_2O_5 with Zinc and B in different combinations.

Groundnut variety GPBD-4 was used as the test crop. The experiment was laid out in Randomized Block Design with nine treatments and three replications. The soil of the experimental site was clay in texture. Observations on growth, yield and yield components were recorded at harvest of the crop. Based on the results following conclusions were drawn

- Application of 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg Gypsum (T_6) recorded the highest plant height, number of branches at all the growth stages. The lowest was recorded in the treatment receiving Bhoochetana STNA (T_2) recommendation.
- The dry matter production increased in all the treatments from early stage to harvest. Highest dry matter was recorded in the treatment which received 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg Gypsum (T_6).
- The yield components *viz.*, number of pods per plant, pod weight per plant, shelling percentage and test weight were highest with the application of 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg Gypsum (T_6).
- Application of 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg Gypsum (T_6) recorded significantly higher total uptake of N, P, K, S, Zn and B by groundnut at harvest. The lowest uptake of nutrients was recorded in the RDF-Bhoochetana (T_2).
- Available N, P, Zn and B in post harvest soil were higher in the treatment T_9 (140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum). Available K and S were highest in the treatment receiving RDF modification by Soil test (RPP).

REFERENCES

Agasimani, C.A., Babalad, H.B. and Patil, P.L.,1993, Response of groundnut to sulphur and boron. *J. Maharastra Agric. Univ.*, 18: 318-319.

Alur, A. S., 1994, Properties of red soils of Agro-climate zone-3 (Region-II) of North Karnataka. *Karnataka J. Agric. Sci.,* 6 (1): 120-123.

Ananthanarayana, R., Reddy, M.N., Mithyantha, M.S. and Perur, N.G., 1986, Status of available secondary nutrients in acid soils of Karnataka. *J. Indian Soc. Soil Sci.,* 34: 614-616.

Angadi, V. V., Patil, S. V., Sheelavanthar, M. N. and Chittapur, B. M., 1990, Effect of NPK levels and split application of N on growth and yield of bunch groundnut in vertisol under irrigation. *Karnataka J. Agric. Sci.,* 3 (1&2): 9-14.

Anonymous, 1989, Studies of available phosphorus and forms of phosphorus in Himalayan Region.

Asha, L., Mehta, D.D., Malania. B.B., Kaneria and Khanpara, 1996, Response of groundnut to farm yard manure, phosphorus and phosphate solubilizing micro-organism, *Indian J. Agron.*, 41 (1): 172-174.

Ashok Kumar, S., 2000, Studies on soil aggregation in Vertisols of North Karnataka. *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Dharwad (India).

Ashok, K. B., 2001, Sulphur status of selected soil series of Karnataka and studies on direct and residual effect of graded level of sulphur on crop. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Ashoka, K., 1998, Studies on the properties of an alfisol under selected forest plantations. *M. Sc. (Agri.) Thesis*, Unvi. Agric. Sci., Bangalore (India).

Asokan, S. and Raj, D., 1974, Effect of forms and levels of boron application on groundnut. *Madras Agric. J.*, 61:467-471.

Aulakh, M. S., Sidhu, B. S., Arora, B. R. and Singh, B., 1985, Content and uptake of nutrients by pulses and oilseeds crops. *Indian J. Eco.,* 12 (2): 238-242.

Badole S. B., More S. N., Adsul P. B., Shaikh A. K. and Dhamak A. L., 2003, Residual effect of integrated nutrient management system of cotton on yield and nutrient uptake of summer groundnut. *J. Soils and Crops*, 13 (1): 77-80.

Badrinath, M. S., Krishnappa, A. M., Sridharherle, P., Patil, B. N., Balakrishna Rao, K. and Janardhana Gowda, N. A., 1987, Distribution of available micronutrients in saline soils of Ankola (Uttar Kannada, Coastal Karnataka, India. *Current Res.*, 26: 24-26.

Bahl, G. S., Baddesha, H. S., Pasricha, N. S. and Aulakh. M.S., 1986, Sulphur and zinc nutrition of groundnut grown on total loamy sand soil. *Indian J. Agric. Sci.*, 56 (6): 429-433.

Balanagoudar, A. B., 1989, Investigation on status and forms of sulphur in soils of North Karnataka. *M. Sc. (Agri.) Thesis,* Univ. Agric. Sci., Dharwad, Karnataka (India).

Balasubramaniyan, P., 1997, Integrated nutrient management in irrigated groundnut (*Arachis hypogaea*). *Indian J. Agron.,* 42 (4): 683-687.

Bali S. K., Raj-Kumar., Hundal H. S., Singh Kuldeep. and Singh Bhupinder., 2010, GIS-aided mapping of DTPA extractable zinc and soil characteristics in the state of Punjab. *J. Indian Soc. Soil. Sci.,* 58 (2): 189-199.

Barik, A. K. and Mukherjee, 1995, Effect of cropping system and nitrogen on the yield, oil content and nodulation in summer groundnut. *J. Oilseed Res.*, 12 (1): 60-64.

Barik, A., Jana, P.K., Sounda, G. and Mukhejee, 1994, Influence of nitrogen, phosphorus and potassium fertilization on growth, yield and oil content of kharif groundnut, *Indian Agriculturist,* 38 (27): 105-111.

Basavaraju, D., Naidu, M.V.S., Ramavatharam, N., Venkaiah, K., Rama Rao, G. and Reddy, K.S., 2005, Characterization, classification and evaluation of soils in Chandragiri mandal of Chittoor district andhra Pradesh. *Agropedology*, 15: 55–62.

Bell, R. W., Rerkasem, B., Keeratikasikorn, P., Pherchawee, S., Hirenburana, N., Ratanarat, S. and Pongsakul, P., 1990, Mineral nutrition of food legumes in Thailand with particular reference to micronutrients. *ACIAR –Technical reports series,* No. 16, 52pp; 5pp of ref.

Bhadrapur, T. G. and Seshagiri Rao, T., 1979, The effect of seepage and water logging on the development of saline and sodic soils in Tungabhadra Project Area of Karnataka. *J. Indian Soc. Soil Sci.,* 27: 408-413.

Bhalerao, P.D., Jadhao, F.N. and Fuilzele, 1993, Response of promising groundnut (*Arachis hypogaea* L.) genotypes to fertilizer levels during summer. *Indian J. Agron.,* 38: 505-507.

Bhuiyan, M. A. H., Rahman , M. H. H., Khanam, D. and Khatum, M. R., 1997, Effect of micronutrients (OM and B) and Rhizobial inoculums on nodulation and yield of groundnut. *Legume Res.*, 20: 3-4, 155-159.

Binita, N.K., Dasog, G.S. and Patil, P.L., 2009, soil fertility mapping in Ghatprabha left bank canal command area of north Karnataka by geographic information system technique. *Karnataka J. Agric. Sci.,* 22 (1): 73-76.

Black, C.A., 1965, Methods of Soil Analysis Part – II. Chemical and microbiological Properties. Agronomy Monograph No. 9. American Society of Agronomy, Inc. Madison, Wisconsin, USA, pp. 18-25.

Bopathi, H. K. and Sharma, K. N., 2006, Phosphorus adsorption and desorption characteristics of some soils as affected by clay and available phosphorus content. *J. Indian Soc. Soil Sci.,* 54 (1): 111-114.

Channabaasvanna, A. S. and Setty, R. A., 1993, Effect of nitrogen, ferrous sulphate and zinc sulphate on groundnut yield in deep black soils. *Indian J. Agron.,* 38 (2): 329-330.

Chaube, A.K., Srivastava, P.C., Singh, S.K. and Gangawar, M.S., 2002, Efficacy of different methods of zinc application in groundnut. *J. Oilseeds Res*., 19 (2): 237-238.

Chaubey, A. K., Singh, S.B. and Kaushik, M. K., 2000, Response of groundnut (A *.hypogaea L.*) to source and level of sulphur fertilization in mid-western plains of Uttar Pradesh. *Indian J. Agron.,* 45 (1): 166-169.

Chavan, K. N., Kenjale, R. G. Adn Chavan, A. S., 1995, Effect of forest tree species on properties of lateritc soil. *J. Indian Soc. Soil Sci.,* 43 (1): 43-46.

Chitdeshwari, T. and Poongothai, S., 2003, Yield of groundnut and its nutrient uptake by zinc, boron and sulphur. *Agric. Sci. Dig.*, 23 (4): 263-263.

Chitkala devi, T., Ramakrishna Reddy, M. G., Rami Reddy, S., Subramaniyam, M. V. R. and Ravi kumar, A., 1987, Effect of time of application of nitrogen, phosphorus and gypsum on groundnut. *J. Oilseed Res*., 4 (1): 118-121.

Choudhery, T.S.D., Vaidya, C.S. and Sekhar, A.C., 1991, Effect of graded doses of phosphorus and sulphur on the growth, yield and oil content of groundnut. *J. Maharashtra Agric. Univ*., 16 (1): 133-134.

Chouhan, Y.S., Jain, V. K., Khandekar, M. P. and Jain, P.C., 1987, Response of groundnut varieties to phosphorus fertilization. *Madras Agric. J*., 74 (6-7): 261-264.

Christopher lourduraj, A., Krishnan, P. K. and Geethalakshmi, V., 1997, Micronutrient fertilization in groundnut. *Madras Agric. J*., 84 (7): 362-363.

Das, K. P. and Ali, M.H., 1993, Studies on the response of some micronutrients on growth and yield of groundnut (*Arachis hypogaea L.*). Proc. Workshop on micronutrients, 22-23 January Bhabaneswar, India, pp. 295-296.

Dasharath Singh, Mannikar, N. D. and Srivas, N. C., 1979, Effect of Silvi-pasture systems on change in soil fertility. *J. Indian Soc. Soil Sci.,* 27 (4): 486-488.

De, N. K. and Chatterjee, B. N., 1976, Effect of trace elements on the growth and yield of groundnut in leached sandy loam soil. *Indian J. Agron*., 21 (3): 209-216.

Deka, N. C., Gogoi, P. K., Pinku Barman and Dutta, R., 2001, Effect of levels of lime and phosphorus on nutrient content and uptake of groundnut. *Annals of Agric. Res.,* 22 (4): 503-507.

Deshmuk, V.N. and Atre, A.H., 1993, Effect of phosphorus and potassium application on growth and quality and nutrient uptake by groundnut, *J. Potassium Res.,* 9 (1): 72-75.

Devarajan, L. and Kothanandaraman, G.N., 1982, Studies on the effect of phosphorus and potassium on the yield and shelling percentage of groundnut*, Madras Agric. J.,* 69 (1): 17-22.

Dhananjaya, B. N., 2000, Physico-chemical properties of soils under different land use systems in central dry zone of Karnataka. *M. Sc. (Agri.) Thesis*, Univ. Agril. Sci., Bangalore.

Dilip Singh AND Singh, S. M., 2000, Response of summer groundnut (*Arachis hypogaea*) and succeeding maize (Zea mays) to sulphur and phosphorus fertilization. *Indian J. Agric. Sci.,* 70 (10): 657-660.

Dimree, S. and Dwivedi, K. N., 1994, Response of sulphur and phosphorus on groundnut. *J. Oilseeds Res.,* 11 (2): 193-195.

Divakar, B. L., Bhagat, K. N., Tewari, J. C. and Mehta, N. S., 1989, Soil fertility status of horticultural areas in Nainital district of Uttar Pradesh hills. *Progressive Hortic.,* 21 : 95-99.

Dongale, J. H. and Zende, G. K., 1976, Response of groundnut to the application on Mn, B and S both in presence and absence of FYM through soil and foliar spray, *Indian J. Agron*., 21 (4): 321-325.

Gajera, M.S. and Patil, J.C., 1984, Response of summer groundnut to irrigation scheduling based on cumulative irrigation under varying fertility levels*, Indian J. Agron.,* 29 (3): 394-395.

Gayathri A., Vadivel A., Santhi R., Murugesa Bhoopathi P. and Natesan R., 2009. Soil test based fertilizer recommendation under integrated plant nutrition syste1m for potato (*Solanum tuberosum L.)* In hilly tracts of nilgiris districts. *Indian J. Agric Res*., 43 (1): 52-56.

Geetha, K. N., Shanta, A. G. and Shiva Shankar, K., 1996, Effect of molybdenum, zinc and calcium on productivity of groundnut. *J. Oilseeds Res.,* 13 (2): 167-172.

Gnanamurthy, P. and Balasubramaniyan, P., 1992, Influence of phosphorus and potassium on rainfed groundnut (*Arachis hypogaea L.*). *Indian J. Agron..,* 37 (4): 755-757.

Gomez, K. A. and Gomez, A. A., 1984, *Statistical Procedures for Agricultural Research,* Second Edition, John Wiley and Sons, New York, p. 680.

Gopal Gowda, N., Shivaraj, B. and Andani Gowda, 1994, Effect of zinc and molybdenum application on yield and uptake of zinc by groundnut. *J. Res. APAU*., 22 (1&2): 40-42.

Gopal Gowda, N., Shivaraj, B. and Andani Gowda, 1995, Effect of zinc and molybdenum on the yield and quality of groundnut. *J. Oilseeds Res.,* 12 (1): 133-136.

Gupta, U. C., 1967, A simplified method for determining hot-water soluble boron in podzol soils. *Soil Sci.,* 103: 424-428.

Gupta, V. K. and Potalia, B. S., 1987, Effect of molybdenum and zinc on yield, Mo and Zn concentration in peanut. *J. Indian Soc. Soil Sci.*, 35: 82-84.

Gurumurthy, P., Seshagiri Rao, M., Bhanu Prasad, V., Pillai, R.N. and Lakshmi, G.V., 1996, Characterization of red, black and associated soils of Giddalur mandal of Andhra Pradesh. *The Andhra Agric. J.,* 43: 123-127.

Halepyati, A. S., 2001, Effect of moisture regimes and zinc levels on the growth and yield of summer groundnut. *Karnataka J. Agric. Sci.*, 14 (2): 451-453.

Hegde, D. M. and Babu, S. N. S., 2004, Balanced fertilization for nutritional quality in oil seeds. *Fertilizer News,* 49 (4): 57-62, 65-66, 93.

Hirekurabar, P. M., Satyanarayana, T., Sarangmati, P. A. and Manjunatham, H. M., 2000, Forms of potassium and their distribution in soils under cotton - based cropping system in Karnataka. *J. Indian Soc. Soil Sci.*, 48: 604-608.

http:// eands.nic.in.

Jackson, M.L., 1967, Soil Chemical Analysis, Prentice Hall of India, Pvt. Ltd., New Delhi.

Jakhro, A.A., 1984, Growth, nodulation and yield of groundnut as affected by nitrogen rates, *Planter*, 60: 149-153.

Janakiraman, N., Venkataravana, P., Seenappa, C., 2004, Effect of micronutrients on growth and yield of groundnut (*Arachis hypogaea L.*). *Environment* and *Ecology*, 22 (spl. 4), 666: 668.

Joffee and Levine, A. K., 1939, Relation of potassium fixation to the exchangeable capacity of the soil. *Proceed. Soil Sci. Soc. America*, 4: 157- 161.

Joshi, S.S., Thorve, P.V. and Nagre, K.T., 1989, Effect of rhizobium and nitrogen on yield and quality of groundnut and soyabean. *PKV Res. J.,* 22 (2): 152-155.

Kadam, U. A., Pawar, V. S. and Pardeshi, H. P., 2000, Influence of planting layouts, organic manure and levels of sulphur on growth and yield of summer groundnut. *J. Maharashtra Agric. Univ.,* 25 (2): 211-213.

Kathmale, D. K., Kamble, M. S., Jadhav, J. D. and Patil, R. C., 2000, Effect of nutrient management on productivity and economics of sorghum- groundnut cropping system. *J. Maharashtra Agric. Univ.*, 25 (1); 50-51.

Katyal, J. C. and Sharma, B. D., 1991, DTPA extractable and total Zn, Cu, Mn and Fe in Indian soils and their association with some soil properties. *Geoderma*, 49: 165-179.

Kaushik, M.K. and Jain, G.L., 1991, Effect of growth regulators, soil conditioner and phosphorus on production and nutrient uptake of summer groundnut. *Indian J. Agron.,* 36 (3): 405-407.

Khan, S., Zada, K.S., Wadan, D., Gul, F. and Khans, 1993, Growth and yield potential of groundnut in relation to phosphorus rates and frequency of irrigation. *Sarhed J. Agric.,* 9 (6): 599-603.

Khanda, C. and Dixit, L., 1995, Effect of zinc and nitrogen fertilization on summer rice (*Oryza sativa*). *Indian J. Agron.*, 40 (4): 695-697.

Krishna Murthy, R. and Srinivasa Murthy, C. A., 2005, Distribution of some available micronutrients in black and red soils of Karnataka. *The Mysore J. Agric. Sci.,* 31: 578-63.

Krishnamurthy, K. G., 1993, Properties genesis and classification of red soil of North Karnataka. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad, Karnataka (India).

Krishnappa, M., Srinivasan, C. N., Baskar, P. W. and Sastry, J. A., 1992, Effect of iron, zinc and molybdenum on protein content of groundnut varieties. *J. Maharashtra Agric. Univ.*, 17 (2); 232-235.

Kuligod, V.B., Revanappa., Kulkarni, G.N. and Upperi, S.N., 2007, Nutrient management for sustainable groundnut productivity in Black soils of Upper Krishna Canal Commands. *Karnataka J.Agric.Sci*., 20 (4): 732-734.

Kulkarni, J. H., Joshi, P. K. and Sojitra, V. K., 1986, Influence of phosphorus and potassium application on pod yield of groundnut. *Legume Res*., 9 (1): 34-38.

Kulkarni, J. H., Sojitra, V. K. and Bhat, D. M., 1989a, Effect of micronutrient application on nodulation and pod yield of groundnut (*Arachis hypogaea L*.). *Legume Res.,* 12: 49-50.

Kulkarni, J. H., Sojitra, V. K. and Bhat, D. M., 1989b, Effect of micronutrient application on nodulation and pod yield of groundnut (*Arachis hypogaea L*.). *Legume Res.,* 12 (1): 49-51.

Kumaran, S., 2000, Role of organic manure, fertilizer levels, split application of phosphorus and gypsum application on shelling percentage, harvest index, pod and oil yield of irrigated groundnut. *Res. on Crops,* 1 (3): 344-347.

Lakshmamma, P. and Raj, A.S., 1997, Effect of cobalt, phosphorus and potassium on groundnut (*Arachis hypogaea L*.). *Legume Res*., 20: 3-4, 160-164.

Latha, M. R., Savithri, P., Inditani, R. and Kamaraj. S., 2002, Residual effect of zinc enriched organic manures on availability of micronutrients in maize- sunflower cropping system. *Madras Agric. J*., 89 (1-3): 120-121.

Lindsay, W. L. and Norvell, W. A., 1978, Development of DTPA test zinc, iron, manganese and copper. *Soil Sci. Soc. American J*., 42: 421-428.

Loganathan, S. and Krishnamurthy, K. K., 1977a, Effect of calcium application on the uptake of nutrients by groundnut kernel and shell. *Madras Agric. J*., 64: 653-658.

Lourduraj, A.C., Meyyazhagan, N. and Prabakaran, N. K., 1998a, Effect of balanced fertilization and biozyme spray on groundnut. *Legume Res.,* 21 (1); 48-50.

Lourduraj, A.C., Sanbagavalli, S. and Panneersalvam, S., 1998b, Integrated nutrient management in groundnut. *Agric. Sci. Dig*., 18 (4); 252-254.

Luo, X. Y., Veng, Y.C. and Wang, B.Y., 1993, Effect of boron fertilizer on yield and quality of groundnut. *Seed Abstract*. 16 (5): 20.

Madhumitadas, Singh B. P. and Khan, S. K., 1997, Effect of major land use on soil characteristics of Alfisols in Meghalaya. *J. Indian Soc. Soil Sci.,* 45 (3): 547-553.

Mahakulkar, B. V., Bathkal, B.G. and Wanjari, S. S., 1992, Growth rate studies in summer groundnut as influenced by nitrogen and phosphate levels. *Crop Res.,* 5 (1): 1-9.

Mahale, S. S., Singh, O. P. and Sawani, C. V., 1991, Effect of different levels of nitrogen and phosphorus on different varieties of groundnut, *J. Maharashtra Agric. Univ*., 16 (1): 137-138.

Mahalingam, P.K. and Durairaj, D.J., 1968, Nutrient status and cation exchange capacity of high level Nilgeri soil. *Madras Agric. J.* 55 (5): 216-222.

Maji, B. and Bandyopadhyay, B. K., 1995, Characterization and classification of coastal soils of various pH groups in Sundarbans of West Bengal. *J. Indian Soc. Soil Sci*., 43: 103-107.

Manojkumar. D, 2011, Characterization and classification of soils of a microwatershed on basalt parent rock in northern transition zone of karnataka. *M. Sc (Agri) Thesis*, Univ. Agric. Sci., Dharwad (India).

Mathews D., Patil. P.L. and Dasog, G.S., 2009, Identification of soil fertility constraints of a pilot site in coastal agro ecosystem of Karnataka by geographic information system technique. *Karnataka J. Agric. Sci.,* 22 (1): 77-80.

Mini, V., Patil, P.L. and Dasog G.S., 2004, Mapping of Nutrient status in a pilot site of coastal Agro-Eco-system of Karnataka. Paper presented during 24th Indian Society of Remote Sensing Annual Convention and National Symposium on "Converging Space Technologies for National Development to be held at BM Birla Science and Technology Centre, Jaipur from November 3-5, 2004.

Mishra, C. M. and Vyas, M. D., 1992, Response of fertilizer application on groundnut in west nimar region of Madhya Pradesh, *Bharatiya Krishi Anus*and*han Patrika*, 7 (4): 251-254.

Mishra, C. M., 1994, Effect of fertilizer application on groundnut. *Madras Agric. J.,* 81 (9): 473-475.

Mishra, C. M., 1996, Response of sulphur on yield of groundnut under dryland conditions. *Madras Agric. J.,* 83 (7): 470-471.

Mohapatra, A.K.B. and Dixit, L., 2010, Integrated nutrient management in rainy season groundnut. *Indian J. Agron*., 55 (2): 123-127.

Mousa, B. I. M., Dahdoh, M. S. A. and Shehata, H. M., 1996. Interaction effects of some micronutrients on yield elemental composition and oil content of peanut. *Communication in Soil Sci.* and *plant analysis,* 27 (5-8): 1995- 2004.

Mruthunjaya, S. and Kenchanagowda, S. K., 1993, Physico-chemical properties of some salt affected soils of Vani Vilas Command Area of Karnataka. *Mysore J. Agric. Sci.,* 27: 349-355.

Nayak, R. K., Sahu, G. C. and Nanda, S. S. K., 2002, Characterization and classification of the soils of Central Research Station, Bhubaneswar. *Agropedology*, 12: 1-8.

Newase, V. B., Wagh, R. L., Thorat, S. T. and Patil, B. P., 1990, Production potential and economics of promising groundnut genotypes under varying levels of phosphorus in Konakan, *J. Indian Soc. Coastal Agric. Res.*, 8 (3): 31-35.

Nimje, P. N., 1992, Effect of land treatment system and phosphorus fertilization on groundnut in vertisols. *J. Oilseeds Res.*, 9 (2): 227-233.

Noor, S., Hannan, M. A. and Islam, M. S., 1997, Effect of molybdenum and boron on the growth and yield of groundnut. *Indian J. Agric. Sci*., 31 (1): 51-58.

Patel B.T, Patel J. J. and Patel M. M., 2007. Response of groundnut (*Arachis hypogaea*) to FYM, sulphur and micro nutrients and their residual effect on wheat (*Triticum aestivum*). *J. Soils and Crops*., 17 (1): 18-23.

Patel, A. L., Patel, R. B. and Patel, J. C., 1983, Response of groundnut varieties to sowing dates and levels of NPK, *Indian J. Agron*., 28 (3) :37-38.

Patil, P.L., Radder, B.M., Patil, S.G., Aladakatti, Y.R., Meti C.B. and Khot, A.B., 2006, Response of maize to micronutrients and moisture regimes in vertisols of Malaprabha Command, Karnataka. *J. Indian Soc. Soil Sci.,* 54 (3): 261-264.

Patra, A. K., Samui, R. C., Tripathy, S. K., Moha, S. C. and Nanda, M. K., 1994, Physiological basis of yield variation in kharif groundnut as influenced by variety and planting method, *Indian Agriculturist*, 38 (14) : 233-238.

Patra, A. K., Tripathy, S. K. and Samui, R. C., 1995, Response of summer groundnut to potassium with varying levels of nitrogen, *J. Oilseed Res*., 12 (1): 83-86.

Piper, C. S., 2002, Soil and Plant Analysis, *Hans Publishers*, Bombay, India.

Powar, S. L. and Patil, V. S., 1995, Characterization of the coastal coconut growing soils of the Konkan in relation to soil fertility. *J. Indian Soc. Coastal Agric. Res*., 13 (1): 11-17.

Powar, S.L. and Mehta, V.B., 1999, Characterization of soils of the Konkan coast. *J. Indian Soc. Soil Sci*., 47 (2): 334-337.

Prabakaran, J. and Ravi, K. B., 1996, Response of soybean to Rhizobium and organic amendments in acid soils. *Madras Agric. J.*, 83 (2): 132-133.

Prabakaran, N. K., Christopher Lourduraj, A., Madhiyazhagan, R., Venkatasamy, R. and Sridharan, C. S., 1998, Fertilizer management in Rabi / summer groundnut. *Madras Agric. J.,* 85 (10-12): 685-686.

Prasad, S. N. and Sahi, B. P., 1989, Distribution of manganese in relation to soil properties in some typical soil profiles. *J. Indian Soc. Soil Sci.,* 37 (3): 567-570.

Pulakeshi. P.H.B, 2010, Characterization and classification of soil resources of a Mantagani village of Haveri district. *M. Sc (Agri) Thesis*, Univ. Agric. Sci., Dharwad (India).

Purushotham, S., Sadashivaiah, T., 1994, Response of groundnut to NPK combinations in Kolar district, *Current Res. Univ. Agric. Sci.,* 22 (9- 10): 116-118.

Raghupathi, H. B., 1989, Investigation on soil copper and crop response in selected soils of Karnataka. *M. Sc. (Agri.) Thesis*, Univ. Agric. Sci., Dharwad (India).

Rajaramannan, A., Ramaswami, P.P. and Krishnamoorthy, K.K., 1979, Organic matter level and some related characteristics of latertic soils under plantations. *J. Indian Soc. Soil Sci.*, 27 (4): 399-401.

Ram, G., Joshi, B.S. and Choudhary, K.K., 1993, Beneficial effect of Rhizobium, zinc sulphate and Gypsum on summer groundnut. *Advanced Plant Sci.*, 6 (1): 49-53.

Ramamoorthy, B. and Bajaj, J.C., 1969, Available N, P and K status of Indian soils. *Fertilizer News*, 14; 25-36.

Ramamurthy, K. and Sudarsan, S., 1992, Supply of zinc and boron on yield and seed quality in groundnut (*Arachis hypogaea L.*). *Annuals of Plant Physi.*, 6 (1): 33-38.

Ramani, V.P., Patel, K.P., George, V., Patel, K.C. and Rathod, D.D., 2007, Evaluation of different methods of micronutrient application in groundnut. *J. Oilseeds Res.*, 24 (1): 81-83.

Rao, V. P. and Gangakishan, A., 1993, Response of rainfed groundnut to nitrogen application. *J. Maharashtra Agric. Univ.*, 18: 460-461.

Ravikumar, M.A., Patil, P.L. and Dasog, G.S., 2007, Mapping of Nutrients Status of 48A Distributary of Malaprabha Right Bank Command of Karnataka by GIS Technique. I-Major Nutrients". *Karnataka J. Agric. Sci.,* 20 (4): 735-737.

Ravikumar, M.A., Patil, P.L. and Dasog, G.S., 2007, Mapping of Nutrients Status of 48A Distributary of Malaprabha Right Bank Command of Karnataka by GIS Technique. II-Micro Nutrients". *Karnataka J. Agric. Sci.,* 20 (4): 738-740.

Revathy, M., Jriahnasamy, R. and Chitdeshwari, T., 1997, Chelated micronutrients on the yield and nutrient uptake by groundnut. *Madras Agric. J.,* 84 (11-12): 659-662.

Roshanlal and Gangasaran, 1988, Influence of nitrogen and phosphorus on yield and quality of groundnut under irrigated conditions, *Indian J. Agron.*, 33 (4): 460-461.

Sahu, G. C., Patnaik, S. N. and Das, P. K., 1990, Morphology, genesis, mineralogy and classification of soils of Northern plateau Zone of Orissa. *J. Indian Soc. Soil Sci.*, 38: 116.

Sahu, G.C. and Mishra, K.N. 1997, Morphology, Characteristics and Classification of soils of an irrigated river flood plain in the eastern coastal region. *J. Indian Soc. Soil Sci.,* 45 (1): 152-156.

Sahu, S.K., Dhal, J.K., Das, B.B. and Das, P.K., 1995, Response of groundnut to boron with and without molybdenum and time in lateritic soils in Orissa, India. *Int. Arachis News Letter,* 15: 79-80.

Sammireddy, K., Sriramamurthy, V. M. and Shantaram, M. V., 1992, Nitrogen, phosphorus and sulphur nutrition of groundnut grown in alfisols. *J. Oilseeds Res.,* 9 (2): 189-195.

Saren, B.K. and Sarkar, K. 2007, Response of groundnut under different levels of irrigation and zinc. *J. oilseeds Res.*, 24(1): 94-95.

Sarkar, A. and Gangwar, B., 1999, Synthetic cropping systems for Indian coastal system. *J. Indian Soc. Coastal Agric. Res.*, 17 (1&2): 117-120.

Sarkar, R.K., Chkaraborty, A. and Bala, B., 1998, Analysis of growth and productivity of groundnut (*Arachis hypogaea* L.) in relation to micronutrients application. *Indian J. Plant Phys.,* 3 (3): 234-236.

Sathone, K.M. and Babulkar, P. S., 1991, Response of summer groundnut to phosphate fertilization in vertisol. *J. Maharashtra Agric. Univ.,* 16 (1): 113-114.

Satyavathi, P. L. A. and Suryanarayana Reddy, M., 2004, Distribution of DTPA extractable micronutrients in soils of Telangana andhra Pradesh. *Agropedology*, 14 (1): 32-37.

Satyavathi, P.L.A. and Suryanarayan Reddy, M., 2004, Soil site suitability for six major crops in Telangana region of Andhra Pradesh. *J. Indian Soc. Soil Sci.,* 52 (3): 220-225.

Shahjahan, M., Allam, M. and Shahida, 1989, Response of variable dose of nitrogen, phosphorus, potash and zinc on the growth, yield and quality of groundnut. Proceedings of the 4th annual Bangladesh Science conference section I, Dhaka BAAS, 1989, p.67.

Sharawat, K.L. and Burford, J.R., 1982, Modification of alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. *Soil Sci.*, 133: 53-57.

Sharma, P.K., Sood, A., Setia, R.K., Tur, N.S., Mehra, D. and Singh, H., 2008, Mapping of macronutrients in soils of Amritsar district (Punjab) – A GIS approach. *J. Indian Soc. Soil Sci.*, 56 (1): 34-41.

Sharma, Y. K. and Gangwar, G. S., 1997, Distribution of different forms of sulphur and their relationship with some soil properties in Alfisols, Inceptisols and Mollisols of Moradabad district, Uttar Pradesh. *J. Indian Soc. Soil Sci.*, 45: 332-335.

Shelke, D.K., Jadhav, G.S. and Oza, S. R., 1997, Optimization of irrigation and phosphate requirement of post monsoon groundnut under different land layout. *Indian J. Agron.*, 42 (4):618-620.

Shinde, S. H., Kaushik, S. S. and Bhilare, R. L., 2000, Effect of plastic film mulch, levels of fertilizer and foliar sprays on yield and quality of summer groundnut. *J. Maharashtra Agric. Univ.,* 25 (2): 227-229.

Shiva Prasad, C.R., Reddy, R.S., Sehgal, J. and Velayutham, M., 1998, Soils of Karnataka for optimizing land use. NBSS Publications 47, p. 15.

Shiva Prasad, Reddy, R. S., Sehgal, J. and Velyutham, M. M., 1998, Interpretation for soil and land resource management. *Annu. Rep.,* NBSS and LUP, 47: 65-68.

Singh, A. L., Joshi, T.C., Koradia, V.G., Sinha, S.K., (ed). Sane, P. V., (ed): Bhargava, S. C., (ed) and Agarwal, P. K. (ed)., 1990, Effect of micronutrients and sulphur on groundnut (*Arachis hypogaea L.*) in calcareous soils. Proceedings of the International Congress of Plant Physiology New Delhi, India, February, 15-20, 1988: 2: 1236-1240.

Singh, A.L. 2004. Mineral nutrient requirement, their disorders and remedies in groundnut. Groundnut Research In India, National Research Centre for Groundnut, Junagadh, India. pp. 137-159.

Singh, D.P., 2000, Drought management in field crops. *Recent Advan. Agron.*, pp. 253-257.

Singh, K. A. and Ahuja, K. N., 1985, Dry matter accumulation, oil content and nutrient uptake in groundnut as affected by fertilizers and plant density, *Indian J. Agron.,* 30 (1): 40-45.

Singh, K., Pratap Narain, Sharda, U. N. and Juyal, G. P., 1993, Soil characterstics under different land use in Fakot watershed of western Himalayas (up). *Indian J. Soil Conesr.*, 21 (3): 14-24.

Singh, V. K., Paliwal, A. K. and Singh, R. N., 1994, Response of groundnut (*A. hypogaea)* to phosphorus and potassium. *Indian J. Agron.*, 39 (4): 694-695.

Singh., D., Chhonkar, P.K. and Dwivedi, B.S., 2010, Methods of soil, plant and water analysis. Westville publishing house, New Delhi.

Sonawane, B.B., Nawalkar, P.S. and Patil, V.D., 2010, Effect of micronutrients on growth and yield of groundnut. *J. Soils and Crops.,* 20 (2): 269-273.

Sontakey, P.Y., Chore, C.N., Nair, B., Potkile, S.N. and Deotale, R.D., 1999 Response of sulphur and zinc as soil application in groundnut. *J. Soils and Crops.,* 9 (2): 258-261.

Sood, A., Sharma, P.K., Tur, N.S. and Nayak, V.K., 2009, Micronutrient status and spatial variability in soils of Muktsar district of Punjab- A GIS approach. *J. Indian Soc. Soil Sci.,* 57 (3): 300-306.

Sparks, 1996, Methods of Soil Analysis Part – 3: Chemical Methods. *Soil Sci. Soc. America*, USA.

Srikant, K.S., Patil. P.L. and Dasog, G.S. and Gali, S.K., 2008, Mapping of available major nutrients of a microwatershed in northern dry zone of Karnataka. *Karnataka J. Agric. Sci.,* 21 (3): 391-395.

Srinidhi, N., 2000, Studies on sulphur nutrition of onion and garlic in sulphur deficient soil of ghataprbha left bank command area. *M. Sc (Agri) Thesis*, Univ. Agric. Sci., Dharwad (India).

Srinivasan, P.S. and Velu, G., 1982, The effects of different sources and methods of application of zinc on the chlorophyll content, nodulation and yield in groundnut varieties. *Madras Agric. J.,* 85 (6): 384-389.

Subrahmaniyan, K., Kalaiselven, P. and Arulmozhi, N., 2001, Response of confectionary groundnut to micronutrients. *Legume Res.,* 24 (2): 139-140.

Sudarsan, S. and Ramaswamy, P.P., 1993, Micronutrient nutrition in groundnut- blackgram cropping system. *Fert. News,* 38: 2, 51, 53, 55, 57.

Survase, D.N., Dongale, J.H. and Kodrekar, S.B., 1986, Growth, yield, quality and composition of groundnut as influenced by FYM, calcium sulphur and boron in lateritic soil. *J. Maharashtra Agric. Univ*., 11(1): 49-51.

Tandon, H.L.S., 1998, Methods of Analysis of Soils, Plants, Water and Fertilizers. *Fert. Dev. and Consultation Org*., 31: 9-16.

Thangasamy, A., Naidu, M. V. S., Ramavatharam, N. and Raghava Reddy, C., 2005, Characterization, classification and evaluation of soil resources in Sivagiri micro-watershed of Chittoor district in Andhra Pradesh for sustainable land use planning. *J. Indian Soc. Soil Sci*., 53: 11–21.

Thimmegouda, S., 1993, Effect of fertilizer levels on growth and yield of groundnut after kharif rice*, J. Res.* APAU., 21 (42): 36-38.

Thimmegowda, S., 1993, Direct and residual effect of fertilization on yield and uptake of nutrients by groundnut. *J. Indian Soc. Soil Sci.,* 41 (3): 495-497.

Thorave, D.S. and Dhonde, M.B., 2005, Morphological indices and yield Attributes as influenced by integrated nutrient management in summer groundnut. *Ann. Plant Physiol*., 21 (2): 186-188 (2007).

Thorve, P. V., Nagre, K. T. and Joshi, S. S., 1989, Economics of groundnut and soyabean as influenced by nitrogen and rhizobium inoculation. *PKV, Res. J.*, 13 (2): 180-181.

Tiwari, R. B. and Dhakar, L. L., 1997, Productivity and economics of summer groundnut as affected by irrigation, fertilizer and weed control, *Indian J. Agron*., 42 (3) : 490-494.

Tomar, R. A.S., Kushwaha, H. S. and Tomar, S. P. G., 1990, Response of groundnut (*Arachis hypogaea* L.) varieties to phosphorus and zinc under rainfed conditions. *Indian J. Agron*., 35 (4): 391-394.

Tripathi, B. R. and Singh, R. M., 1984, Studies on boron toxicity in gram (*Cicer arietinum*) and groundnut (*Arachis hypogaea*). *Indian J. Agron*., 29 (4): 545-546.

Tripathy, S.K., Patra, A.K. and Sumai, R. C., 1999 a, Effect of micronutrients on nodulation, growth, yield and nutrient uptake groundnut (*Arachis hypogaea L.*). *Indian J. Plant Physi*., 4 (3): 207-209.

Tripathy, S.K., Patra, A.K. and Sumai, R. C., 1999 b, Effect of micronutrients on nodulation, growth, yield and nutrient uptake of summer groundnut (*A. hypogaea*). *Annuals Agric. Res*., 20 (4): 439-442.

Tur N. S., Meenakshi., Sharma P. K., Sood Anil., Setia R. K., Singh Harpinder. and Nayyar V. K., 2008. Mapping of micro nutrient status and multi-macronutrient deficiency in Patiala district using frontier technologies. *J. Soils and Crops.,* 18 (1): 1-6.

Vali, P.M., Reddy, M. N. and Reddy, G. M., 1978, Effect of different levels and methods of fertilizer application on rainfed groundnut. *Mysore J. Agric. Sci*., 12 (3): 408-412.

Vara Prasad Rao, A.P., Naidu, M.V.S., Ramavatharam, N. and Rama Rao, G., 2008, Characterization, classification and evaluation of soils on different landforms in Ramachandrapuram mandal and Chittoor district in Andhra Pradesh and sustainable land use planning. *J. Indian Soc. Soil Sci*., 56 (1): 23-33.

Ved Singh, S., Sharma, B. L., Verma and Siag, R. K., 1994, Effect of irrigation schedules and phosphorus fertilization on yield, water use and phosphorus uptake of groundnut in North- West Rajasthan, *Indian J. Agron*., 39 (1) : 58-61.

Veerabhadrappa, B. H., 2003 Effect of foliar nutrition (N, P K, Ca and S) on growth and yield of groundnut. *M. Sc (Agri) Thesis*, Univ. Agric. Sci., Dharwad (India).

Venkatesh Bharadwaj, Bansal, S. K., Maheshwari, S. C. and Omanwar, P. K., 1994, Long term effect of continuous rotational cropping and fertilization on crop yields and soil properties – III changes in soil fractions of N, P and K of the soil. *J. Indian Soc. Soil Sci.,* 42: 392-397.

Vinay, L., 2007, Characterization and classification of soil resource of Bhanapur microwatershed (Koppal district) for land evaluation. *M. Sc (Agri) Thesis*, Univ. Agric. Sci., Dharwad (India).

Vinod Kumar, Ghosh, B. C., Ravi Bhat and Karmakar, S., 2000, Effect of irrigation and fertilizer on yield, water- use efficiency and nutrient uptake of summer groundnut (A.*hypogaea*). *Indian J. Agron*., 45 (4): 756-760.

Vishwakarma, A.K., K.A. Brajendra, R.S. Pathak and A.L. Singh, 2008, Effect of different sources of boron application on productivity of groundnut in Mizoram. *Int. J. Trop. Agric.,* 26: 157-159.

Viswanath, D.P., Perur, N.G. and Rao, B.V.V., 1978, Zinc and major nutrient status of some soils of heavy rainfall coastal mountainous region of Karnataka. *Current Res*., 7: 152-154.

Yadav, G. L.,1990, Fertilizer requirement of groundnut under dry land conditions on cultivators fields, *J. Oilseed Res*., 7 (1) ; 133-135.

Yadav, R. S., Patel, M. S. and Hadvane, G. J., 1991, Effect of FYM, phosphorus and zinc on groundnut in calcareous soil. *J. Indian Soc. Soil Sci*., 39: 391-393.

Yakadri, M., Mir Mustafa Husain and Satyanarayana, V., 1992, Response of rain fed groundnut (A.*hypogaea*) to potassium with varying levels of nitrogen and phosphorus. *Indian J. Agron*., 37 (1): 202-203.

Appendix 1: Monthly meteorological data for the experimental year 2011 and average of 60 years (1950-2010) at Neeralakatti village of Dharwad district

Months	Rainfall (mm)		Mean Temperature (^{o}C)				Relative humidity (%)	
			Maximum		Minimum			
	2011	1950-2010	2011	1950-2010	2011	1950-2010	2011	1950-2010
January	0.0	0.039	29.2	28.7	12.5	14.07	59	64.81
February	21.6	0.684	30.8	31.6	14	16.56	48	54.41
March	0.8	15.02	32.2	34.9	18.6	19.71	44	64.24
April	77.4	41.54	34.9	36.6	20.2	20.11	57	78.05
May	66.6	65.74	34.7	35.2	21.3	20.95	61	75.78
June	194	107.51	27.5	30.2	21.3	21.68	84	86.29
July	131	137.72	26.9	27.3	20.6	20.85	85	89.18
August	124.2	150.45	26.2	27.2	20.7	20.16	87	88.6
September	82.8	132.33	28.1	27.9	19.9	19.96	80	86.68
October	219.7	97.63	29.9	29.5	19.5	18.65	73	79.4
November	4.6	53.49	29.8	28.9	15.8	15.93	55	73.62
December	0.0	2.26	29.6	27.8	13.7	13.20	57	69.12
Total	**922.7**	**804.38**	**-**	**-**	**-**	**-**	**-**	**-**

Appendix II: Details of cost of cultivation in different treatments (/ha)

Sl. No	Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
1	Land preperation	1500	1500	1500	1500	1500	1500	1500	1500	1500
2	Seed cost	7500	7500	7500	7500	7500	7500	7500	7500	7500
3	**Fertilizer**									
	Urea	66	0	33	90	102	90	102	90	102
	DAP	1584	792	1980	1872	2188	1872	2188	1872	2188
	MOP	221	106	221	179	133	179	133	179	133
	$ZnSO_4$	500	500	500	500	500	700	700	1000	1000
	$FeSO_4$	650	0	650	0	0	0	0	0	0
	Vermicompost	0	0	156	78	78	109.5	109.5	156	156
	Agribor	0	375	0	300	300	450	450	600	600
	FYM	3750	3750	3750	3750	3750	3750	3750	3750	3750
	Rhizobium	125	125	125	125	125	125	125	125	125
	P solubeliser	125	125	125	125	125	125	125	125	125
	Gypsum	1500	600	1500	600	600	600	600	600	600
	Application rate	400	400	400	400	400	400	400	400	400
4	Intercultivation	1500	1500	1500	1500	1500	1500	1500	1500	1500
5	Weeding	800	800	800	800	800	800	800	800	800
6	Plant protection	550	550	550	550	550	550	550	550	550
7	Harvesting	3000	3000	3000	3000	3000	3000	3000	3000	3000
8	Total variable cost	25542	23244	25134	24577	24879	24985	25287	25516	25818
9	Total fixed cost	4551	4551	4551	4551	4551	4551	4551	4551	4551
10	Total cost of cultivation	30093	27795	30648	29128	29430	29536	29838	30067	30369

RESPONSE OF GROUNDNUT TO SOIL FERTILITY CONSTRAINTS IN NORTHERN TRANSITION ZONE OF KARNATAKA

KALMESH PUJARI **2012** **Dr. P. L. PATIL**
MAJOR ADVISOR

ABSTRACT

A study was undertaken in Kotur micro-watershed under northern transition zone of Karnataka to identify soil fertility constraints using GIS technique and response of groundnut to identified constraints. Surface soil samples collected at 10” grid interval were analyzed for pH, EC, O.C, N, P, K, S, Ca, Mg, Zn, Fe, Cu, Mn and B and mapped by GIS technique. Soil fertility maps revealed that major portion of the study area was deficient in available N, P, S, Zn and B.

A field experiment was conducted with groundnut as test crop. The results revealed that, the treatment receiving120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg ha^{-1} gypsum recorded the significantly highest value for plant height, number of branches and dry matter production at all the growth stages of crop. The yield components *viz*., number of pods per plant, pod weight per plant, shelling percentage, test weight and yield were found to be highest in same treatment, while RDF-Bhoochetana treatment recorded the lowest value.

Application of 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg ha^{-1} gypsum recorded the highest total uptake of N, P, K, S, Zn and B at the harvest with highest B:C ratio. Residual N, P, Zn and B was found highest in the treatment 140% RD N and P_2O_5 + 60% RD K_2O + 10 kg Zn + 0.4 kg B + 200 kg gypsum. However, residual K and S were highest in the treatment receiving modified RDF based on soil test (RPP). The treatment 120% RD N and P_2O_5 + 80% RD K_2O + 7.5 kg Zn + 0.3 kg B + 200 kg ha^{-1} gypsum was found promising for increasing groundnut productivity.