Forms of Boron in Relation to Soil Properties under Groundnut Cultivation in Jaipur District of Rajasthan

राजस्थान के जयपुर जिले की मूंगफली उगायी जाने वाली मृदाओं के गुणों का बोरॉन के रूपों से संबंध

PRADEEP KUMAR

Thesis

Master of Science in Agriculture

उत्तमा वृतिस्तु कृषिकर्मेव

2010

Department of Soil Science and Agricultural Chemistry
S.K.N. College of Agriculture, Jobner - 303329
Swami Keshwanand Rajasthan Agricultural University,
Bikaner

Forms of Boron in Relation to Soil Properties under Groundnut Cultivation in Jaipur District of Rajasthan

राजस्थान के जयपुर जिले की मूंगफली उगायी जाने वाली मृदाओं के गुणों का बोरॉन के रूपों से संबंध

Thesis

Submitted to the
Swami Keshwanand Rajasthan Agricultural
University, Bikaner
in partial fulfilment of the requirement
for the degree of

Master of Science

in the

Faculty of Agriculture

(Soil Science & Agricultural Chemistry)

By

Pradeep Kumar

2010

Swami Keshwanand Rajasthan Agricultural University, Bikaner
S.K.N. College of Agriculture, Jobner

CERTIFICATE- I

Dated : 26-07-2010

This is to certify that **Mr. Pradeep Kumar** has successfully completed the Comprehensive Examination held on 1[illegible]-05-2010 as required under the regulation for **Master's degree.**

(S.P. Majumdar)
Professor & Head
Department of Soil Science and Agril. & Chem.
S.K.N. College of Agriculture,
Jobner

Swami Keshwanand Rajasthan Agricultural University, Bikaner
S.K.N. College of Agriculture, Jobner

CERTIFICATE- II

Dated :.26.07..2010

This is to certify that the thesis entitled **"Forms of boron in relation to soil properties under groundnut cultivation in Jaipur district of Rajasthan"** submitted for the degree of **Master of Science** in the subject of **Soil Science and Agricultural Chemistry** embodies bonafide research work carried out by **Mr. Pradeep Kumar** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of the thesis was also approved by the advisory committee on 05-07-2010.

(S.P. Majumdar)
Prof. & Head
Department of Soil Science and
Agricultural Chemistry

(B.L. Yadav)
Major Advisor

(G.L. KESHWA)
Dean
S.K.N. College of Agriculture, Jobner

Swami Keshwanand Rajasthan Agricultural University, Bikaner
S.K.N. College of Agriculture, Jobner

CERTIFICATE- III

Dated : 09.9. 2010

This is to certify that the thesis entitled **"Forms of boron in relation to soil properties under groundnut cultivation in Jaipur district of Rajasthan"** submitted by **Mr. Pradeep Kumar** to the Swami Keshwanand Rajasthan Agricultural University, Bikaner, in partial fulfilment of the requirements for the degree of **Master of Science** in the subject of **Soil Science and Agricultural Chemistry** after recommendation by the external examiner, was defended by the candidate before the following members of the advisory committee. The performance of the candidate in the oral examination on his thesis has been found satisfactory, we therefore, recommend that the thesis be approved.

(B.L. YADAV)
Major Advisor

(S.R. SHARMA)
Advisor

(V.K. YADAV)
Advisor

(O.P. SHARMA)
Dean, PGS, Nominee

(S.P. MAJUMDAR)
Prof. & Head
Department of Soil Science
& Agril. Chem.

(G.L. KESHWA)
DEAN
S.K.N. College of Agriculture,
Jobner

Approved

DEAN
POST GRADUATE STUDIES

Swami Keshwanand Rajasthan Agricultural University, Bikaner
S.K.N. College of Agriculture, Jobner

CERTIFICATE- IV

Dated :--13.9.-- 2010

This is to certify that **Mr. Pradeep Kumar** of the **Department of Soil Science and Agricultural Chemistry**, S.K.N. College of Agriculture, Jobner has made all corrections/modifications in the thesis entitled **"Forms of boron in relation to soil properties under groundnut cultivation in Jaipur district of Rajasthan"** which were suggested by the external examiner and the advisory committee in the oral examination held on 09-09--2010. The final copies of the thesis duly bound and corrected were submitted on 13.09.-2010 and forwarded herewith for approval.

(B.L. YADAV)
Major Advisor

(S.P. MAJUMDAR)
Professor & Head
Department of Soil Science & Agricultural Chemistry
S.K.N. College of Agriculture, Jobner

(G.L. KESHWA)
DEAN
S.K.N. College of Agriculture, Jobner

Approved

DEAN, PGS
SKRAU, Bikaner

Contents

List of Tables

List of Tables

Acknowledgements

I take great pleasure to express my intense sense of gratitude to modest, industrious, generous and courteous personality Dr. B.L. Yadav, Associate Professor, Department of Soil Science & Agricultural Chemistry, S.K.N. College of Agriculture, Jobner for suggesting and planning the present investigation, valuable guidance, helpful criticism and constant encouragement throughout the course of investigation and preparation of this manuscript.

I am highly thankful to members of my advisory committee namely, Dr. S.R. Sharma, Assistant Professor, Department of Soil Science and Agricultural Chemistry, Dr. V.K. Yadav, Associate Professor, Department of Biochemistry and Dr. O.P. Sharma, Associate Professor, Department of Agronomy (Dean, PGS nominee) for their valuable guidance during the course of study.

Words can hardly acknowledge the help made by Dr. S.P. Majumdar, Prof. & Head, Deptt. Soil Science and Agril. Chemistry for providing necessary facilities and benevolent patronage.

I wish to record my cordial thanks to Dr. G.L. Keshwa, Dean, S.K.N. College of Agriculture, Jobner for providing necessary facilities during the study.

I feel gratified to record by cordial thanks to Dr R. S. Manohar , Dr. B.L. Kumawat, Associate Professors and Dr. K.K. Sharma, Sh.K.S. Manohar Assistant Professors, Sh Teja Ram Boori, Sh. V.K. Singh, Sh. S. K. Kala and B.R.Singh and other staff members of the Department of Soil Science and Agril. Chem. for their ready help whenever needed during the course of investigation.

Also the help rendered by my seniors Sita Ram, Dhanshi Ram (Rao shab), Kuldeep, Animesh colleagues Bhoop Singh, Sita Kumawat, Sewa Ram dear juniors Sita Ram Raj Kumar and friends Atul, Akash, Govind, Prashant, Ravi, Rahul, Pradeep, Anuj during study period is duly acknowledged for their regular support, motivation and inspiration.

My vocabulary falls short to express heartiest regards to my grand parents Late Sh.Moti Lal Kushwaha, and Late Smt. Phul Mati Devi and my parents Sh. Amar Singh and Smt. Siya Rani whose consistent encouragement and blessings are beyond my expression that brough me here up to dream without which it could not have been sketched. I tender my deep affection to my younger brothers Yogendra Singh and Aman Kushwaha whose incessant love affection, inspiration, encouragement and determinative incentive brought the present task to its completion.

I am also grateful to Sh. Suresh Yadav, M/s. Vimal Computer's, Jobner, for typing the script neatly and efficiently within a very short period.

Lastly I just do not find the words how to express my heartful feeling to my esteemed mother Smt. Siya Rani whose blessing, desire and spiritual effect sustained my good academic as well as social career, as gratification I bow my head and seek more blessings.

Last but not the least, a million thanks to almighty GOD, who made me to this task and made every job a success for me.

Place : Jobner
Dated : 25 / 7 /2010

Pradeep kumar
(Pradeep kumar)

1 Introduction

Groundnut (*Arachis hypogaea*. L.) is the premier oil seed crop of India, popularly known as peanut, monkeynut and called as moogphali" mainly grown in *kharif* season. It is the member of family leguminaceae and sub-family papilonaceae. It is the world's fourth most important source of edible oil and third most important source of vegetable protein. Groundnut seeds contain high quality of edible oil (48%), easily digestible protein (26%) and carbohydrates (20%). Globally 50 % of groundnut produce is used for oil extraction, 37% for confectionary use and 12% for seed purpose. In India 80% of the total produce is used for oil extraction, 11% as seed, 8% as direct food and only 1% produce is exported.

India contributes about 20% area and less than 10% production of total oil seed production of world. Whereas, it accounts 40% of the area (8 million hectare) and 30% of the production (6.70 million tonnes) of total oil seed in India (Anonymous, 2005-06). In Rajasthan, groundnut covers an area of 5.47 lakh hactare with 4.96 lakh tonnes of production with an average productivity of 1547 kg ha^{-1} (Anonymous, 2005-06). In Rajasthan groundnut is mainly grown in Jaipur, Bikaner, Sikar, Chittore and Jodhpur districts. Jaipur district rank first in respect of both area and production where it is grown on 97426 ha area with production of 97336 tonnes with average productivity of 999 kg ha^{-1}, however, the productivity in Jaipur district leg behind the Sikar (1986 kg ha^{-1}) and Jodhpur (1847 kg ha^{-1}) district (Anonymous, 2005-06). Jaipur teshil is the major producer of groundnut followed by Amber, Chomu, Phulera and Dudu tehsil and all five tehsils account for 80% of the total groundnut production in the Jaipur district.

The yield levels of groundnut in the district are, however, far below the potential yield. Inadequate and imbalanced nutrition seems to be one of the important major factor for such low yields. Micronutrient deficiencies or toxicities based on visual observations are of common occurrence in different groundnut fields of the district. Boron (B) is an essential nutrient for normal growth of higher plants, and B availability in soil and irrigation water is an important determinant of agricultural production. To date, a primordial function of B is undoubtedly its structural role in the cell wall; however, there is increasing evidence for a possible role pathways. In recent years, the knowledge of the molecular basis of B deficiency and toxicity responses in plants has advanced greatly (Cristobal, *et al.* 2008). It is an essential micronutrient for all vascular plants, is having special significance in groundnut crop because of its role in pollination, peg initiation and fruit setting. Boron has favourable effect on the number of effective pegs (Golkiya and Patel, 1986) and the Ca/B ratio responsible for flower setting, peg initiation and pod formation in groundnut (Golkiya and Patel, 1988).

Boron deficiency is widespread in highly leached coarse textured, low organic matter and high pH and $CaCO_3$ (Gupta *et al.* 1985) soils of

India leading to low crop yields. Among micronutrients, boron deficiency in plant is second after Zn and about 33% soils tested to be deficient in boron (Singh, 2001). Available B content in Indian soils ranges from traces to 12.2 mg kg^{-1} (Das, 2000) Boron toxicity in arid soils is often confounded with the problem of salinity (Keren and Bingham, 1985). Boron toxicity may also occur in arid and semi-arid areas due to addition of boron through irrigation water. Boron is unique among the essential micronutrients as it is the only element present in soil solution as a non ionised speci over the pH range suitable for the plant growth (Arora and Chahal, 2001). Boric acid (H_3BO_3) is the main constituents of soluble boron in soil. This acid does not dissociate under most prevailing soil pH conditions and thus, in contrast to all other essential plant nutrients, boron is mainly present in a non ionised form in soil solution. The range between the boron deficiency and toxicity being narrow, poses difficulty to maintain appropriate boron levels in soils solution.

The availability of boron is greatly influenced by soil characteristics like pH, EC, organic matter, texture and $CaCO_3$ content (Keren and Bingham, 1985). It is well established that much of the boron in soil is associated with organic matter in tightly bound compounds, which is released in available form by microbial action (Berger and Pratt, 1963). Further, there exists a relationship between available boron and exchangeable Ca in soil with respect to boron nutrition of plants. Earlier studies have shown that when plants have access to increasing amounts of Ca, they require more boron for growth (Reeve and Shive, 1944). The adsorption of boron on clay minerals and fixation via ligand exchange (Kareen *et al.* 1994) reduced available boron contents in soil.

Knowledge of elemental distribution of nutrient in different fractions is fundamental for understanding soil chemistry and plant nutrition. Boron is found in soil in various forms and is distinguished in many categories (Hou *et al.* 1994, 1996). However, the contribution of various boron fractions towards boron availability in soils has not been examined extensively. Hence, their determination is important for estimation of its availability to plants.

The soils of Jaipur district are Typic Ustipsamments which occur in alluvial terraces in old flood plains of N.E. Rajasthan. Being highly productive, these soils are extensively cultivated for groundnut and wheat and are being exhausted in nutrients at much faster rate and no study was undertaken to ascertain the cause of groundnut yield decline in the district. The present investigation therefore, has been undertaken to get information about different forms of boron to asses its availability to groundnut in relation to various physico-chemical properties of soil with the following objectives :

(i) To assess the status of different forms of boron in soils of Jaipur district under groundnut cultivation.

(ii) To find out the relationship between soil properties and different forms of boron.

(iii) To find out the relationship between different forms of boron and nutrient content in groundnut plant.

(iv) To delineate the area of deficiency or sufficiency of boron based on soil analysis.

2 Review of Literature

2.1 Different forms of boron

Boron in soils can exist as labile species in the soil solution and less labile forms such as non-specifically adsorbed B on phyllosilicate clays (Goldberg *et al.* 1993), specifically adsorbed B on variable charge oxides and (oxy) hydroxides (Goldberg and Glaubing, 1985; Su and Suarez, 1994), organic B- complexes (Duin *et al.* 1985; Gu and Lowe 1990) and adsorbed B on carbonate minerals (Goldberg and Forster 1991). Non labile forms include B isomorphously replacing Al^{3+} or Fe^{3+} in (oxy) hydroxides or Si^{4+} in the tetrahedral sheets of phyllosilicate clays (Hingston 1964) and B in primary minerals, such as tourmaline, or secondary minerals, such as colemanite.

Jin *et al.* (1987); Tsadilas *et al.* (1994) and Hou *et al.* (1994, 1996) developed various fractionation techniques for soil boron using methods originally developed for selective dissolution of trace metals, in which a particular fraction of the element might be removed by specific extractant. In their previous schemes for soil boron fractionation, soil boron was generally differentiated into water-soluble, non specifically and specifically adsorbed, Fe- Al and Mn oxide bound forms and residual fractions.

Jin *et al.* (1988) concluded that oxyhydroxide of Al and Fe sorb boron was unavailable form.

Hou *et al.* (1994) found that upto 23% of soil boron was extracted by HNO_3^--H_2O_2 and was therefore, presumed to be organically bound.

Tsalidas *et al.* (1994) reported no correlation between the Mn oxyhydroxide B fraction and either specifically adsorbed B or non specifically adsorbed B fractions in Greek soils. They also reported that the state of dynamic equillbrium among the three forms of boron was evident from the fact that there was a significant and positive correlation of water soluble boron with non-specifically adsorbed boron and specifically adsorbed boron. Similarly, specifically adsorbed boron was significantly and positively correlated with non-specifically adsorbed boron.

Wojcik (2000) fractionated boron into three forms, which are most important from the point of plant nutrition. These forms are water soluble, non-specifically adsorbed and specifically adsorbed boron.

Xu *et al.* (2001) reported that boron was fractionated by sequential extraction in 13 soils collected from north (47^0 N) to south (20^0N) in eastern China. The non specifically adsorbed B (NSA-B) and specifically adsorbed boron (SPA-B) comprised < 1% of total boron. By contrast, B occluded in Mn oxy hydroxide (MOH-B), in amorphous Fe and Al oxide (AMO-B) and in crystalline Fe and Al extract (CRO-B) comprised from 0.01 to 7.6% of total B.

Datta *et al.* (2002) reported that residual fraction of B constituted 91 to 99% of total B, with a mean of 97% in some soils of India.

Choudhary and Shukla (2004) reported that available B content in irrigated soils of western Rajasthan showed significant and positive correlation with EC, pH and organic carbon.

Choudhary and Shukla (2004) in another study, observed that specifically adsorbed B was found to correlate significantly and positively with EC and organic carbon content of soil and available B was significantly and positively correlated with readily soluble B, specifically adsorbed and organically bound B. They further stated that hot 0.01 m $CaCl_2$ is capable of extracting boron from readily soluble, specifically adsorbed and organically bound pools.

Raina *et al.* (2006) reported that the amount of B in different forms followed the order, total-B > hot water soluble –B> leachable (adsorbed + soluble) B. Soil pH, organic carbon (OC) and clay content evidenced a positive relationship with different forms of B. Three forms of B studied were significantly and positively related with one another. On an average, 2.8, 2.3 and 39.1% of applied B was transformed into hot water soluble, leachable and total B, respectively, after six month of application.

Murthy (2006) observed that boron deficiency is a global phenomenon, at present, nearly 33 per cent of Indian soils were found deficient in boron. Further, it was observed that the application of boron responded positively.

Arora and Chahal (2007) found that water soluble boron content in surface soils in typic Happlinstalfs of Punjab varied from 0.14 to 0.28 mg kg^{-1} with a mean value of 0.21 mg kg^{-1}. Further, they have observed that the hot water soluble B content varied from 0.20 to 0.72 mg kg^{-1} with mean value of 0.37 mg kg^{-1} and leachable boron content ranged from 0.26 to 0.84 mg kg^{-1} with mean value 0.54 mg kg^{-1} and total boron content varied from 18.16 to 28.54 mg kg^{-1} with mean value of 23.26 mg kg^{-1}.

2.2 Soil properties and their relationship with different forms of boron

2.2.1 Physico-chemical properties

Gupta (1968) found a positive correlation between organic matter and hot water soluble boron content in soils, while the correlation between total boron and organic content in the soil was very poor.

Singh and Randhawa 1977, Choudahry and Shukla, 2003,; Pradhan *et al.* 2003 and Arora and Chahal, 2005 found a significant positive correlation between pH of soil and available B content, while negative correlation between pH and available boron was observed by Datta *et al.* (1993) in upland soils of Tripura.

Gupta *et al.* (1985) reported that B deficiency in plants in most widespread in coarse-textured, low organic matter and high pH and $CaCO_3$ soils.

Keren and Bingham (1985) reported that the availability of B is greatly influenced by soil characteristics like pH, EC, Organic matter, texture free Al and Fe oxide and $CaCO_3$ content.

Jin *et al* (1987); Mandal *et al.* (1993); Hou *et al.*(1994), Tsadilas *et al.*(1994) and Yermiyahu *et al.* (1995)reported that a variety of factors such as pH, OM, clay minerals, Fe and Al oxide, carbonates and tillage management may change the content of extractable boron and transformation among different soil fractions.

Sahu *et al.* (1990) reported that boron deficiency was observed in all the soil groups except Haplustalf and Ustochrept. Boron content of saline soils viz. Haplaquept and Halaquent were in toxic levels. Clay content had significant positive correlations with boron. Available boron content of soils had significant positive correlation with their concentration in rice plant.

Gu and Lowe (1990) concluded that in most acid to near neutral soils, humic acid are likely to have only a minor role in boron adsorption, however, Marzadori *et al.* (1991) found that treating soils to remove OM increased B sorption by the soil.

Deficiency of B in alluvium derived arid and semi- arid soils of Punjab had been reported by Bansal *et al.* (1991) and Singh and Nayyar (1999).

Bhogal *et al.,* (1993) reported that the available B was correlated negatively with pH while positively and significantly correlated with organic carbon in Bihar.

Datta *et al.* (1993) reported that available B had significant and negative correlation with pH in upland soils of Tripura.

Sakal *et al.* (1993) reported a significant positive correlation between organic carbon and available boron in calcareous soils of Bihar.

Hou *et al.* (1994, 1996) have considered it necessary to include OM-bound forms in their B fractionation procedure, and their results showed no correlation between humic acid content of the synthetic soil and either organically bound B or other fractions extracted.

Hou *et al.* (1994) and Datta *et al.* (2002) observed a significant and positive correlation between readily soluble B and pH of soil.

Lehto and Malkonen (1994) found that practice of liming of soils might result in a significant decrease of boron uptake presumably because of increased B sorption.

The irregular distribution of $CaCO_3$ with depth were also observed by Raj Kumar (1995) in soils of Punjab and Joshi and Dhir (1995) in soils of Thar desert of Rajasthan. Whereas, accumulation of $CaCO_3$ in lower part of the control section was observed by Qureshi *et al.* (1996) in saline and sodic soils of Bharatpur (Rajasthan).

Simard et al. (1996) reported that the clay soils rich in organic matter were low in plant available B in eastern Canada.

Hou *et al.* (1996) found that residual boron was significantly correlated with the content of clay mica.

Wang *et al.* (1997) reported that boron from fertilizer did leach in three soils (out of 13 soils) from southeast china but generally not below the root zone of crops. The soils on which measurable leaching below the 60 cm depth was reported was an alluvial soil from Zhejiang province. They also reported that leaching of boron occurred in the field of an alluvial soil to depth of > 60 cm, but in two other rice paddy soils from southeast china, with higher clay content, negligible leaching of boron occurred from root zone.

Yadav and Vyas (1998) reported that majority of soils of semi arid eastern plain (Agro-climatic zone III-A) of Rajasthan were coarse textured in nature and the textural class of the soils of region varied from loamy sand to sandy loam.

Xu *et al.* (2001) reported that the content of the Non specifically adsorbed boron (NSA) fraction significantly decreased with increasing mean annual rainfall of the site and increased with increasing soil pH and exchangeable Ca. The Specifically adsorbed boron (SPA-B) fraction was not correlated with any soil properties or climate factor. Their results emphasized that the form of boron in Chinese soils were distinctly different from those in soils of southeast USA and Greece.

Moafpouryan and Shukla (2002) reported that the organic carbon, cation exchange capacity and clay contents were much higher in the entisol than in alfisol and the hot water soluble boron (i.e. available boron) was sufficient in entisol and low in alfisol as per the critical value of soil boron *i.e.* below 0.5 mg kg^{-1} and 0.5 – 1.0 mg kg^{-1} as deficient and low status, respectively.

Nourbakhsh *et al.* (2003) conducted a study to understand the association between CEC and sand, silt clay, organic matter and pH. 464 soil samples from ABC horizons of different soil types were collected. Results revels that CEC was negatively correlate with sand (r=0.389) and was positively correlated with organic matter (r=0.7727), clay (r=0.391) and silt (r=0.233).

Al-Busaidi *et al.* (2003) collected thirty surface (0-10 cm) and sub-surface (10-20 cm) agricultural calcareous soil sample from Oman and resulted a negative relationship between soil salinity and pH. The main factor contributing to this relationship was probably the presence of soluble Ca^{2+} ion in soil. Variation in soluble Ca^{2+} ion concentration between soil were negatively related to soil pH and positively related to soil salinity.

Moafpouryan and Shukla (2004) reported that water soluble; non-specifically adsorbed and specifically adsorbed B were significantly and positively correlated with organic carbon, C.E.C and clay content and significant positive correlation was existed between these forms.

Chaudhary and Shukla (2004a) studied soils of western Rajasthan and found that major portion of boron in soils existed in residual forms and it was significantly and positively correlated with organic carbon and CEC of soil.

Kumar (2005) found that CEC of soils of Parbatser soil series varied between 4.8 to 9.2 cmol (p^+) kg^{-1} and found to increase significantly with clay (r = 0.703**) and organic carbon (r = 0.969**) and decreased significantly with increase in sand (r = -0.867**) and $CaCO_3$ (r = -0.468**) contents.

Barala (2005) found that the calcium carbonate content of soils of Shahpura tehsil of Jaipur district varied between 0.5 to 3.5 per cent with mean value 2.04 per cent and it was found to decrease significantly with increase in silt, clay, organic carbon and CEC, while, it was significantly enhanced by the sand content.

Yadav (2005) found that CEC of soils of Degana soil series varied between 4.8 to 9.2 cmol (p^+) kg^{-1}. Its values were found to be increased significantly with silt (r=0.319*), clay (r = 0.377**) and organic carbon (r=0.576**), while, it decreased significantly with $CaCO_3$ (r= -0.490**) and pH_2 (r =-0.369**) of soils.

Mathur *et al.* (2006) found that soils of North-West Plain of Rajasthan were sandy clay loam to clay loam, loamy sand to sandy loam and sand to loamy sand. They also observed that CEC of soils varied from 14.65 to 31.45 cmol (p+) kg^{-1} of soil, pH varied from 7.20 to 8.60 and EC ranged from 0.20 to 2.60 dSm^{-1}.

Meena *et al.* (2006) reported that the soils of Tonk district, Rajasthan were loamy sand to clay, low to medium in organic carbon (0.19 to 0.90 per cent) moderate to high pH (7.10 to 8.10) and non-saline (EC 0.10 to 1.50 dSm^{-1}).

Kher and Isher (2006) reported a positive relationship of available boron with soil pH, organic carbon and total boron but available boron did not show any significant relationship with EC, $CaCO_3$ and Clay content of soil.

Pandey and Girish (2007) investigated the soils of New Delhi Valley and found that the soils were loamy sand to clay loam in nature. Sand, silt and clay content ranged from 6 to 80, 6 to 46 and 5 to 56 per cent.

Arora and Chahal (2007) studied the Gurdaspura soil series of Punjab and found that the soils were loamy in texture and organic carbon content of soil ranged from 0.30 to 1.02 per cent, pH values varied from 7.65 to 8.22, EC varied from 0.18 to 0.34 dSm^{-1} and CEC varied between 5.98 to 12.0 cmol (p^+) kg^{-1}.

Sharma and Chaudhary (2007) studied the soils of Solan district in North-West Himalayas and found that organic carbon content varied from 1.50 to 15.9 g kg^{-1} which showed considerable variation with depth.

Balpande *et al.* (2007) studied the grape-growing soils of Nasik district, Maharashtra and found that the soils were neutral to strongly alkaline in nature (pH 7.20 to 8.90). The pH was significantly affected by $CaCO_3$ (r=0.60). EC of these soils ranged from 0.08 to 1.22 dS m^{-1}.

Sharma and Chaudhary (2007) determined vertical distribution of micronutrient cation in relation to soil characteristics in lower Shiwaliks of Solan district in North-West Himalayas and found that the soils were slightly acidic to neutral in reaction (pH 6.25 to 7.29) and EC ranged from 0.09 to 0.40 dS m^{-1}, which showed considerable variation with depth. Similar results were also found by Singh (2006), Meena (2006), Babel (2007), Mehra (2007), Nitharwal (2007), Singh (2007) and Sanwal (2008).

Arora *et al.* (2009) reported that the soils of Punjab positively and significantly correlated with organic carbon content while there had negative association with soil pH and clay content. The total describable B was negatively correlated with clay content and organic carbon, while it is positively associated with sand content.

Yadav and Meena (2009) reported that the CEC ranged between 8.18 to 12.32 cmol (p^{+}) kg^{-1} calcium carbonate content varied between 0.5 to 4.0 per cent, pH_2 values varied from 7.32 to 9.45 and EC values varied from 0.11 to 1.84 dSm^{-1} indicating that soils of Degana Series (Rajasthan) were neutral to alkaline and non-saline in nature.

2.2.2 Available nutrient content in soil

Kartyal *et al.* (1982) reported that available B content of the surface soils of Punjab has been vary from 0.40 to as high as 7.49 mg kg^{-1} and in many area typical B deficiency and toxicity symptoms can be observed in many crops.

Sahu *et al.* (1990) reported B deficiency in soils growing rice in orissa. The sedentary soils of chotangur have been found to be low in available B (Sinha and Singh, 1966; Singh *et al.*, 1991).

Malewar (1991) pointed out that available S deficiency in Maharastra soils ranges between 27.9 to 66 per cent.

Akbari *et al.* (1993) reported that the available phosphorus (as P_2O_5) and available potassium (as K_2O) content varied from 13.44 to 132.16 and 104.84 to 953.68 kg ha^{-1}, respectively in soils of Mewan region.

Mahapatra *et al.* (1996) reported that available P, Ca, Mg, S and B content of four soil groups (Alfisols, Inceptisols, Ultisols and Entisols) of orissa growing groundnut show that these soils are deficient in Ca, Mg, S and B but adequately supplied with P. Available Ca and Mg show significant positive correlation with clay, plus silt, pH and organic carbon.

Das (2000) reported that available B content in Indian soils ranged from traces to 12.2 mg kg^{-1}.

Arain *et al.* (2000) reported that the levels of some macro and micro nutrients showed that the soils is highly deficient in organic matter (0.35%) and phosphorus (6.2 ppm). Soil pH was 8.35 (alkaline). The soil contained sufficient potassium (500 ppm), calcium (10500 ppm) and magnesium (5500 ppm) in the soils of Nawabshab, Padedon and Sakrand in Pakistan.

Sellamuthu *et al.* (2000) reported that the available N content was low in 96% of the surface and in 98% of subsurface soil samples. The available P was low in 50% of the surface and in 61% of the sub surface soil samples. Medium in 27% of the surface and 18% of the subsurface soil samples. 45% of surface low 51% of surface soil samples medium and remaining were high in available K. Hot water soluble B was sufficient in 84% of surface soil samples in the soils of sugar cane growing areas of Uttiramerus taluk. Kancheepuram District, Tamil Nadu.

Reddy *et al.* (2000) evaluated the available nutrient status of surface (0.30 cm) soils (red lateritic and alfisols) of mulberry gardens of siddlaghatta taluk of kolar district of Karnataka. Out of 2003 soil samples tested 46% of the soil recorded normal range of pH (6.3 to 7.2), 42% were moderately alkaline (7.3 to 8.3) and 9% of the soils were acidic (<

6.3 pH). Organic carbon content was low (< 0.5%) in 74% of the soil and 26% were in the medium range (0.5 – 1.0%). Available P content was low (< 9.0 kg/acre) in 34 and 51% of the sample were in the medium range (9.22 kg / acre) 44% of the soil. The soils were normal with respect to soil salinity.

Qureshi *et al.* (2000) collected 48 composite soil samples from different sites of tehsil in Gujar Khan Pakistan to investigate its K status. Soil pH values of the area varied from 7.3 to 7.9. The texture of the soil samples were sandy loam (25%) loam (80%) and clay loan (15%). Out of 48 samples, 84 per cent samples were found satisfactory (80-150 mg K Kg^{-1}) soil) level, while 14 per cent samples had adequate (< 150 mg K kg^{-1} soil). The maximum K content (230 mg K kg^{-1} soil) were recorded in Bardiana site, while minimum K (100 mg K kg^{-1} soil) were recorded in Bardiana in Gojra Badahna site.

Srivastava *et al.,* (2000) conducted a study in sugar mill zone of U.P. A total 317 soil samples were collected from different villages in 6 district (Muzaffarnagar, Haridwar, Saharanpur, Meerut, Bagpat, Dehradun) of western UP in 1997-98 and 1999-2000. The pH, available N, P and K were measured. The soil samples were (pH 7.0- 7.5), low in N and P but average in K.

Sharma *et al.* (2000) reported that the fertility of well managed garden soil varied from medium to high status with respect to N, P, K and organic carbon. Soil pH was also in optimum range (4.6 – 5.9) for successful tea production. Mg was deficient in 90-95% of the soil sample but was in medium fertility class in tea shoots. Same is the condition with sulfur which was deficient in 10% of soils but in medium fertility class in shoots in the tea garden soils of Palampur, Himachal Pradesh.

Choudhary and Shukla (2002) collected 140 soil samples belonging to seven soil great groups of arid soils of western Rajasthan, which were analyzed to assess the available sulphur status. These soils varied widely in their characteristics. The available sulphur content of most of the soils was in the high range, with the mean value of 59.3 mg kg^{-1}. Only a few samples (5.7 per cent) tested were low in available sulphur content. Among the soil characteristics pH, EC and free $CaCO_3$ content were significantly affected the availability of sulphur. The EC of soil was found to have greater impact on available sulphur followed by free $CaCO_3$ and pH.

Goswami *et al.* (2002) reported that the soils of the citrus research station, Tinsukia A.A.U., Assam were coarse textured, acidic in nature and having high organic matter content but low in cation exchange capacity. The surface soils were medium to high in available N and low to medium in available P_2O_5 and K_2O. The available N, P_2O_5 and K_2O decreased with depth. The soils were deficient in B. the soil properties particularly soil pH, clay content and organic matter influenced the availability of nutrients.

Singh *et al.* (2002) studied the relationship between soil physico-chemical characteristics in 62 surface soil samples (0-15 cm) collected from cultivator's fields representing different agro-climatic zones of Punjab state. They found that the available N and P status ranged from low to highly, whereas, K status ranged from medium to high status. The correlation matrix between different soil parameters exhibited a significant relationship of pH with $CaCO_3$ content. Significant correlations were also found to exist between $CaCO_3$ and clay contents, organic carbon with clay, available P and K status. Available P status of soil also exhibited significant relationship with clay and available K status.

Shrotriya and Phillips (2002) reported available B content and the magnitude of B deficiency in some boron deficient states of India.

State Major soil group	Sample analysed	Available soil boron (mg kg^{-1})	per cent soil deficient
Assam			
Old alluvial soils	687	0.14-23.73	17
acid soils	320	0.05-0.72	43
Meghalaya			
Alfisols	20	0.10-0.50	50
West Bengal			
Red and lateritic soils	2544	0.02-3.30	64
Tarai and Teesta Alluvial soils	633	0.05-0.76	84
Bihar			
Red yellow category soils	466	Trace – 3.76	40
Calcareous soils	1201	0.06-8.00	48
Recent alluvial soils	1732	Trace – 6.50	41
old alluvial soils	703	0.06-7.30	32
Tal (Pond)- land soils	563	0.04-5.67	35
Orissa			
Red and lateritic soils	882	0.10-2.20	69
Panjab			
Ustochrepts	116	0.30-2.00	43
Utter Pradesh			
Saline – alleali soils	45	0.20-4.10	23

Bansal *et al.* (2003) collected surface (0-15 cm) soil samples numbering 200, 100 and 100 from Lundhiana, Jalandhar and Sangrur district of Punjab, were analysed for available B and physico- chemical characteristics. The available boron content varied between 0.22 to 2.16, 0.28 to 1.84 and 0.32 top 2.00 mg kg-1 soil in soil of Ludhiana, Jalandhar and Sangrur district respectively. Considering soils containing available B less than 0.5 and 0.5 to 1.0 mg B kg-1 soil as low to medium in B supply, respectively, 78% samples of Ludhiana district were medium to adequate in available boron, while 22% were low in available B. In Jalandhar district, the available B in 25 and 53% of the investigated soils were in the low and medium range, respectively, and 22% samples had the adequate B status. Similarly in Sangrur district, 96% of soil samples were medium to adequate in the available B, while 40% were low in available B. B deficiency decreased with the increase in fineness of soil texture, soil alkalinity and organic matter content.

Gathala *et al.* (2004) reported that soils under pomegranate orchard in Jaipur district were low with respect to available N, P and B while available K content was found to be medium.

Kundu *et al.* (2005) collected 120 soil samples from the rice growing plot of 4 village (viz Uttar Duppara, Kurumbelia, Mollabelia and Dasdia) of Nadia district of West Bengal, India, and were analyzed to evaluate the fertility status (available N, P_2O_5 and K_2O status) of the study area and study their interrelationship with other soil properties (soil pH, and organic carbon). It was found that the soils of four villages were neutral in soil reaction (average soil pH of 7.4). The organic carbon and available nitrogen status were medium in Utter Duttapara, Kurumbalia and Dasdia villages were high in Mollabelia. The available P_2O_5 status in the soils of all the four villages was high but the available K_2O status was medium.

Boron toxicity has also been reported on soil of Punjab (Sharma and Bajwa, 1989; Arora and Chahal, 2005) and its effect on crop (Arora and Chahal, 2007b).

Verma *et al.* (2005) collected 280 soil samples of Mansa district, Punjab, India. The soils are low in organic carbon content, which ranged from 0.02-0.04 percent with a mean value of 0.29 percent. The available P content varies from 1.8 to 56.6 kg/ha with a mean value of 18.56 kg/ha. The available K content is generally medium to high, and only 3 percent soil samples tested low in available K. It ranged from 67.2 to 851.2 kg/ha with a mean value 229.15 kg ha^{-1}. In overall the study revealed that the soils are low in available N, low to high in available P and medium to high available K content.

Baskar *et al.* (2006) in an investigation was carried out in *tsunami* affected areas of the Union Territory of Pondicherry to characterize the soils for the developing site specific reclamation. Accordingly, a total number of 2762 soil samples were collected and analyzed for EC, pH and gypsum requirement. The result from the whole of U.T. of Pondicherry showed that around 26.11% of the *tsunami* affected soils were saline in nature, 30.59% sodic, 38.38% saline-sodic, while 4.82% were normal.

Jat and Yadav (2006) observed that the sulphate fraction of the sulphur is the most important for plant nutrition and may prove a suitable index in evaluating the amount of sulphur available to plants. SO_4-S showed a significant positive correlation with organic carbon, clay and silt content of soil but sand content showed negative correlation with this form indicates that soils dominant in sand fraction are devoid of sulphur. They also reported that 34% soil samples were found under deficient, 45% under medium and 21% under sufficient categories out of 80 samples of Jaipur district.

Bhatnagar *et al.* (2006) conducted a study in 15 ber orchards in Bikaner district of Rajasthan, and reported that the soil pH varied from (8.07 to 8.94), organic matter was low (0.09 – 0.31%). The N, P, K content in soil varied from 19.33 to 53.70 mg kg^{-}, 11.33 to 27.60 mg kg^{-} and 59.62 to 109.59 mg kg^{-} respectively. The N, P and K in leaves varied from 0.20- 1.62%, 0.09 to 1.08% and 0.07- 1.42% respectively.

Singh *et al.* (2007) reported that distribution of flood plain soils of Punjab soils were low to medium in Olsen phosphorus and available sulphur and medium in available K and N distribution pattern of nutrients indicated the dominance of inorganic fractions that controls the availability reactions in the flood plain soils. Total S and P exhibited significant positive relationship with clay fraction of soil. However, total nitrogen and potassium were significantly and positively correlated with soil organic carbon and sand fraction.

Prasad and Jangra (2007) collected 4921 surface soil sample from different district of Rajasthan during 2003-04 to 2005-06. Out of 4921 soil samples, the soil samples falling under low (< 10 ppm), medium (10.20 ppm) and high (> 20 ppm) categories of available S were 65, 18 and 17 per cent, respectively.

Xu-Zong Lin *et al.* (2008) studied 3183 soil samples collected from 18 areas for soil fertility monitoring in sichvan Provincl, China.

suggested that the content of soil organic matter in paddy field was obviously higher than that in dry land. However the increase in the content of soil organic matter in dry land was not significant. The content of soil alkaline hydrolytic slightly increased, but the surplus of soil N in dry land may be harmful to the environment. The content of available P was increased, but the increase in available phosphorus in paddy field was low. Further the content of soil K was deficient, particularly in the paddy field.

Arora and Chahal (2009) reported that maximum desorbable boron was higher in coarse textured soils as compared to the fine textured soils of Punjab. The boron desorption from soils were positively and significantly correlated with organic carbon content, while these had negative association with soil pH and clay content. The total desorbable boron was negatively correlated with clay content, EC and organic carbon while, it was positively associated with sand content.

Afrifa *et al.* (2009) found that the available boron in the 0-30 cm depth ranged from 0.77 to 1.54 mg B kg^{-1} soil. Surface soil pH values ranged from 5.4 to 6.8. All locations of sampling indicated that there was positive correlation between percent OC, Ca and available boron in the surface soils. Similarly relationship between per cent clay, Ca and available boron in the sub surface soils was positively correlated. Soil available boron at 0-30 cm depth was highly influenced by organic carbon and pH. Kumar (2005) found that the available boron content in soils of Parbatsar soil series ranged between 0.40 to 2.00 mg kg^{-1} with average value 0.98 mg kg^{-1}. Working on the same line, Barala (2005) also reported that the available boron content in soils of Shahpura teshsil of Jaipur district varied between 0.48 to 1.60 mg kg^{-1} with mean value 0.90 mg kg^{-1}.

Yadav and Meena (2009) reported that the DTPA extractable boron content in soils of Degana soil series ranged between 0.32 to 2.17 mg kg^{-1} with mean value of 0.96 mg kg^{-1} and also found that only 21 per soil samples were deficient in boron. Similar results were found by Babel (2007), Mehra (2007), Nitharwal (2007), Singh (2007) and Sanwal (2008).

2.3 Relationship between different forms of boron and nutrient content in groundnut plant

Jin *et al.* (1987) concluded that water soluble and non-specifically adsorbed forms of boron were readily available to maize (*Zea mays* L.) and may be considered as intensity factor for boron-supplying power in soils. The specifically adsorbed and Mn oxide-bound boron forms were slowly available to maize during growing period and were called quantity factor to boron- supply of soil.

Golakiya and Patel (1988) conducted on experiment to study the effect of $CaCO_3$ and boron on Ca/B ratios in soil and plant and their consequence effect on yield of groundnut. Results revealed that yield attributes and yield fluctuated throughout the range of Ca/B ratio but exhibited a plateau between 218 to 224. The Ca/B ratios in soil and plant were inversely related to B application and positively to Ca supply. Higher yields were recorded when Ca/B ratio in the haulm ranged from 218 to 214 and in the soil form 5 x 10^5 to 6x10^6.

Tsadilas *et al.* (1994) found that the available forms of soil boron vary with plant species and showed that B content in olive tree (*Olea* *europaea* L.) leaves was well correlated with amorphous Fe-Al oxyhydroxide-occluded boron, specifically adsorbed B, and Mn oxyhydroxide-occluded B besides water soluble B and in barley (*Hordeum vulgare* L.) leaves, boron content was correlated with non-specifically adsorbed B as well as amorphous Fe-Al oxyhydroxide-occluded B, specifically adsorbed B, and water soluble B, but not with Mn oxyhydroxide-occuluded boron.

Mahapatra *et al.* (1996) reported that monocalcium phosphate extrable S and hot water soluble B content of the soils of orissa are significantly and positively correlated with their concentration in groundnut plants.

Wojcik (2000) reported that the boron content in sunflower plant was significantly correlated with water soluble, non specifically adsorbed boron and specifically adsorbed boron.

Moafpouryan and Shukla (2002) reported that highest shoot yields were obtained when the hot water soluble boron contents in soils were at sufficient level as per the critical levels of boron in soils.

Yener *et al.* (2002) collected soil and plant samples (full leaf, leaf blade and petiole) at post – flowering and ripening stages from 25 different vineyards at Alasehir, Turkey. the soil had 48, 24, 52, 68% N, available P, K and Ca respectively, which could lead to plant nutrient deficiencies. The vineyards were adequate in nutrients, recording only 36, 88, 50 and 48 N, P, K and Ca. The boron content was ≈ 80% which could be toxic to plant. All the vineyards were sufficient in Mg. However, this nutrient was found to be at level which could cause a problem for availability in 80% of the soil, significant correlation were found between plant nutrient contents of the 2 soil depths. Significant correlation were also determined with nutrient content of full leaf, leaf blade and petiole of both sampling dates. Soil and plant correlation were found in case of P, K and Mg.

Niskanen *et al.* (2002) reported that the nutrient for straw berry leaves, the mean nutrient concentration were : N 19.1, P 2.8, K 15.0, Mg 2.7, Ca 9.3 and B 0.05 g/kg dry matter. Nutrient levels were lowest in the leaves of Zefyr. The average leaf N, P, Mg and B were within the recommendation limits, but Ca and K concentration were considered to be low. Leaf nutrient concentration were only slightly dependent on soil nutrients, the values of the linear correlation coefficients between soil and leaf nutrients for P, Mg, Ca and B were 0.22, 0.299, 0.33 and 0.37, respectively.

Singh *et al.* (2003) collected foliage samples of wheat at anthesis stage from northwestern indo-Gangetic plains to study K, P, Ca and Mg status in leaf tissue. The analysis indicated a widespread K deficiency. Wheat crops growing on three of the six soil series. viz. Lukhi (Haryana), Nabha (Indian Punjab) and Bagru (Himachal Pradesh) had 75, 47 and 47% samples moderately deficient in K respectively, whereas in Khatki, Akharpur and Rarha soil series from U.P., 23, 20 and 26% samples were found moderately deficient in K respectively. P was found to be sufficient in wheat plant growing an all the soil series, except Bagru. The Ca + Mg content ranged from 15.62 to 81.25 c mol (P^+) kg^{-1} leaf dry matter. On an average, sum of the macronutrient cations (Ca + Mg + K) in wheat foliage was found to be almost similar in all the soil series; ranging from 107 in Bagru to 114 c mol (P^+) kg^{-1} in Akabarpur. This indicate that wheat plants growing on these alluvial soils tend to maintain a constant cationic balance irrespective of their soil K fertility status. A negative association between K concentration and that of Ca+ Mg content was also observed which indicated that K has antagonistic relationship with Ca + Mg in soil.

Moafpouryan *et al.* (2004) observed significant correlation of boron uptake with water soluble boron, non- specifically adsorbed boron and specifically adsorbed boron and no relationship was observed between dry matter yield of sunflower plants and the forms of soil boron.

Kumar (2005) reported that the boron content in wheat straw and grain ranged between 34.00 to 45.00 and 47.00 to 59.29 $\mu g\ g^{-1}$, respectively. Further, it was also observed that the content of boron in straw (r = 0.687**) and grain (r = 0.697**) was enhanced significantly with increased availability of boron in soils. Further Mehra (2007) observed that the boron content in wheat grain and straw ranged between 28.30 to 70.10 and 21.20 to 63.20 $\mu g\ g^{-1}$, respectively. Similar results were also reported by Babel (2007), Nitharwal (2007), Singh (2007) and Sanwal (2008).

Afrifa *et al.* (2009) reported that the boron in leaf of coffee was between 28.7 and 42.5 mg B kg^{-1}. The leaf Ca/B ratio used as index of boron difference was between 331.4 to 398.8, coffee leaf, boron content and soil pH was negatively correlated at pH above 5.8, but was positive when the pH was below 5.8. Boron levels in the coffee leaves within the critical range of 2-40 mg B kg^{-1} although soil available boron appeared low.

Literature reviewed above pertaining to role of soil properties influencing the availability of boron to groundnut crop. Literature further indicates that much of knowledge of different forms of boron and their interdependence between them and on soil properties and availability to groundnut crop is lacking. Thus, the present study carried out in real situation on farmer's field for dynamics of different forms of boron and their availability is expected to help in a long way to advocate the soil sustainability in terms of finite soil resource of semi-arid region of Rajasthan.

3 Materials and methods

The present investigation entitled "Forms of boron in relation to soil properties under groundnut cultivation in Jaipur district of Rajasthan" was carried out. The general description of the area including materials used and methods followed during the course of investigation are as under:

3.1 General description of survey area :

3.1.1 Location :-

Jaipur district comes under agro-climatic zone III-A (semi arid eastern plain) of Rajasthan. It is situated between 26^0 33' to 27^0 51' North latitude and 74^0 55' to 75^0 50' East longitude surrounded by sawai-Madhopur, Dausa, Alwar, Sikar, Nagour, Ajmer and Tonk district of Rajasthan. The location and list of villages under study are given in Fig3.3 and table 3.3.

3.1.2 Geology :

The soils have been developed from recent local alluvium of metamorphic and igneous origin from Aravallies, but few localities of the tract includes coastal and littoral alluvium and aeolian sand. The geology of this area has developed in aeolian alluvial materials or nearly levels to gently slopping lands at an elevation of 427 meter above mean sea level.

3.1.3 Climate :

Rainfall and temperature are the two elements of the climate. The climate of the area is typically semi-arid which is characterized by aridity of atmosphere, scarcity of the water and extreme of temperature during summer. Maximum average temperature ranges between 35^0 to 48^0C

LEGENDS

● S.NO. OF TEHSILS AS PER TABLE NO. 3.2.
X SAMPLING SITE
▬ DISTRICT BOUNDARY
~ TEHSIL BOUNDARY

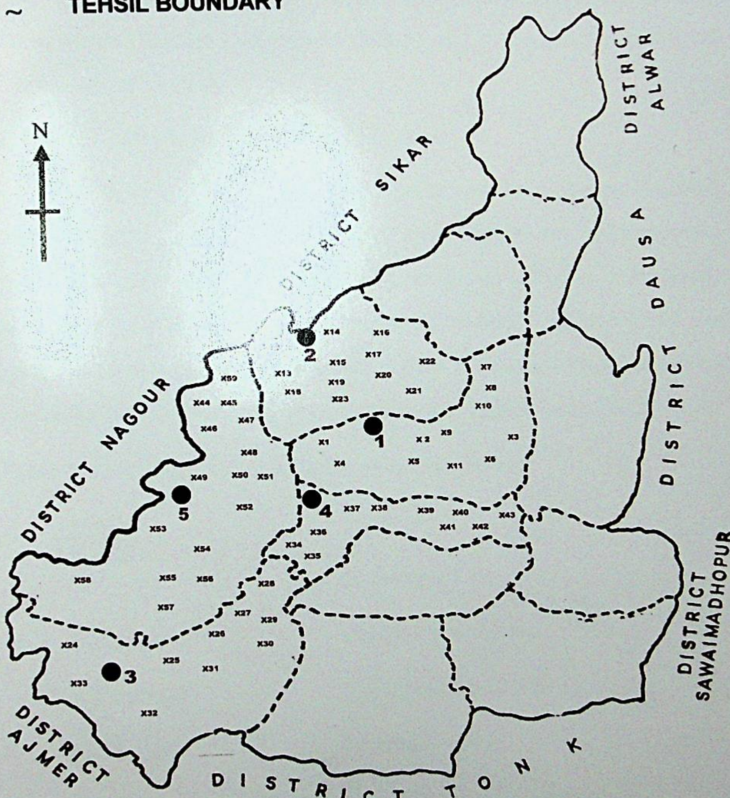

Figure – 3.1 MAP OF JAIPUR DISRICT SHOWING SITE OF SAMPLES whereas, minimum temperature in winter occasionally falls below 0^0C. The rainfall is seasonal, erratic and highly variable with respect to place and time. The mean annual rainfall of the locality is about 400 mm which is mostly received during the monsoon lasting from July to September. Rainy season begins from middle of June and starts receeding around the end of September.

3.1.4 Classification of soils of study area :

In general, the soils of Jaipur district are deep coarse textured, weak structured, excessively to well drained alluvial, non-calcareous to calcareous, moderately eroded lying to gently sloping and gently undulating land having moderate to strong alkalinity problems. On the basis of above soil characteristics, these soils have been classified according to soil taxonomy, 1975 by Lal *et al.*, 1994, (Table 3.1).

Table 3.1 : Classification of soils of Jaipur district

Order	Entisols
Suborder	Psamments
Great group	Ustipsamments
Sub group	Typic ustipsamments
Soil series	Chomu
Family	Loamy sand, hyper thermic

3.1.5 Vegetation

The main crops grown in Jaipur district are wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), mustard (*Brasicca juncea*), gram (*Cicer arietinum* L.), pea (*Pisum sativum* L.) and other vegetables in Rabi season. Bajra (*Pennisetum typhoides*), moth (*Vigna aconitifolia*

81568

L.), mungbean (*Vigna radiata* L.), guar (*Cyamposis tetragenoloba*) and groundnut (*Arachis hypogaea* L.) are grown in *Kharif* season. The most common cropping sequences followed in the district are as under:

Pearlmillet - mustard/pea/gram/wheat

Groundnut - wheat

Clusterbean - wheat

Fallow - onion

Fruit vegetation is scanty and common trees are Ber (*Zyzyphus mauritrana* L.), Lime (*Citrus sps.*), Pomegranate (*Punica granatum*), Aonla (*Emblica officienalis*), mango (*Mangifera indica*), Guava (*Psidium guajava*), Karonda (*Carissa carandas* L.) and Papaya (*Carica papaya*). Natural vegetations are khejari (*Prosopis cinenraria*), babool (*Acacia arabica*), roonj (*Acacia leucophloea*), sheesham (*Dalbergia sissioo*), neem (*Azadirachta indica*) and ardu (*Alianthus excelsa*). The common shrubs and bushes of the district are ak (*Calotrophis procera*), dhatura (*Dhatura metal*), munja (*Saccharum munja*) and dhamasa (*Tephrosia purpuria*). The common grasses of the area are *Cynodon dactylon, Phalaris minor, Cenchrus and Penicum antidotale.*

3.2 Collection of soil samples

Fifty nine composite surface (0-15 cm) soil samples were collected from groundnut growing fields of various villages of selected tehsils of Jaipur district. Samples were taken where the groundnut (spreading type local variety) is grown for the last 5 years of so. The list of farmers field is given in Table 3.2. Approximately 2 kg soil samples were collected with the help of khurpi from different farmers field in cloth bags. Soils samples were air dried, ground and passed through 2 mm sieve and stored in properly labeled plastic bottles for further analysis by the standard procedure given Table 3.3.

3.3 Plant samples

Plant samples of groundnut from same field were also taken at peg initiation stage and brought in laboratory in paper bags. The bags were gently removed and plant samples were dried immediately at 72^{0}C till constant weight and then ground for nutrient concentration analysis as per procedures given in table 3.3.

3.3.1 Pod yield

A quadrat of 1 m^2 was used to measure pod yield by placing it at four places in a selected field. The yield so obtained was averaged and converted into kg ha^{-1}.

Table 3.2 List of sampling sites

S. No	Sample Code	Sampling site	Farmer's name	Source of irrigation	Groundnut growing since (year)	Previous crop	Fertilizer used
1	2	3	4	5	6	7	8
	A	Amber Tehsil					
1.	A_1	Raithal	Sankar Lal Yadav	Tube well	5	Wheat	PM, DAP, Gypsum
2.	A_2	Pratappura	Kanhaiya Lal Yadav	,,	7	Wheat	FYM, DAP, Urea
3.	A_3	Jalsu	Gopal Lal Prajapat	,,	12	Mustard	PM, SSP, Urea
4.	A_4	Atal Biharipura	Muralidhar Jangid	Well	6	Barley	PM, SSP, Urea
5.	A_5	Maudi	Lala Ram Shyoran	Tube well	10	Wheat	PM, SSP, Urea
6.	A_6	Jahota	Narayan Lal Yadav	,,	7	Wheat	PM, SSP, Urea
7.	A_7	Devguda	Narayan Lal Choudhary	,,	6	Mustard	PM, SSP, Urea
8.	A_8	Mohanpura	Pappulal Yadav	,,	10	Pea	PM, DAP, Gypsum
9.	A_9	Anochpura	Dula Ram Jat	Tube well	10	Wheat	PM, DAP, Gypsum
10	A_{10}	Mukandpura	Jag Mal Yadav	Tube well	15	Barley	PM, DAP, Gypsum
11	A_{11}	Anopura	Sona Ram	Well	7	Pea	PM, DAP, Gypsum

Contd.....

1	2	3	4	5	6	7	8
	C	**Chomu**					
12	C_1	Gulabbadi	Jagdish Meena	Tube well	6	Barley	FYM, SSP, Urea
13	C_2	Tankpura	Govardhan Sharma	,,	10	Wheat	FYM, SSP, Urea
14	C_3	Jaisinghpura	Banshi Prajapat	,,	17	-	FYM, SSP, Urea
15	C_4	Devpura	Kaluram Sod	,,	12	-	FYM, SSP, Urea
16	C_5	Loharwara	Godhram Yadav	,,	5	Barley	FYM, SSP, Urea
17.	C_6	Naya bas	Prabhu Dayal	,,	7	Mustard	PM, SSP, Urea
18.	C_7	Udaipuriya	Vinod Yadav		8	Wheat	PM, SSP, Urea
19.	C_8	Kanarpura	Shravan Yadav	,,	10	-	PM, SSP, Urea
20.	C_9	Kaladera	Shankar Lal Meena	,,	9	Barley	PM, SSP, Urea
21.	C_{10}	Bai Ka Bas	Kana Ram	,,	13	-	PM, SSP, Urea
22.	C_{11}	Dhodhsar	Gauri Shankar Samota	,,	6	-	PM, DAP, Gypsum
23.	C_{12}	Bada Badi Dhanni	Richh Pal Choudhary ,,	,,	7	Wheat	PM, DAP, Gypsum
	D	**Dudu Teshil**					
24.	D_1	Devala	Motiram Jat	Tubewell	7	Pea	FYM, SSP, Urea
25.	D_2	Jharna	Hanuman Nayak	"	10	Wheat	FYM, SSP, Urea
26.	D_3	Kesari Singhpura	Rameshwar Prasad Mehta	"	10	Mustard/ pea	PM, SSP, Urea
27.	D_4	Boraj	Mukesh Kumawat	"	6	Pea	PM, SSP, Urea
28.	D_5	Mehala	Ram Pratap Yadav	"	15	Pea	PM, SSP, Urea
29.	D_6	Kharaniya Ki Dhani	Gopal Lal Kumawat	"	8	Pea	PM, SSP, Urea
30.	D_7	Surpura	Ram Swaroop Bachher	"	10	Wheat	PM, SSP, Urea
31.	D_8	Chandramanpura	Gyan Chandra Bairwa	"	8	Wheat	FYM, SSP, Urea
32.	D_9	Aydon Ka bas	Jagdish Prasad Yadav	"	6	Wheat	FYM, SSP, Urea
33.	D_{10}	Khedi Alufa	Chhitarmal Choudhary	"	5	Wheat/ pea	FYM, SSP, Urea
	J	**Jaipur**					
34.	J_1	Lalpura	Sh. Krishna Yadav	Tube well	10	Wheat	PM, DAP, Gypsum
35.	J_2	Mondabhopawas	Lalu Ram Jat	"	8	-	PM, DAP, Gypsum
36.	J_3	Pachar	Radhey Shyam Yadav	"	10	-	FYM, DAP, Urea
37.	J_4	Begus	Mukesh Kumawat	"	7	Pea	PM, DAP, Gypsum
38.	J_5	Ramkui	Banwari Kumawat	"	12	Onion	PM, DAP, Gypsum
39.	J_6	Mehriya Ka Bas	Gopal Devnanda	"	9	Barley	PM, DAP, Gypsum
40.	J_7	Fathehpura	Ramswaroop Sharma	"	6	-	PM, DAP, Gypsum
41.	J_8	Himatpura	Jeevan Ram Bhambhoriya	Tube well	6	Wheat	PM, DAP, Gypsum
42.	J_9	Kalwar	Jai Ram	"	5	Wheat	PM, DAP, Gypsum
43.	J_{10}	Ramla Ka Bas	Chandra Prakash	"	8	Barley	PM, DAP, Gypsum

Contd....

1	2	3	4	5	6	7	8
	P	**Phulera**					
44.	P_1	Dhakakala	Kalyan Badhala	Tube well	10	Onion / Pea	FYM, SSP, Urea
45.	P_2	Kalkh	Shravan Boori	"	6	Wheat	FYM, SSP, Urea
46.	P_3	Murlipura	Gulsan Sharma	"	8	Mustard	PM, SSP, Urea
47.	P_4	Math	Kalyan Kumawat	"	7	Fallow	PM, SSP, Urea
48.	P_5	Kesha ka bas	Bhagirath Mal Yadav	"	5	-	FYM, DAP, Urea
49.	P_6	Basdi Kalan	Sita Ram Yadav	"	10	Barley	FYM, DAP, Urea
50.	P_7	Dungari khurd	Suja Ram Kumawat	"	10	-	PM, DAP, Gypsum
51.	P_8	Kheerava	Khaga Ram	"	6	Wheat	PM, DAP, Gypsum
52.	P_9	Hingonia	Sankhar Lal Sharma	"	7	Wheat	PM, DAP, Gypsum
53.	P_{10}	Bobas	Moti Ram Jat	"	8	Pea	PM, DAP, Gypsum
54.	P_{11}	Gokulpura	Nanu Ram Kumawat	"	6	Fenugreek	PM, DAP, Gypsum
55.	P_{12}	Ghatolai	Bhura Ram Jat	"	9	Wheat	FYM, SSP, Urea
56.	P_{13}	Kalkh	Jagdish Singh Sarwal	"	10	Wheat	PM, DAP, Gypsum
57.	P_{14}	Kuchiabas	Nanak ram	"	6	Barley	PM, DAP, Gypsum
58.	P_{15}	Josibas	Ramuram Sepat	"	5	Wheat	FYM, SSP, Urea
59.	P_{16}	Bassi Nagan	Radheshyam Kumawat	"	8	Pea	FYM, SSP, Urea

3.4 Methods of soil and plant analysis

Standard methods used for analysis of soil and plant samples are given in Table 3.3. Low boron glassware and distilled deionised water were used in all determinations.

Table 3.3 Methods for soil and plant analysis

Item of analysis		Methods	References
A.	**Soil analysis**		
I.	**Physical determination**		
1.	Mechanical analysis (sand, silt & clay)	International pipette method	Piper (1950)
II.	**Chemical determination**		
2.	pH	1:2 soil water suspension using systronic pH meter model 322-1 as described in USDA Hand Book No. 60.	Richards (1954)
3.	EC (Electrical conductivity)	1:2 soil water suspension with the help of EC meter as per method (4b) USDA Hand book No. 60	Richards (1954)
4	Cation exchange capacity (CEC)	Method No. 19 of USDA Hand book No. 60	Richards (1954)
5	$CaCO_3$	Hutchinson rapid titration method	Piper (1950)
6	Different forms of boron	Extraction : Boron in different forms was extracted sequentially with 0.01 M $CaCl_2$, 0.05 M KH_2PO_4, 0.175 M ammonium oxalate and 0.05 M NaOH. Boron was estimated in extract fraction-wise following the methods as given below:	Hou *et al.* (1996) and Modified by Dutta *et al.* (2002)
(i)	Readily soluble boron	Colorimetrically by Azomethine-H method	John *et al.*, (1975)
(ii)	Specifically adsorbed boron	Colorimetrically by Azomethine-H method	John *et al.*, (1975)
(iii)	Oxide bound boron	Colorimetrically by Carmine method	Hatcher and Wilcox, (1950)
(iv)	Organically bound boron	Colorimetrically by Carmine method	Hatcher and Wilcox, (1950)
(v)	Residual boron	Difference between total boron and first four fraction	

Contd…

(vi)	Total boron	Extracted by digestion of soil in H_2SO_4, HF and $HClO_4$ acids	Datta *et al.* (2002)
7	Organic carbon	Walkley and Black rapid titration method	Walkley and Black (1934)
8	Available N	Alkaline $KMnO_4$ method	Subbaih and Asija (1956)
9	Available P	Extraction of soil with 0.5 M Na HCO_3 at pH 8.5 and developed colour by $SnCl_2$ and measured colour intensity on spectrophotometer	Olsen *et al.* (1954)
10	Available K	Extraction of potassium carried out with 1N neutral ammonium acetate solution and estimated by flame photometer	Jackson (1973)
11	Available Ca	Using EDTA solution	Richards (1954)
12	Available Mg	Using EDTA solution	Richards (1954)
13	Available S	Heat soluble method	Williams and Steinbergs (1959)
14	Available B	Available boron was extracted with hot water and determined colorimetically	Gupta, (1979)
B.	**Plant analysis**		
1	N content	Wet digestion of plant sample with H_2SO_4 and estimated on colorometer after development of colour with Nesseler's reagent (extract-I)	Snell and Snell (1949)
2	P content	Wet digestion of plant samples was done with diacid mixture of HNO_3-$HClO_4$ by using vanado-molybdophosphoric acid yellow colour method	Jackson (1973)
3	K content	Analysis of suitable aliquot of acid digested plant material (extract-I) by flame photometer	Jackson (1973)

Contd…

4	Ca content	Analysis of suitable aliquot of acid digested plant material (extract-I) by flame photometer	Richards (1954)
5	Mg content	Analysis of suitable aliquot of acid digested plant material (extract-I) by flame photometer	Richards (1954)
6	S content	Digested with nitric & perchloric acid extract was analysed for sulphate –S with the help of colorimeter using a wavelength of 420 nm.	Tabatabai and Bremner, (1970)
7	B content	The plant samples were ashed in a muffle furnace at 550^0C and boron in the ash was extracted with 0.1 N HCl and extract was analysed for total boron with help of colorimeter using a wavelength of 420 nm.	John *et al.* (1975)

3.4 Fertility indices

The fertility indices were calculated as per formula given by Muhr *et al.*, (1965).

$$\text{Nutrient index} = \frac{\text{\% of sample testing "low"} \times 1 + \text{\% of sample testing "medium"} \times 2 + \text{\% of sample testing "high"} \times 3}{100}$$

3.5 Statistical analysis

To find out the relationship between different form of boron and soil properties, the simple correlation coefficients (r) and determination coefficients (R^2) were worked out as per the statistical methods outlined by Gomez and Gomez (1984).

Correlation coefficient

$$r = \frac{SP\ (xy)}{\sqrt{SS\ (x)\ SS\ (y)}}$$

Where,

r	=	Coefficient of correlation
SP (xy)	=	Sum of products of x, y variable
SS (x)	=	Sum of square of x variable
SS (y)	=	Sum of square of y variable

Coefficient of determination

$$R^2 = \frac{SSR}{\Sigma y^2}$$

4 Results and Discussion

To study the boron status of soils of Jaipur district from groundnut growing areas, 59 surface samples (0-15 cm) were collected from fiftynine village of five tehsils. Out of the total samples, 11 from Amber, 12 from Chomu, 10 from Dudu, 10 from Jaipur and 16 from Phulera were collected. Plant samples from the same fields were also collected at peg initiation stages. These soils samples were analysed for physico-chemical properties and different forms of boron. Plant samples were analysed for nutrient content. The pod yield was also recorded from each field at harvest.

The results obtained have been presented and discussed in this chapter under appropriate headings and attempt has been made to give suitable explanation for the observed parameters. The results are presented under following heading.

4.1 Physico-chemical properties of soil

4.1.1 Mechanical analysis

4.1.2 Soil reaction (pH_2)

4.1.3 Electrical conductivity (EC_2)

4.1.4 Cation exchange capacity (CEC)

4.1.5 Calcium carbonate ($CaCO_3$)

4.1.6 Organic carbon

4.1.7 Available nitrogen

4.1.8 Available phosphorus content (P_2O_5)

4.1.9 Available potassium content (K_2O)

4.1.10 Available Calcium

4.1 Physico-chemical properties of soil

The data on mechanical analysis, pH_2, electrical conductivity, cation exchange capacity, calcium carbonate, organic carbon, available nitrogen, available phosphorus, available potassium, available calcium and available magnesium are presented in Table 4.1 and 4.4. The range and mean values of the soil parameters have been computed tehsil wise and presented in Table 4.2 and 4.5.

4.1.1 Mechanical analysis

Mechanical analysis gives the percentage of sand, silt and clay fraction in soils and points to their textural classification.

The data related to mechanical composition (Table 4.1 and 4.2) revealed that sand content in different soils of Jaipur district ranged between 79.0-85.29 per cent with the mean value of 82.57 per cent. The minimum (79.00) and maximum (85.29) sand per cent was found in soils of village Bai ka bas (C_{10}) of Chomu and Pratappura (A_{10}) of Amber, respectively. Data further indicated that maximum silt content (11.40 per cent) was recorded in soils of village Bai Ka bas (C_{10}) of Chomu tehsil whereas, minimum silt (7.91 per cent) was found in soils of village Pratappura (A_2) of Amber tehsil with the mean value of 9.41 per cent. A perusal of data in the same table indicated that clay content in soils of Jaipur district ranged from 6.30 to 9.1 per cent with the mean value of 7.51 per cent. Minimum clay content (6.3 per cent) was found in soils of village Pratappura (A_2) of Amber tehsil while, maximum clay (9.10 per cent) was in soils of village Bai ka bas (C_{10}) of Chomu tehsil.

Based on sand, silt and clay contents, these soils have been classified as sandy, loamy sand and sandy loam. Out of 59 surface

Table :4.1 Physico-chemical properties of soils under groundnut cultivation

S.No.	Name of village	Sample Code	pH_2	EC_2 (dSm^{-1})	$CaCO_3$ (%)	CEC (Cmol (p+) kg^{-1})	OC (%)	Sand (%)	Silt (%)	Clay (%)	Textural class
1	2	3	4	5	6	7	8	9	10	11	12
	Amber Tehsil										
1	Raithal	A_1	8.40	2.95	1.80	5.50	0.30	80.60	10.50	8.40	LS
2	Pratappura	A_2	8.70	1.80	3.00	3.90	0.18	85.29	7.91	6.30	S
3	Jalsu	A_3	8.40	2.65	1.30	5.40	0.28	83.00	9.30	7.20	LS
4	Atal Biharipura	A_4	8.60	2.50	2.50	6.80	0.31	80.40	10.50	8.60	LS
5	Moudi	A_5	8.60	2.57	2.80	4.00	0.24	83.90	8.60	7.00	LS
6	Jahota	A_6	8.20	3.54	1.30	4.00	0.23	84.10	8.40	7.00	LS
7	Devguda	A_7	8.60	2.32	2.80	3.90	0.24	83.54	8.81	7.15	LS
8	Mohanpura	A_8	8.20	3.64	1.30	4.90	0.28	83.40	8.90	7.20	LS
9	Anoochpura	A_9	8.50	2.75	2.30	4.00	0.25	84.00	8.50	7.00	LS
10	Mukandpura	A_{10}	8.60	2.55	3.00	3.70	0.24	83.80	8.70	7.00	LS
11	Anopura	A_{11}	8.50	2.81	2.80	4.20	0.25	83.80	8.60	7.10	LS
	Chomu Tehsil										
12	Gulabbadi	C_1	8.50	2.85	2.00	3.60	0.17	84.20	8.50	6.80	LS
13	Tankarda	C_2	8.60	2.55	2.10	4.10	0.25	83.70	8.70	7.10	LS
14	Jai Singhpura	C_3	8.50	2.80	2.00	4.30	0.21	84.88	8.12	6.50	LS
15	Devpura	C_4	8.20	3.50	1.80	4.40	0.22	84.85	8.15	6.50	LS
16	Loharwara	C_5	8.30	3.40	2.00	3.50	0.19	85.10	8.00	6.40	LS
17	Naya bas	C_6	8.50	2.80	3.80	4.70	0.30	80.95	10.30	8.25	LS
18	Udaipuriya	C_7	8.50	2.59	3.20	5.10	0.32	80.70	10.40	8.40	LS
19	Kanarpura	C_8	8.60	2.48	4.50	4.10	0.25	83.50	8.90	7.10	LS
20	Kaladera	C_9	8.20	3.45	2.00	4.50	0.29	81.50	10.00	8.00	LS
21	Bai Ka Bas	C_{10}	8.40	2.90	3.30	5.70	0.40	79.00	11.40	9.10	SL
22	Thodsar	C_{11}	8.20	3.50	2.30	4.90	0.34	80.15	10.75	8.60	LS
23	Bada ki Badi Dhani	C_{12}	8.60	2.59	3.50	4.50	0.29	80.80	10.50	8.20	LS

Contd....

1	2	3	4	5	6	7	8	9	10	11	12
	Dudu Tehsil										
24	Devala	D_1	8.30	3.48	2.00	4.20	0.22	83.75	8.75	7.00	LS
25	Jhama	D_2	8.70	1.65	3.30	4.40	0.22	83.60	8.80	7.10	LS
26	Kesari Singhpura	D_3	8.60	2.20	3.50	4.10	0.25	83.55	8.80	7.15	LS
27	Begus	D_4	8.40	2.90	3.10	3.70	0.19	84.20	8.50	6.80	LS
28	Mehala	D_5	8.40	2.95	3.30	4.50	0.23	83.70	8.80	7.00	
29	Kharaniya ki dhani	D_6	8.50	2.75	3.80	4.40	0.23	83.85	8.60	7.05	LS
30	Surpura	D_7	8.20	3.35	2.00	5.00	0.31	81.40	10.10	8.00	LS
31	Chandramanpura	D_8	8.50	2.64	3.30	4.00	0.21	82.50	9.45	7.55	LS
32	Aydan Ka bas	D_9	8.20	3.10	1.30	4.20	0.22	82.40	9.50	7.60	LS
33	Kheri Alufa	D_{10}	8.40	2.95	2.00	4.40	0.24	82.05	9.65	7.80	LS
	Jaipur Tehsil										
34	Lalpura	J_1	8.40	2.54	3.20	5.00	0.28	81.50	10.00	8.00	LS
35	Mandabhopawas	J_2	8.30	3.24	2.50	4.40	0.26	81.70	9.90	7.90	LS
36	Pachar	J_3	8.40	2.80	3.30	4.20	0.22	82.25	9.60	7.65	LS
37	Ramsinghpura	J_4	8.40	2.84	3.50	4.90	0.27	81.60	10.00	7.90	LS
38	Ramkui	J_5	8.50	2.90	4.00	4.60	0.26	81.90	9.80	7.80	LS
39	Mehraya Ka Bas	J_6	8.60	2.78	4.50	2.00	0.30	81.30	10.10	8.10	LS
40	Fathehpura	J_7	8.40	2.90	3.50	4.50	0.26	81.75	9.90	7.85	LS
41	Himmatpura	J_8	8.50	2.75	3.80	4.20	0.25	82.05	9.70	7.75	LS
42	Kalwar	J_9	8.30	3.45	2.50	4.10	0.23	82.15	9.65	7.70	LS
43	Ramla Ka Bas	J_{10}	8.50	2.80	2.50	4.80	0.26	81.90	9.80	7.80	LS

Contd....

1	2	3	4	5	6	7	8	9	10	11	12
	Phulera Tehsil										
44	Dhakawala	P_1	7.80	3.65	1.30	4.90	0.25	81.98	9.80	7.72	LS
45	Kalkh	P_2	7.90	3.52	1.00	5.00	0.26	81.73	9.92	7.85	LS
46	Murlipura	P_3	8.40	2.74	4.00	5.10	0.30	81.30	10.10	8.10	LS
47	Math	P_4	8.10	3.18	1.50	5.00	0.28	81.38	10.12	8.00	LS
48	Kesha ka bas	P_5	8.10	2.17	1.50	4.40	0.25	82.55	9.45	7.50	LS
49	Basdi Kalan	P_6	8.10	1.75	1.30	4.00	0.21	83.40	9.10	7.00	LS
50	Dungari Kalan	P_7	8.40	2.85	3.00	5.00	0.27	82.35	9.55	7.60	LS
51	Kheerava	P_8	8.50	4.33	3.30	5.40	0.31	81.25	10.15	8.10	LS
52	Hingonia	P_9	8.40	3.20	2.50	4.50	0.25	82.45	9.50	7.55	LS
53	Bobas	P_{10}	8.20	1.98	1.50	4.80	0.26	82.25	9.65	7.60	LS
54	Gokulpura	P_{11}	8.70	1.03	4.00	5.00	0.27	82.18	9.70	7.62	LS
55	Ghatolai	P_{12}	8.10	2.15	1.30	4.00	0.21	83.38	9.12	7.00	LS
56	Kalkh	P_{13}	8.30	2.59	1.50	5.20	0.30	81.40	10.10	8.00	LS
57	Kuchchaybas	P_{14}	8.70	2.29	5.30	5.00	0.29	81.80	9.80	7.90	LS
58	Josibas	P_{15}	8.50	3.53	4.00	3.00	0.12	84.85	8.40	6.25	LS
59	Bassi Nagan	P_{16}	8.50	1.51	4.20	4.20	0.23	83.25	9.15	7.10	LS

S = Sandy, LS = Loamy sand, SL = Sandy loam

Table : 4.2 Tehsil wise range and mean value of physico-chemical properties of soil under groundnut cultivation

S.No	Sampling site	pH_2	EC_2 (dSm^{-1})	$CaCO_3$ (%)	CEC (Cmol (p+) kg^{-1})	Organic carbon (%)	Sand (%)	Silt (%)	Clay (%)
1	**Amber tehsil**								
	Minimum	8.20	1.80	1.30	3.70	0.18	80.60	7.91	6.30
	Maximum	8.70	3.64	3.00	6.80	0.31	85.29	10.50	8.60
	Mean	-	2.73	2.26	4.57	0.25	83.26	8.97	7.27
	CV	-	18.96	31.25	21.20	14.31	1.77	9.21	9.05
2	**Chomu**								
	Minimum	8.20	2.48	1.80	3.50	0.17	79.00	8.00	6.40
	Maximum	8.60	3.50	4.50	5.70	0.40	85.10	11.40	9.10
	Mean	-	2.95	2.71	4.45	0.27	82.44	9.48	7.58
	CV	-	13.54	33.38	13.80	24.87	2.60	12.66	12.47
3	**Dudu**								
	Minimum	8.20	1.65	1.30	3.70	0.19	81.40	8.50	6.80
	Maximum	8.70	3.48	3.80	5.00	0.31	84.20	10.10	8.00
	Mean	-	2.80	2.76	4.29	0.23	83.10	9.10	7.31
	CV	-	19.29	30.75	8.03	13.75	1.12	5.90	5.49
4	**Jaipur**								
	Minimum	8.30	2.54	2.50	2.00	0.22	81.30	9.60	7.65
	Maximum	8.60	3.45	4.50	5.00	0.30	82.25	10.10	8.10
	Mean	-	2.90	3.33	4.27	0.26	81.81	9.85	7.85
	CV	-	8.96	20.47	20.03	8.81	0.36	1.67	1.74
5	**Phulera**								
	Minimum	7.80	1.03	1.00	3.00	0.12	81.25	9.12	7.00
	Maximum	8.70	4.33	5.30	5.40	0.31	84.85	10.15	8.10
	Mean	-	2.65	2.58	4.66	0.25	82.34	9.60	7.56
	CV	-	33.39	53.86	13.15	18.31	1.19	4.98	6.63
	Mean	-	**2.80**	**2.70**	**4.47**	**0.25**	**82.57**	**9.41**	**7.51**

Table : 4.3 Classification of soil according to their texture

S.No.	Tehsils	Sandy	Loamy sand	Sandy loam	Total
1	Amber	1	10	0	11
2	Chomu	0	11	1	12
3	Dudu	0	10	0	10
4	Jaipur	0	10	0	10
5	Phulera	0	16	0	16
	Total	**1**	**57**	**1**	**59**

samples, one Sample falls in sandy, 57 samples in loamy sand and one sample in sandy loam, category. Therefore, the majority of soils belonged to loamy sand category (Table 4.3).

The data on mechanical analysis of soils revealed that these soils had been formed mostly from alluvial material and were thus, characterized coarse texture. On the basis of broad reconnaissance survey, Mathur *et al.* (1968) also classified the soils of Jaipur district in undifferentiated alluvial soil groups. These soils were sandy to sandy loam, however, majority of soils were loamy sand in texture, *i.e.* these were light in texture which reflect their immature character. Sand content was significantly and negatively correlated with silt (r=-0.996**) clay (r= -0.993) content, while, silt content positively and significantly correlated with clay (r= 0.979**) content of soil (Table 4.6). The results of present investigation found support from the findings of Kolarkar *et al.* (1989), Kameriya (1995) and Yadav and Vyas (1998).

4.1.2 Soil reaction (pH_2)

Soil reaction is one of the most important property of soil because it controls the availability of nutrients, microbial activities and physical conditions of soils upto a great extent. Soil reaction indicates the activities of H^+ and OH^- ions in soil solution.

A perusal of data given in Table 4.1 and 4.2 indicated that the lowest pH (7.80) was observed in soils of village Anopura (A_{11}), Begus (D_4) and Basdi Kalan (P_6) of Amber, Dudu and Phulera tehsil and highest (8.70) of it was found in of village Atalbiharipura (A_4) of Amber tehsil. The pH of soil samples varied from 8.20 to 8.70 in Amber, 8.20 to 8.60 in Chomu, 8.20 to 8.70 in Dudu, 8.30 to 8.60 in Jaipur and 7.80 to 8.70 in Phulera tehsil.

The pH_2 of soils of Jaipur district showed that these soils were alkaline in reaction. Relatively high pH_2 of these soils appeared due to medium to high degree of base saturation which on hydrolysis gives OH^- ions and high amount of carbonate and bicarbonate. The rainfall or irrigation applied might not have been sufficient to leach down bases and thus pH_2 maintained at relatively high level (Singh *et al.* 1997). The pH_2 was positively and significantly correlated (Table 4.6) with $CaCO_3$ (r=0.724), whereas, it was correlated negatively with EC_2 (r=-0.158), CEC (r=-0.147), silt (r=-0.158) and clay (r=-0.102). Tendency of soils for sodium adsorption on account of low organic carbon resulted in an increase in soil pH was also reported by Singh *et al.* (2009). These results get support from findings of Lal and Singh (1974), Bhargava and Sharma (1982) and More *et al.* (1988).

4.1.3 Electrical conductivity (EC_2)

Electrical conductivity of soils is a measure of the total concentration of soluble salts.

Data presented in Table 4.1 and 4.2 indicate that the lowest EC_2 (1.03 dSm^{-1}) was observed in soil of village Ghatolai (P_{12}) of Phulera tehsil and highest (4.33 dSm^{-1}) in soils of village Kheerava (P_8) of Phulera tehsil. The EC_2 in soil samples ranged from 1.80 to 3.64 in Amber, 2.48 to 3.50 in Chomu, 1.65 to 3.48 in Dudu, 2.54 to 3.45 in Jaipur and 1.03 to 4.33 dSm^{-1} in Phulera tehsil. The highest (2.95 dSm^{-1}) and lowest (2.65 dSm^{-1}) mean EC_2 (1.03 dSm^{-1}) value of soil was found in tehsil Chomu and Phulera, respectively.

A reference to data given in Table 4.1 revealed that the total soluble salts in terms of EC_2 in soils under study varied from low to moderate salinity. The lower EC_2 value of soil may be due to high leaching of soils afforded by their light texture as well as high permeability. On the other hand, high EC_2 value in soils as a result of irrigation with poor quality water and low lying area. Therefore, the EC_2 was positively correlated with silt (r= 0.109) content of soil. Similar findings were reported by Vyas *et al.* (1973), Kaushik and Shukla (1977), Tiwari *et al.* (1983), Dubey *et al.* (1984) and Sharma and Gangawar (1997).

4.1.4 Cation exchange capacity (CEC)

A perusal of data given in Table 4.1 and 4.2 revealed that the lowest CEC (2.00 cmol (p+) kg^{-1}) was observed in soils of village Mehraya Ka Bas (J_6) of Jaipur tehsil and highest (6.80 cmol (p^+) kg^{-1}) of it was found in soil of village Atal Biharipura (A_4) of Amber tehsil. The CEC of soil samples varied between 3.70 and 6.80 cmol (p^+) kg^{-1} in Amber, 3.50 and 5.70 cmol (p^+) kg^{-1} in Chomu, 3.70 and 5.00 cmol (p^+) kg^{-1} in Dudu, 2.00 and 5.00 cmol (p^+) kg^{-1} in Jaipur and 3.00 and 5.40 cmol (p^+) kg^{-1} in Phulera tehsil. The highest (4.66 cmol (p^+) kg^{-1} and lowest (4.27 cmol (p^+) kg^{-1}) mean CEC of soils was found in tehsil Phulera and Jaipur, respectively. Rather low CEC of these soils might be due to their coarse texture and low organic matter content presence of high amount of $CaCO_3$ and predominance of 1 : 1 type clay minerals (Nair and Chamuah, 1988 and Yadav and Meena 2009).

A significant and positive correlation (Table 4.6) was existed between CEC and silt (r= 0.592**), clay (r=0.611**) and OC (r=0.650**) of soil, but negatively correlated with sand content (r=-0.604**). Hence, CEC of soil increased with increase in silt, clay and OC content of soil due to increase in fineness of active surface area of soil particles and charge density of soil colloids on account of decreasing proton addition to the basic groups of soil (Srivastava and Srivastava, 1991 and Yadav and Meena, 2009).

4.1.5 Calcium carbonate ($CaCO_3$)

Calcium carbonate content of soil is a useful parameter to asses the extent of nutrient availability and their release behaviour. It was apparent from the data elucidated in Table 4.1 and 4.2 that the lowest amount of $CaCO_3$ (1.00 per cent) was observed in soils of village Kalkh (P_2) of Phulera tehsil and highest (5.30 per cent) amount of it was found in soil of village Kuchchaybas (P_{14}) of Phulera tehsil. The $CaCO_3$ content of soil samples varied from 1.30 to 3.00 per cent in Amber, 1.80 to 4.50 per cent in Chomu, 1.30 to 3.80 per cent in Dudu, 2.50 to 4.50 per cent in Jaipur and 1.00 to 5.30 per cent in Phulera tehsil. The highest (3.33 per cent) and lowest (2.26 per cent) mean $CaCO_3$ content in soils was found in tehsil Jaipur and Amber, respectively. Therefore, majority of soils of the area under investigation were non calcareous ($CaCO_3$ content < 5 per cent) in nature as per classification given by F.A.O. (1973).

The accumulation of $CaCO_3$ in soils might be due to semi-arid climatic condition. In arid and semi-arid regions, rainfall is less as compared to annual evapotranspiration, hence, less water is available for the leaching of insoluble carbonates and bicarbonates of calcium. This may have facilitated the accumulation of $CaCO_3$ in these soils (Dhir *et al.* 1979, Saxena and Singh, 1992 and Qureshi *et al.* 1996). This contention got support from the existence of positive and significant correlation between $CaCO_3$ and pH_2 (r= 0.724**) of soil. Since $CaCO_3$ is a salt of strong base and weak acid, which after hydrolysis produces more OH^- ions in soil solution, thus $CaCO_3$ increases the pH_2 of soils (More *et al.*, 1988).

4.1.7 Organic carbon (OC) content

A perusal of data given in Table 4.1 and 4.2 indicate that the lowest OC content (0.12 per cent) was observed in soils of village Josibas (P_{15}) of

Phulera tehsil and highest (0.40 per cent) in soil of village Bai ka Bas (C_{10}) of Chomu tehsil. The OC content of soil samples ranged from 0.18 to 0.31 per cent in Amber, 0.17 to 0.40 per cent in Chomu, 0.19 to 0.31 per cent in Dudu, 0.22 to 0.30 per cent in Jaipur and 0.12 to 0.31 per cent in Phulera tehsil. The mean highest (0.27 per cent) and lowest (0.23 per cent), OC content of soils was found in tehsil Chomu and Dudu, respectively. All the soil samples fall under low category of organic carbon. The low organic carbon content in the sandy soils might be due to the absence of stable aggregate (Jolivet *et al.* 1997), severe wind erosion (Wu and Tiessen, 2002), high microbial decay (Shephered *et al.* 2001) and high temperature of the region. This could be judged from negative and significant correlation of organic carbon with sand content (r = -0.847**) and positive and significant correlation with silt (r =0.821**) and clay (r=0.869**). The results of the present investigation are in close proximity with the findings of Kanthalia and Bhatt (1991), Singh *et al.* (1997), Meena *et al.* (2006), Yadav and Meena (2009) and Singh *et al.* (2009) who reported rapid oxidation of organic carbon of sandy soil in hot arid region.

4.1.8 Available nitrogen

Data on available nitrogen presented in Table 4.4 and 4.5 indicate that the lowest amount of available N (110.80 kg ha^{-1}) was observed in soils of village Basdi Kalan (P_{16}) Phulera tehsil and highest (138.10 kg ha^{-1}) amount of it was found in soil of village Surpura (D_7) Dudu tehsil. The available N content of soil samples varied from 120.00 to 136.80 kg ha^{-1} in Amber, 118.00 to 140.00 kg ha^{-1} in Chomu, 120.00 to 138.10 kg ha^{-1} in Dudu, 124.00 to 135.60 in Jaipur and 110.80 to 135.60 kg ha^{-1} in Phulera tehsil. The maximum (129.11 kg ha^{-1}) and minimum mean available N (124.80 kg ha^{-1}) value of soils was found in tehsil Jaipur and Dudu tehsil, respectively.

A reference to data given in Table 4.6 revealed that a positive and significant correlation was found between available N content of soil and CEC (r=0.557**), OC (r=0.830**), silt (r=0.717**) and clay (r=0.767**) but

Table : 4.4 Tehsil wise available nutrient content in soil of under groundnut cultivation

S.No.	Name of village	Sample Code	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Ca (mg/kg)	Mg (mg/kg)	S (mg/kg)
1	2	3	4	5	6	7	8	9
	Amber Tehsil							
1	Raithal	A_1	136.80	20.80	230.50	460.00	144.40	8.80
2	Pratappura	A_2	120.00	15.50	200.20	400.00	142.00	5.50
3	Jalsu	A_3	130.00	17.30	210.50	564.00	164.80	8.00
4	Atal Biharipura	A_4	135.60	25.80	225.50	616.00	166.00	8.50
5	Moudi	A_5	125.00	17.00	220.30	380.00	130.00	7.50
6	Jahota	A_6	120.00	12.60	215.20	400.00	142.00	7.20
7	Devguda	A_7	125.00	17.30	204.60	420.00	154.00	7.60
8	Mohanpura	A_8	130.00	19.20	210.20	340.00	126.40	8.00
9	Anoochpura	A_9	127.00	16.50	205.30	400.00	136.00	7.80
10	Mukandpura	A_{10}	126.00	17.30	200.00	360.00	130.00	7.70
11	Anopura	A_{11}	128.00	18.20	210.00	350.00	124.00	7.90
	Chomu Tehsil							
12	Gulabbadi	C_1	120.00	17.50	210.30	340.00	124.00	5.50
13	Tankarda	C_2	130.00	20.80	215.30	400.00	136.00	7.80
14	Jai Singhpura	C_3	120.00	15.80	200.00	410.00	137.20	7.30
15	Devpura	C_4	122.00	16.50	223.50	420.00	139.60	7.50
16	Loharwara	C_5	118.50	15.20	199.00	344.00	126.40	5.50
17	Naya bas	C_6	135.00	21.30	230.00	468.00	152.80	8.50
18	Udaipuriya	C_7	132.00	24.30	228.00	512.00	152.80	9.20
19	Kanarpura	C_8	125.00	19.80	220.50	424.00	144.40	8.00
20	Kaladera	C_9	135.60	20.70	210.10	448.00	137.20	9.00
21	Bai Ka Bas	C_{10}	140.00	25.80	230.80	566.00	145.60	12.50
22	Thodsar	C_{11}	135.00	22.50	225.00	484.00	146.80	10.60
23	Bada ki Badi Dhani	C_{12}	130.50	20.70	220.00	452.00	137.20	9.20

Contd….

1	2	3	4	5	6	7	8	9
	Dudu Tehsil							
24	Devala	D_1	120.00	16.50	210.30	424.00	136.00	6.90
25	Jharna	D_2	125.00	18.30	215.50	440.00	142.00	7.00
26	Kesari Singhpura	D_3	126.00	21.30	225.00	400.00	132.40	7.80
27	Begus	D_4	120.00	16.50	285.00	370.00	124.00	5.60
28	Mehala	D_5	122.00	17.50	202.60	426.00	132.40	7.70
29	Kharaniya ki dhani	D_6	125.00	18.00	203.30	440.00	134.80	7.60
30	Surpura	D_7	138.10	26.40	225.20	504.00	148.00	9.00
31	Chandramanpura	D_8	121.60	19.50	215.60	400.00	132.40	6.30
32	Aydan Ka bas	D_9	120.00	20.30	210.10	422.00	134.80	6.50
33	Kheri Alufa	D_{10}	130.30	22.30	220.50	436.00	136.00	7.60
	Jaipur Tehsil							
34	Lalpura	J_1	135.60	28.20	225.60	490.00	156.40	7.80
35	Mandabhopawas	J_2	130.40	26.28	220.80	450.00	136.00	7.50
36	Pachar	J_3	125.50	22.30	210.50	400.00	130.00	7.00
37	Ramsinghpura	J_4	130.60	25.20	210.50	500.00	144.40	8.20
38	Ramkui	J_5	128.60	24.10	210.00	460.00	138.40	8.00
39	Mehraya Ka Bas	J_6	132.60	25.20	210.20	500.00	144.40	9.50
40	Fathehpura	J_7	126.60	22.40	205.80	424.00	131.20	7.70
41	Himmatpura	J_8	125.00	22.60	20040.00	420.00	130.00	7.50
42	Kalwar	J_9	124.00	21.20	202.40	400.00	130.00	7.30
43	Ramla Ka Bas	J_{10}	132.20	25.30	213.10	440.00	136.00	7.80

Contd....

1	2	3	4	5	6	7	8	9
	Phulera Tehsil							
44	Dhakawala	P_1	128.60	22.30	220.70	480.00	145.60	7.60
45	Kalkh	P_2	130.50	23.80	215.00	490.00	148.00	7.70
46	Murlipura	P_3	130.60	24.60	209.00	480.00	149.20	8.50
47	Math	P_4	125.60	24.15	217.15	490.00	146.80	8.40
48	Kesha ka bas	P_5	120.00	19.60	215.30	442.00	139.60	8.10
49	Basdi Kalan	P_6	110.80	14.80	205.80	370.00	124.00	7.20
50	Dungari Kalan	P_7	126.00	27.60	220.40	510.00	148.00	8.20
51	Kheerava	P_8	130.60	28.50	220.80	530.00	140.80	9.50
52	Hingonia	P_9	120.00	18.80	220.40	430.00	139.60	7.90
53	Bobas	P_{10}	120.60	19.00	210.40	448.00	145.60	8.20
54	Gokulpura	P_{11}	128.00	28.90	220.40	500.00	148.00	8.30
55	Ghatolai	P_{12}	122.00	23.15	212.40	390.00	130.00	6.50
56	Kalkh	P_{13}	130.60	27.60	230.60	514.00	152.80	8.80
57	Kuchchaybas	P_{14}	135.60	30.11	230.60	482.00	143.20	8.10
58	Josibas	P_{15}	115.60	16.15	190.80	400.00	131.20	5.30
59	Bassi Nagan	P_{16}	130.60	28.50	205.80	420.00	130.00	6.50

Table : 4.5 Tehsil wise range and mean value of available nutrient content in soil under groundnut cultivation

S.No	Sampling site	Available N (kg/ha)	Available P_2O_5 (kg/ha)	Available K_2O (kg/ha)	Available Ca (mg/kg)	Available Mg (mg/kg)	Available S (mg/kg)
1	**Amber tehsil**						
	Minimum	120.00	12.60	200.00	340.00	124.00	5.50
	Maximum	136.80	25.80	230.50	616.00	166.00	8.80
	Mean	127.58	17.95	212.03	426.00	141.78	7.68
	CV	4.24	18.49	4.71	20.71	10.30	11.06
2	**Chomu**						
	Minimum	118.50	15.20	199.00	340.00	124.00	5.50
	Maximum	140.00	25.80	230.80	566.00	152.80	12.50
	Mean	128.63	20.08	217.71	440.00	140.00	8.38
	CV	5.67	16.51	5.01	14.78	6.47	23.49
3	**Dudu**						
	Minimum	120.00	16.50	202.60	370.00	124.00	5.60
	Maximum	138.10	26.40	285.20	504.00	148.00	9.00
	Mean	124.80	19.66	221.31	426.00	135.30	7.20
	CV	4.59	15.61	10.73	8.23	4.67	13.22
4	**Jaipur**						
	Minimum	124.00	21.20	202.40	400.00	130.00	7.00
	Maximum	135.60	28.20	285.00	500.00	156.40	9.50
	Mean	129.11	24.28	211.29	448.00	137.70	7.83
	CV	2.95	8.89	3.40	8.58	6.24	8.68
5	**Phulera**						
	Minimum	110.80	14.80	190.80	370.00	124.00	5.30
	Maximum	135.60	30.11	230.60	530.00	152.80	9.50
	Mean	125.36	23.60	215.35	462.00	141.40	7.80
	CV	5.28	20.38	4.58	10.41	5.95	13.05
	Mean	**126.98**	**21.28**	**203.68**	**442.00**	**139.50**	**7.80**

negatively correlated with sand content (r=-0.743**) of soil. The positive relationship between available N and organic carbon is due to the presence of soil nitrogen in the organic forms (Verma *et al.* 1980, Kanthaliya and be due to increased rate of denitrification at lower pH values (Tisdle, 1997). Similar results were also reported by Meena *et al.* (2006).

4.1.9 Available phosphorus content (P_2O_5)

A perusal of data given in Table 4.4 and 4.5 indicate that the lowest amount (12.60 kg ha^{-1}) of available P_2O_5 was recorded in soils of village Jahota (A_6) of Amber tehsil, whereas, highest amount of available P_2O_5 (30.11 kg ha^{-1}) was recorded in soils of village kuchchaybas (P_{14}) of Phulera tehsil. The available P_2O_5 content of soil samples varied between 12.60 kg ha^{-1} and 25.80 kg ha^{-1} in Amber, 15.20 and 25.80 kg ha^{-1} in Chomu, 16.50 and 26.40 kg ha^{-1} in Dudu, 21.20 and 28.20 kg ha^{-1} in Jaipur and 14.80 and 30.11 kg ha^{-1} in Phulera tehsils. (Table 4.5). The highest mean available P_2O_5 value (24.28 kg ha^{-1}) of soil was recorded in Jaipur tehsil while lowest (17.95 kg ha^{-1}) was in Amber tehsil. Thus, the soils of the study area were found to be medium in available P_2O_5. The range is quite large which might be due to variation in soil properties viz., pH, calcareousness, OC content, texture and various soil management and agronomical practices.

The data (Table 4.6) showed that available P_2O_5 content of soils gave significant and positive correlation with $CaCO_3$ (r=0.340**) CEC (r=0.487**), organic carbon (r=0.610**) silt (r=0.722**), clay (r=0.699**), N (r=0.690**), Ca (r=0.649**) Mg (r = 0.401**) and S (r=0.483**) but non-significant and positive correlation was observed with pH (r=0.054) while, it was correlated negatively with sand (r=-0.715**) content and EC (r= -0.084) of soil. Thus, the availability of phosphorus reduced with increase in salinity hazards of soils on account of the accumulation of soluble salts resulting into precipitation of phosphorus as Ca- phosphate thereby reduction in P availability. Furthermore, the availability of phosphorus also increased with increase in organic carbon due to, (i) formation of phosphorus humic complexes which are easily assimilated by plants, (ii) anions replacement of phosphate by humation and (iii) the coating of sesquioxide by particles of humus to form a protective cover and thus reduce the phosphorus fixing capacity of the soils (Gharu and Tarafdar, 2004). Similar findings were also reported by Kumar and Seth (1983), Singh and Sharma (1984), Akbari *et al.* (1993), Kameriya (1995) and Meena *et al.* (2006).

4.1.10 Available potassium content (K_2O)

A perusal of data given in Table 4.4 and 4.5 indicate that the lowest amount of available K_2O (190.80 kg ha^{-1}) was observed in soils of village Josibas (P_{15}) of tehsil Phulera and highest (285.20 kg ha^{-1}) was found in soil of village Begus (D_4) of tehsil Dudu. The available K_2O content of soil samples varied from 200.00 to 230.50 kg ha^{-1} in Amber, 199.00 to 230.80 kg ha^{-1} in Chomu, 202.60 to 285.00 kg ha^{-1} in Dudu, 202.40 to 225.60 kg ha^{-1} in Jaipur and 190.80 to 230.60 kg ha^{-1} in Phulera tehsil. The highest (221.31 kg ha^{-1}) and lowest mean available K_2O (211.29 kg ha^{-1}) was found in tehsil Dudu and Jaipur, respectively. The soils of Jaipur district found to be medium in available K_2O content. Since potassic fertilizers application is not the part of crop management in semi-arid and arid region of Rajasthan, crops are solely dependent on native stock. Depletion of soil potassium on account of inadequate fertilization and intensive cultivation in sandy soil was also reported by Singh *et al.* (2009).

A significant positive correlation was observed between available K_2O and organic carbon content (Table 4.6). This might be due to creation of favourable soil environment with the presence of high organic matter content of soil. Similar result was also reported by Meena *et al.* (2006). Available K_2O was also correlated positively with clay (r=0.348**) and silt content (r=0.314*), which might be due to the presence of most of the mica in finer fraction (Lodha and Seth, 1970 and Singh *et al.*, 1985).

4.1.11 Available Calcium

Data given in Table 4.4 and 4.5 indicate that the lowest amount of available Ca (340.00 mg kg^{-1}) was observed in soils of village Mohanpura (A_8) of Amber tehsil and highest (616.00 mg kg^{-1}) amount of it was found in soil of village Atalbiharipura (A_4) of Amber tehsil. The available Ca content of soil samples varied from 340.00 to 616.00 mg kg^{-1} in Amber, 340.00 to 566.00 mg kg^{-1} in Chomu, 370.00 to 504.00 mg kg^{-1} in Dudu, 400.00 to 500.00 mg kg^{-1} in Jaipur and 370.00 to 530.00 mg kg^{-1} in Phulera tehsil. The highest (462.00 mg kg^{-1}) and lowest mean available Ca (426.00 mg kg^{-1}) was found in tehsil Phulera, Amber and Dudu, respectively.

The correlation coefficients indicate (Table 4.6) that available Ca content was closely and positively correlated with CEC (r=0.698**) OC (r=0.725**), silt (r=0.737**), clay (r=723**), N (r=0.636**) and P_2O_5 (r=0.649**), Mg (r=0.850**), S (r = 0.664**) and K_2O (r = 0.274*), while, negatively related with sand (r=-0.735**) and soil pH (r=-0.017). The results are in close proximity of Gathala *et al.* (2004) and Hundal *et al.* (2006).

4.1.12 Available magnesium

A perusal of data given in Table 4.4 and 4.5 indicate that the lowest amount of available Mg (124.00 mg kg^{-1}) was observed in soils of village Anopura (A_9), Begus (D_4) and Basdi Kalan (P_{16}) of Amber, Dudu and Phulera tehsil, respectively and highest (166.00 mg kg^{-1}) amount of it was found in soil of village Atalbiharipura of Amber tehsil. The available Mg content of soil samples ranged from 124.00 to 166.00 mg kg^{-1} in Amber, 124.00 to 152.00 mg kg^{-1} in Chomu, 124.00 to 148.00 mg kg^{-1} in Dudu, 130.00 to 156.00 mg kg^{-1} in Jaipur and 124.00 to 152.80 mg kg^{-1} in Phulera tehsil. The maximum (141.78 mg kg^{-1}) and minimum mean available Mg (135.30 mg kg^{-1}) content was found in tehsil Dudu.

The correlation coefficients indicate (Table 4.6) that available Mg content was closely and positively correlated with CEC (r=0.606**) OC (r=0.586**) silt (r=0.504**), clay (r=0.515**) N (r=0.523**) and P_2O_5 (r=0.401**) Ca (r=0.850**) S (r=496**) while, negatively related with sand (r=-0.512**). The results also get supports from the findings of Gathala *et al.* (2004) and Hundal *et al.* (2006).

4.1.13 Available sulphur

It is evident from Table 4.4 and 4.5 that the lowest amount of available S (5.30 mg kg^{-1}) was observed in soils of village Josibas (P_{15}) of Phulera tehsil and highest (12.50 mg kg^{-1}) amount of it was found in soil of village Bai ka bas (C_{10}) of Chomu tehsil. The available S content of soil samples varied between 5.50 and 8.80 mg kg^{-1} in Amber, 5.50 and 12.5 mg kg^{-1} in Chomu, 5.60 and 9.00 mg kg^{-1} in Dudu, 7.00 and 9.50 mg kg^{-1} in Jaipur and 5.30 and 9.50 mg kg^{-1} in Phulera tehsil. The highest (8.38 mg kg^{-1}) and lowest mean available S (7.20 mg kg^{-1}) value of soils was found in tehsil Chomu and Dudu, respectively. Large variation in the available S content may be due to sporadic use of gypsum and or use of single super phosphate fertilizers to meet the S and P requirement of the crop.

The correlation coefficients indicate (Table 4.6) that available S content was positively and significantly correlated with CEC (r=0.529**),

Table 4.6 Interrelationship correlation between soil physico-chemical properties and available nutrient content in soil

	Soil properties								Available nutrient in soil						
	pH_2	EC_2 (dSm^{-1})	$CaCO_3$ (%)	CEC (Cmol (p+) kg^{-1}	OC (%)	Sand (%)	Silt (%)	Clay (%)	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)	Ca (mg/kg)	Mg (mg/kg)	S (mg/kg)	B (mg/kg)
pH	1.000	-0.455**	0.724**	-0.147	-0.032	0.134	-0.158	-0.102	0.121	0.054	-0.029	-0.017	0.016	-0.030	0.016
EC		1.000	-0.290*	0.051	0.097	-0.120	0.109	0.132	0.104	-0.084	0.026	0.028	-0.074	0.126	0.127
$CaCO_3$			1.000	-0.155	0.090	-0.117	0.113	0.121	0.221	0.340**	0.034	0.114	-0.008	0.096	0.177
CEC				1.000	0.650**	-0.604**	0.592**	0.611**	0.557**	0.487**	0.308*	0.698**	0.606**	0.529**	0.597**
OC					1.000	-0.847**	0.821**	0.869**	0.830**	0.610**	0.342**	0.725**	0.586**	0.943**	0.956**
Sand						1.000	-0.996**	-0.993**	-0.743**	-0.715**	-0.330*	-0.735**	-0.512**	-0.777**	-0.819**
Silt							1.000	0.979**	0.717**	0.722**	0.314*	0.737**	0.504**	0.757**	0.794**
Clay								1.000	0.767**	0.699**	0.348**	0.723**	0.515**	0.793**	0.839**
N									1.000	0.690**	0.323*	0.636**	0.523**	0.716**	0.820**
P										1.000	0.268*	0.649**	0.401**	0.483**	0.557**
K											1.000	-0.049	-0.129	-0.031	-0.022
Ca												1.000	0.850**	0.664**	0.683**
Mg													1.000	0.496**	0.527**
S														1.000	0.932**
B															1.000

* significant at 5 per cent level of probability
** significant at 1 per cent level of probability

OC (r=0.943**), silt (r=0.757**), clay (r=0.793**), N (r=0.716**), P_2O_5 (r=0.483**), Ca (r=0.664**) and Mg (r=496**) while, negatively related with sand (r=-0.777**). The negative correlation of available S with sand content indicates that soils dominant in sand fraction are devoid of S which is in accordance with the observation of Jat and Yadav (2006). Organic carbon and clay content were positively correlated with available S content of soil because organic matter could be a good reservoir or source of sulphur. Similar results were also reported by Jat and Yadav (2006), Sarkar *et al.* (2007) and Kour and Jalali (2008).

4.1.14 Classification of soils of Jaipur district according to fertility status

The nutrient indices for organic carbon, available N, available P_2O_5 and K_2O were calculated for surface soils of study area as proposed by Muhr *et al.* (1965) indicate that the nutrient indices for organic carbon, available nitrogen, available P_2O_5 and available K_2O were 1.00, 1.00, 1.33 and 2.00, respectively (Table 4.7). A perusal of data, further indicate that, 100, 100, 66.11 per cent soil samples were rated as low in OC, available nitrogen and P_2O_5 and 33.89 and 100 per cent as medium in available P_2O_5 and K_2O, respectively. None of the sample were rated as high with respect to OC, available, N, P_2O_5, and K_2O. Therefore, soils of the study area were found low in organic carbon, available N and P_2O_5 and medium in available K_2O status. The soils of Jaipur district were also classified into different fertility classes(Table 4.8)on the basis of general limits given by Tandon (1992). The soils contain N and P_2O_5 in low range as only 33.89 per cent samples were medium in available P_2O_5. The available K_2O content was found to be medium in all soils samples. Status of Ca and Mg

Table 4.7 Nutrient index for organic carbon, available N, P_2O_5 and K_2O of soils (Muhr *et al.* 1965)

Nutrient	Range	Sample (per cent)	Nutrient index
Organic carbon per cent			
	Low <0.5	100	1.00
	Medium 0.5-0.75	-	
	High > 0.75	-	
	Total	100	
Nitrogen (kg ha^{-1})			
	Low <280	100	1.00
	Medium 280-560	-	
	High > 560	-	
	Total	100	
Phosphorus (kg ha^{-1})			
	Low <20	66.11	1.33
	Medium 20-50	33.89	
	High > 50	-	
	Total	100.00	
Potassium (kg ha^{-1})			
	Low <125	-	2.00
	Medium 125-300	100	
	High > 300	-	
	Total	100	

Table 4.8 Fertility class of soils (% samples) under groundnut cultivation (Tandon, 1992)

Nutrient	Low	Medium	High	Critical level
N (kg ha^{-1})	100	-	-	280
P_2O_5 (kg ha^{-1})	66.11	33.89	-	23
K_2O (kg ha^{-1})	-	100	-	130
Ca (mg kg^{-1})	-	100	-	300
Mg (mg kg^{-1})	-	100	-	120
S (mg kg^{-1})	96.61	3.39	-	10

Table : 4.9 Tehsil wise available nutrient status (per cent sample) of soil (Tandon, 1992)

Available Nutrient	Category	Amber	Chomu	Dudu	Jaipur	Phulera
N	L (<280)	100	100	100	100	100
	M (280-560)	-	-	-	-	-
	H (>560)	-	-	-	-	-
P_2O_5	L (<20)	81.81	41.66	60	-	25
	M (20-50)	18.18	58.33	40	100	75
	H (>50)	-	-	-	-	-
K_2O	L (<125)	-	-	-	-	-
	M (125-300)	100	100	100	100	100
	H (>300)	-	-	-	-	-
Ca	L (<300)	-	-	-	-	-
	M	100	100	100	100	100
	H	-	-	-	-	-
Mg	L (<120)	-	-	-	-	-
	M	100	100	100	100	100
	H	-	-	-	-	-
S	L (<10)	100	83.33	100	100	100
	M (10-50)	-	16.66	-	-	-
	H (>50)	-	-	-	-	-

was medium indicating that there was not much leaching of bases About six per cent of the samples were low in available S. Data presented in Table 4.9 revealed that all sample (100%) of all tehsils under study were found low in available N, Ca and Mg content. The available P_2O_5 content was found low in 82, 42, 60 and 25 per cent in soils of Amber, Chomu, Dudu and Phulera tehsil, respectively, while, it was medium in 18, 58, 40, 100 and 75 per cent soils of Amber, Chomu, Dudu, Jaipur and Phulera teshil, respectively. Almost all samples (100%) of all tehsil were found under low category with respect to available S content except Chomu teshil in which about 17 per cent soil samples were rated as medium. This may be attributed to low organic matter content, alkaline reaction coupled with high temperature and light texture of the soils of district (Kumar and Seth, 1983). The low content and variations in nutrients in the groundnut cultivated soils may also be attributed to the differences in soil properties and management practices of crop. Similar finding were also reported by Gathala *et al.* (2004) in soils of Jaipur district under pomegranate orchard.

4.2 Status of available and different forms of boron

The samples from five tehsils of Jaipur district were analysed for available boron, readily soluble boron, specifically adsorbed boron, oxide bound boron, organically bound boron, residual boron and total boron.

4.2.1 Available boron

The highest value of 0.55 mg kg^{-1} was recorded in village Bai ka bas (C_{10}) of Chomu tehsil and the lowest value 0.25 mg kg^{-1} was recorded in village Begus (D_4) and Josibas (P_{15}) of Dudu and Phulera tehsil, respectively. The available boron content of soil surface ranged from 0.27 to 0.42 mg kg^{-1} in Amber, 0.26 to 0.55 mg kg^{-1} in Chomu, 0.25 to 0.41 mg

Table : 4.10 Available boron and different forms of boron in soils under groundnut cultivation

S.No.	Name of village	Sample Code	Available Boron (mg/kg)	Readily (mg kg^{-1})	Specifically (mg kg^{-1})	Oxide bound (mg kg^{-1})	Organically bound (mg kg^{-1})	Residual (mg kg^{-1})	Total (mg kg^{-1})
1	2	3	4	5	6	7	8	9	10
	Amber Tehsil								
1	Raithal	A_1	0.42	0.55	0.65	0.32	0.77	30.21	32.50
2	Pratappura	A_2	0.27	0.95	1.02	0.51	1.15	23.17	26.80
3	Jalsu	A_3	0.37	0.57	0.70	0.30	0.85	31.28	33.70
4	Atal Biharipura	A_4	0.41	0.72	0.95	0.42	1.02	27.89	31.00
5	Moudi	A_5	0.33	0.74	0.97	0.55	1.10	26.14	29.50
6	Jahota	A_6	0.33	0.50	0.65	0.31	0.79	33.75	36.00
7	Devguda	A_7	0.33	0.73	0.92	0.47	0.98	25.40	28.50
8	Mohanpura	A_8	0.38	0.41	0.65	0.31	0.78	34.65	36.80
9	Anoochpura	A_9	0.36	0.65	0.80	0.40	0.87	27.52	30.24
10	Mukandpura	A_{10}	0.33	0.72	0.93	0.45	1.12	25.48	28.70
11	Anopura	A_{11}	0.36	0.65	0.82	0.40	0.89	27.96	30.72
	Chomu Tehsil								
12	Gulabbadi	C_1	0.26	0.65	0.79	0.42	0.85	28.91	31.62
13	Tankarda	C_2	0.36	0.75	0.97	0.40	1.12	25.36	28.60
14	Jai Singhpura	C_3	0.32	0.65	0.82	0.41	0.95	28.37	31.20
15	Devpura	C_4	0.33	0.45	0.62	0.31	0.73	34.21	36.31
16	Loharwara	C_5	0.27	0.54	0.65	0.30	0.77	32.44	34.70
17	Naya bas	C_6	0.41	0.65	0.87	0.48	0.97	26.43	29.40
18	Udaipuriya	C_7	0.44	0.70	0.78	0.34	0.85	27.53	30.20
19	Kanarpura	C_8	0.38	0.75	0.91	0.42	0.99	25.33	28.40
20	Kaladera	C_9	0.40	0.50	0.65	0.38	0.75	33.52	35.80
21	Bai Ka Bas	C_{10}	0.55	0.57	0.72	0.39	0.78	31.04	33.50
22	Thodsar	C_{11}	0.44	0.42	0.59	0.31	0.65	35.83	37.80
23	Bada ki Badi Dhanni	C_{12}	0.40	0.80	0.87	0.45	0.95	26.03	29.10

Contd....

1	2	3	4	5	6	7	8	9	10
	Dudu Tehsil								
24	Devala	D_1	0.31	0.50	0.64	0.32	0.85	32.19	34.50
25	Jharna	D_2	0.32	0.95	1.02	0.55	1.15	22.13	25.80
26	Kesari Singhpura	D_3	0.35	0.85	0.98	0.45	1.10	25.02	28.40
27	Begus	D_4	0..25	0.58	0.72	0.35	0.81	29.74	32.20
28	Mehala	D_5	0.34	0.57	0.70	0.31	0.81	30.11	32.50
29	Kharaniya Ki Dhani	D_6	0.35	0.65	0.77	0.32	0.76	27.60	30.10
30	Surpura	D_7	0.41	0.45	0.59	0.30	0.69	33.77	35.80
31	Chandramanpura	D_8	0.30	0.69	0.82	0.41	0.95	27.33	30.20
32	Aydan Ka bas	D_9	0.32	0.46	0.59	0.31	0.69	34.65	36.70
33	Kheri Alufa	D_{10}	0.35	0.55	0.75	0.35	0.81	29.34	31.80
	Jaipur Tehsil								
34	Lalpura	J_1	0.40	0.57	0.75	0.37	0.82	29.49	32.00
35	Mandabhopawas	J_2	0.37	0.50	0.60	0.24	0.71	32.15	34.20
36	Pachar	J_3	0.32	0.55	0.68	0.35	0.75	32.07	34.40
37	Ramsinghpura	J_4	0.38	0.54	0.70	0.35	0.89	31.32	33.80
38	Ramkui	J_5	0.37	0.68	0.82	0.41	0.91	26.98	29.80
39	Mehraya Ka Bas	J_6	0.41	0.75	0.91	0.45	0.99	25.00	28.10
40	Fathehpura	J_7	0.37	0.55	0.70	0.35	0.91	29.59	32.10
41	Himmatpura	J_8	0.35	0.65	0.81	0.41	0.91	27.62	30.40
42	Kalwar	J_9	0.32	0.50	0.65	0.29	0.79	32.67	34.90
43	Ramla Ka Bas	J_{10}	0.37	0.65	0.80	0.45	0.92	27.68	30.50

Contd....

1	2	3	4	5	6	7	8	9	10
	Phulera Tehsil								
44	Dhakawala	P_1	0.35	0.48	0.29	0.15	0.35	36.93	38.20
45	Kalkh	P_2	0.37	0.40	0.40	0.25	0.52	36.93	38.50
46	Murlipura	P_3	0.40	0.65	0.82	0.40	0.95	27.38	30.20
47	Math	P_4	0.38	0.40	0.39	0.23	0.55	35.63	37.20
48	Kesha ka bas	P_5	0.34	0.38	0.25	0.12	0.35	36.80	37.90
49	Basdi Kalan	P_6	0.29	0.39	0.27	0.15	0.35	37.34	38.50
50	Dungari Kalan	P_7	0.31	0.57	0.71	0.31	0.78	30.53	32.90
51	Kheerava	P_8	0.42	0.65	0.85	0.46	0.95	27.19	30.10
52	Hingonia	P_9	0.38	0.55	0.71	0.32	0.82	29.80	32.20
53	Bobas	P_{10}	0.37	0.45	0.70	0.30	0.79	36.86	39.10
54	Gokulpura	P_{11}	0.38	0.90	1.00	0.55	1.15	23.90	27.50
55	Ghatolai	P_{12}	0.31	0.35	0.39	0.25	0.45	36.76	38.20
56	Kalkh	P_{13}	0.39	0.54	0.62	0.36	0.75	32.73	35.00
57	Kuchchaybas	P_{14}	0.41	0.95	1.05	0.49	1.15	22.56	26.20
58	Josibas	P_{15}	0.25	0.70	0.82	0.45	0.95	27.48	30.40
59	Bassi Nagan	P_{16}	0.32	0.68	0.85	0.41	0.98	25.28	28.20

Table : 4.11 Tehsil wise range and mean of available boron and different forms of boron in soil under groundnut cultivation

S.No.	Sampling site		Different forms of Boron (mg/kg)					
		Available Boron (mg/kg)	Readily (mg kg^{-1})	Specifically (mg kg^{-1})	Oxide bound (mg kg^{-1})	Organically bound (mg kg^{-1})	Residual (mg kg^{-1})	Total (mg kg^{-1})
1	2		3	4	5	6	7	8
1	**Amber Tehsil**							
	Minimum	0.27	0.41	0.65	0.30	0.77	23.17	26.80
	Maximum	0.42	0.95	1.02	0.55	1.15	34.65	36.80
	Mean	0.40	0.65	0.82	0.40	0.94	28.50	31.31
	CV	11.94	22.20	17.29	21.43	15.17	12.67	10.06
2.	**Chomu Tehsil**							
	Minimum	0.26	0.42	0.59	0.30	0.65	25.33	28.40
	Maximum	0.55	0.80	0.97	0.48	1.12	35.83	36.31
	Mean	0.40	0.62	0.77	0.38	0.86	29.58	32.22
	CV	21.11	19.93	16.09	15.12	15.64	12.52	10.22
3.	**Dudu Tehsil**							
	Minimum	0.25	0.45	0.59	0.30	0.69	22.13	25.80
	Maximum	0.41	0.95	1.02	0.55	1.15	34.65	36.70
	Mean	0.34	0.63	0.76	0.37	0.86	29.19	31.80
	CV	32.89	26.41	19.53	21.91	18.35	13.23	10.53
4.	**Jaipur Tehsil**							
	Minimum	0.32	0.50	0.60	0.24	0.71	25.00	28.10
	Maximum	0.41	0.75	0.91	0.45	0.99	32.67	34.90
	Mean	0.40	0.59	0.74	0.37	0.86	29.46	32.02
	CV	8.06	14.09	12.58	18.26	10.25	8.80	7.15
5.	**Phulera Tehsil**							
	Minimum	0.25	0.35	0.25	0.12	0.35	23.90	26.20
	Maximum	0.42	0.95	1.05	0.55	1.15	37.34	38.50
	Mean	0.35	0.57	0.63	0.33	0.74	31.51	33.77
	CV	13.35	32.09	41.98	39.74	37.61	16.96	13.49
	Mean	0.36	0.61	0.74	0.37	0.84	29.81	32.37

kg^{-1} in Dudu, 0.32 to 0.41 mg kg^{-1} in Jaipur and 0.25 to 0.42 mg kg^{-1} in Phulera tehsil. The highest mean value of 0.40 mg kg^{-1} was recorded in Amber, Chomu and Jaipur tehsil, respectively and lowest mean value of 0.34 mg kg^{-1} in Dudu tehsil and overall mean value was 0.36 mg kg^{-1}. The overall range was found to be 0.25 to 0.55 mg kg^{-1} (Table 4.10 and 4.11).

Silt content, clay content, CEC and OC were positively and significantly correlated with available boron content of soil with coefficient values of r = 0.794**, 0.839**, 0.597** and 0.956**, respectively, whereas, relationship with sand content was negatively significant (r=-0.819**) (Table 4.6). Many other workers have reported that fine textured soils contained more available boron than there coarse textured soils (Singh and Randhawa, 1979; Sharma and Bajwa, 1989). Available B content was not related significantly with pH_2 (r = 0.016). According to Hingston (1964) and Sims and Bingham (1967), boron retention, as a function of pH, was maximum between pH 7.5 to 8.5 and all the soil samples in present study are in this range, therefore this may explain the reason for the lower value of correlation coefficients. Positive but statistically non-significant relationship existed between available boron and EC_2 (r = 0.127) and $CaCO_3$ content (r= 0.127).

The availability of boron was enhanced by organic carbon and this might be because, boron forms temporally soluble complexes with organic matter through adsorption. Primarily, as borate complexes solubilize with compounds that contain cis-hydroxyl group such as: saccharides and as the organic matter is mineralized by micro-organisms, boron is released to readily available forms.

The multiple regression equations showed the relative importance of different soil properties on available boron (Table 4.13). It may be inferred

Table 4.13 Effect of soil properties on predictability of available boron and different forms of boron in soil

Forms of Boron	Regression equation	R^2
Available Boron		
	$Y_1 = 0.335 + 0.0088\ X_3$	0.031
	$Y_1 = 0.163 + 0.04379\ X_4$	0.356
	$Y_1 = 0.0785 + 1.099\ X_5$	0.913
	$Y_1 = -\ 0.138 + 0.0527\ X_6$	0.630
	$Y_1 = -0.169 + 0.0701\ X_7$	0.705
	$Y_1 = 0.279 - 0.0260\ X_1 + 0.01378\ X_2 + 0.019470\ X_3 + 0.04633 X_4$	0.465
	$Y_1 = -0.00765 + 0.00645 X_1 + 0.00568\ X_2 + 0.00413\ X_3 + 0.00495\ X_4 + 1.065\ X_5 + 0.00737\ X_6 - 0.00773310\ X_7$	0.923
Readily soluble boron		
	$Y_2 = -5.07 + 0.676\ X_1$	0.812
	$Y_2 = 0.948 - 0.122\ X_2$	0.242
	$Y_2 = 0.33 + 0.101\ X_3$	0.498
	$Y_2 = -4.17 + 0.57\ X_1 + 0.0272\ X_2 + 0.0\ 174\ X_3$	0.827
	$Y_2 = -3.71 + 0.52\ X_1 + 0.0288\ X_2 + 0.0263\ X_3 - 0.0130\ X_4 - 0.15\ X_5 - 0.0494\ X_6 + 0.0469\ X_7$	0.833
Specifically adsorbed boron		
	$Y_3 = -6.75 + 0.89\ X_1$	0.885
	$Y_3 = 1.035 - 0.107\ X_2$	0.117
	$Y_3 = 0.398 + 0.125\ X_3$	0.473
	$Y_3 = -7.21 + 0.93\ X_1 + 0.0336\ X_2 + 0.0961\ X_3$	0.894
	$Y_3 = -6.36 + 0.84\ X_1 + 0.0259\ X_2 + 0.0139\ X_3 + 0.0132\ X_4 + 0.33\ X_5 - 0.10\ X_6 + 0.0951\ X_7$	0.906
Oxide bound boron		
	$Y_4 = -3.154 + 0.419\ X_1$	0.762
	$Y_4 = 0.510 - 0.0516\ X_2$	0.106
	$Y_4 = 0.206 + 0.0592\ X_3$	0.414
	$Y_4 = -3.31 + 0.433\ X_1 + 0.01408\ X_2 + 0.00153\ X_3$	0.768
	$Y_4 = -3.438 + 0.447\ X_1 + 0.0151\ X_2 - 0.00102\ X_3 - 0.00374\ X_4 + 0.125\ X_5 + 0.0223\ X_6 - 0.0291 X_7$	0.770

51568

Contd....

Organically bound boron		
	$Y_5 = -6.732+0.902\ X_1$	0.836
	$Y_5 = 1.138-0.105X_2$	0.105
	$Y_5 = 0.510+0.123\ X_3$	0.423
	$Y_5 = -7.469 + 0.979\ X_1 + 0.0381\ X_2 - 0.0063\ X_3$	0.847
	$Y_5 = -6.758 + 0.917\ X_1 + 0.0370\ X_2 + 0.00590\ X_3 + 0.0172X_4 + 0.431X_5 - 0.0389\ X_6 -0.0056X_7$	0.856
Residual boron		
	$Y_6 = 197.821 - 20.001\ X_1$	0.903
	$Y_6 = 21.743+2.887X_2$	0.173
	$Y_6 = 38.222-3.110X_3$	0.594
	$Y_6 = 178.78 - 17.482\ X_1 -0.0835X_2 - 0.697X_3$	0.917
	$Y_6 = 165.72-16.22X_1 +0.00425X_2 - 0.885X_3 - 0.0488X_4 + 0.912X_5 + 1.499\ X_6 - 1.516X_7$	0.922
Total boron		
	$Y_7 = 176.098- 17.11\ X_1$	0.887
	$Y_7 = 25.375+2.501X_2$	0.174
	$Y_7 = 39.668-2.701X_3$	0.602
	$Y_7 = 156.61- 14.56\ X_1 - 0.0250X_2 -0.68X_3$	0.906
	$Y_7 = 145.44- 13.48X_1- 0.0534X_2 -0.83X_3 - 0.00917X_4 + 1.64X_5 +1.32X_6 -1.40X_7$	0.911

Y_1	=	Available boron			
Y_2	=	Readily soluble boron	X_1	=	pH
Y_3	=	Specifically adsorbed boron	X_2	=	EC
Y_4	=	Oxide bound boron	X_3	=	CaCO3
Y_5	=	Organically bound boron	X_4	=	CEC
Y_6	=	Residual boron	X_5	=	Organic carbon
Y_7	=	Total boron	X_6	=	Silt
			X_7	=	Clay

that simultaneous effect of pH_2, EC_2, $CaCO_3$, CEC, OC, silt and clay accounted for 92.3 per cent variation in available boron content in soil. Soil organic carbon contact alone caused 91.3 per cent variation in available boron content followed by clay content (70.5 per cent) and silt content (63.0 per cent). These equations indicated that OC, CEC and clay content were dominant variable in contribution of available boron. Which may be attributed to the formation of soluble boron–organic complexes. Association of B with organic matter prevents its leaching and resulted into its accumulations in surface soil. Significant positive relationship between organic carbon and available boron confirms the fact that organic matter is one of the main source of available boron in soil. A large amount of total boron is held in organic matter and the available boron is largely released by microbial action (Tisdle *et al.* 1985). Positive association between organic carbon and available boron in arid soils of Rajasthan was also reported by Choudhary and Shukla (2004). The results corroborative of the findings of Choudhary and Shukla (2004), Arora and Chahal (2007), Yadav and Meena (2009).

4.2.2 Readily soluble boron

The data presented in Table 4.10 and 4.11 indicated that the minimum content of readily soluble boron was recorded as 0.35 mg kg^{-1} in village Ghatolai (P_{12}) of Phulera tehsil and maximum as 0.95 mg kg^{-1} in village Pratappura (A_2), Jharna (D_2), Kuchchybas (P_{14}) of Amber, Dudu and Phulera tehsil, respectively. The readily soluble boron content of soil samples varied from 0.41 to 0.95 mg kg^{-1} in Amber, 0.42 to 0.80 mg kg^{-1} in Chomu, 0.45 to 0.95 mg kg^{-1} in Dudu, 0.50 to 0.75 mg kg^{-1} in Jaipur and 0.35 to 0.95 mg kg^{-1} in Phulera tehsil. The overall readily soluble boron content ranged from 0.35 to 0.95 mg kg^{-1} with the mean value of 0.61 mg kg^{-1}.

A perusal of data in Table 4.12 indicate a positive and significant correlation of readily soluble boron with pH (r=0.901**) and $CaCO_3$ content (r=0.706**), On the other hand, it was negatively related with EC (r=-0.492**). These results corroborate the findings of Hou *et al.* 1994, Datta *et al.* (2002), Choudhary and Shukla (2004) and Sharma and Katyal (2006) who observed a significant and positive correlation between readily soluble boron and pH of soil.

Stepwise regression analysis (Table 4.13) indicate that soil properties (pH_2, EC_2, $CaCO_3$, CEC, OC, silt and clay) jointly contributing 83.30 per cent variation in readily soluble boron content and the partial contribution of pH_2, EC_2 and .$CaCO_3$ were 8.12, 24.2 and 49.8 per cent, respectively. The combined effect of pH2, EC_2 and $CaCO_3$ content of soil accounted for about 82.7 per cent.

4.2.3 Specifically adsorbed boron

The data given in Table 4.10 and 4.11 indicated that the minimum content of specifically adsorbed boron was recorded as 0.25 mg kg^{-1} in village Kesha ka Bas (P_5) of Phulera tehsil and maximum as 1.05 mg kg^{-1} in village Kuchchaybas (P_{14}) of Phulera tehsil. The specifically adsorbed boron of soil samples ranged from 0.65 to 1.02 mg kg^{-1} in Amber, 0.59 to 0.97 mg kg^{-1} in Chomu, 0.59 to 1.02 mg kg^{-1} in Dudu, 0.60 to 0.91 mg kg^{-1} in Jaipur and 0.25 mg kg^{-1} to 1.05 mg/kg in Phulera tehsil. The overall readily soluble boron content ranged from 0.25 to 1.05 mg kg^{-1} with the mean value of 0.74 mg kg^{-1}.

A perusal of data in Table 4.12 indicate a positive and significant correlation of specifically adsorbed boron with pH (r=0.941**), $CaCO_3$ (r=0.688**), readily soluble (r=0.900**), oxide bound (r=0.932**) and organically bound (r=0.978**), but it showed a non significant positive correlation with OC (r=0.009) and sand (r=0.131). On the other hand, it was negatively related with EC (r=-0.342**), CEC (r=-0.108) silt (r=-0.163), clay (r=-0.090), residual boron (r=-0.929**) and total boron (r=-0.909**) content of soil Multiple regression analysis also showed that soil properties (pH_2, EC_2, $CaCO_3$, CEC, OC, silt and clay) jointly contributing 90.60 per cent variation in available boron content and the partial contribution of pH_2, EC_2 and $CaCO_3$ individually was 88.5, 11.7 and 47.7 per cent respectively (Table 4.13).

The simultaneous effect of pH, EC and $CaCO_3$ content accounted for 89.4 per cent variation in specifically adsorbed boron (Table 4.16) Hou *et al.* (1994) postulated that this fraction includes desorbed B from inorganic constituents such as hydrous oxides through legend exchange reactions and established a positive and significant relationship of specifically adsorbed B with pH of soil, while, Datta *et al.* (2002) could not establish any relationship between specifically adsorbed B and soil properties. This fraction of B probably originated from weak binding sites of both organic and inorganic constituents. The results are in conformity with the findings of Hou *et al.* (1994 and 1996) and Choudhary and Shukla (2003 and 2004a).

4.2.4 Oxide bound boron

The data given in Table 4.10 and 4.11 indicate that the minimum content of oxide bound boron was recorded in 0.12 mg kg^{-1} in Kesha Ka Bas (P_5) of Phulera tehsil and maximum as 0.55 mg kg^{-1} in villages Moudi (A_5), Jhama (D_2) and Gokulpura (P_{11}) of Amber, Dudu and Phulera tehsil respectively. The oxide bound boron content of soil samples varied between 0.30 and 0.55 mg kg^{-1} in Amber, 0.30 and 0.48 mg kg^{-1} in Chomu, 0.30 and 0.55 mg kg^{-1} in Dudu, 0.24 and 0.45 mg kg^{-1} in Jaipur and 0.12 and 0.55 mg kg^{-1} in Phulera. The overall oxide bound boron content ranged from 0.12 to 0.55 mg kg^{-1} with the mean value of 0.37 mg kg^{-1}.

A perusal of data in Table 4.12 indicate a positive and significant correlation of oxide bound boron with pH (r=0.873**), $CaCO_3$ (r=0.644**), readily soluble boron (r=0.860**), specifically adsorbed boron (r=0.932**) and organically bound (r= 0.919**). It was negatively related with residual boron (r = -0.878**) and total boron content (r=-0.857**). The multiple regression analysis (Table 4.13) also indicate that combined effect of (pH_2, EC_2, $CaCO_3$, CEC, OC, silt and clay accounted for about 77.00 per cent variation in oxide bound boron content. While, pH_2, EC_2 and $CaCO_3$ content of soil jointly contributed 76.8 per cent variation in oxide bound boron content. The regression equations further indicated that 76.2, 10.6 and 41.4 per cent variation in oxide bound boron was due to the pH_2, EC_2 and $CaCO_3$ content, respectively. The equations also showed that with a unit increase in pH_2 of soil, the increase in oxide bound boron content was 0.762 mg kg-^{1} followed by $CaCO_3$ content (0.414 mg kg-^{1}). As NH_4- oxalate can solubilize non-crystalline and amorphous oxides of Fe and Al from soils, the relationship of oxide bound boron with pH is a logical one as adsorption of boron both as $B(OH)_3$ and $B(OH)_4$ species takes place on oxides via ligand exchange (Su and Suarez, 1995).

4.2.4 Organically bound boron

The data presented in Table 4.10 and 4.11 revealed that the minimum content of organically bound boron was recorded as 0.35 mg kg^{-1} in Basdi Kalan (P_6) of Phulera tehsil and maximum as 1.15 mg kg^{-1} in village Gokulpura (P_{11}), Jharna(D_2) and Pratappura (A_2) of Phulera, Dudu and Amber tehsil, respectively. The organically bound boron content soil samples varied from 0.77 to 1.15 mg kg^{-1} in Amber, 0.65 to 1.12 mg kg^{-1} in Chomu, 0.69 to 1.15 mg kg^{-1} in Dudu, 0.71 to 0.99 mg kg^{-1} in Jaipur and 0.35 to 1.15 mg kg^{-1} in Phulera. The overall organically bound boron content ranged from 0.35 to 1.15 mg kg^{-1} with the mean value of 0.84 mg kg^{-1}.

A perusal of data in correlation matrix (Table 4.12) revealed a positive and significant correlation of organically bound boron with pH (r= 0.914**), $CaCO_3$ (r=0.651**), available boron (r=0.794**), readily soluble boron (r=0.874**), specifically adsorbed boron (r=0.978**) and oxide bound boron (r=0.919**) on the other hand it was related negatively with residual boron (r= -0.905**), total boron (r= -0.883**) and EC_2 (r= -0.324*).

Stepwise regression analysis (Table 4.13) indicate that soil properties (pH_2, EC_2, $CaCO_3$, CEC, OC, silt and clay) jointly contributing 85.60 per cent variation in organically bound boron content in the soil. Regression analysis also showed that pH_2 of soil alone accounted for 83.6 variability in organically bound B fraction indicating pH as major contributor to this fraction. Inclusion of EC_2 and $CaCO_3$ with pH_2 improved the prediction value to 84.7 per cent. The contribution of pH to this fraction may be explained in terms of close association of pH with $CaCO_3$ content. Similar results have also been reported by Hou *et al.* (1994).

4.2.6 Residual boron

The minimum content of residual boron was recorded as 22.13 mg kg^{-1} in village Jharna (D_2) of Dudu tehsil and maximum as 37.34 mg kg^{-1} in village Basdi Kalan (P_6) of Phulera tehsil. The residual boron content of soil samples ranged from 23.17 to 34.65 mg kg^{-1} in Amber, 25.33 to 35.83 mg kg^{-1} in Chomu, 22.13 to 34.65 mg kg^{-1} in Dudu, 25.00 to 32.67 mg kg^{-1} in

Jaipur and 23.90 to 37.34 mg kg^{-1} in Phulera. The overall organically bound boron content ranged from 22.13 to 37.34 mg kg^{-1} with the mean value of 29.81 mg kg^{-1} (Table 4.10 and 4.11).

The positive and significant correlation of residual boron with EC (r=0.416**) and total boron (r= 0.999**) was existed but negative and significant correlation with pH (r= -0.950**), $CaCO_3$ (r= -0.771**), readily soluble boron (r= 0.949**), specifically (r =-0.929**), oxide bound boron (r= -0.878**) and organically bound boron (r= - 0.905**) was observed (Table 4.12).

The stepwise regression analysis (Table 4.13) indicates that soil properties (pH_2, EC_2 and $CaCO_3$) jointly contributing 91.70 per cent variation in residual boron content and inclusion of CEC, OC, silt and clay content as another variables with pH, EC and $CaCO_3$ improved the prediction value to 92.20 per cent indicating that these soil characteristics failed to establish any relationship with residual boron. Hou *et al.* (1994) also failed to establish any relationship of residual B with soil characteristics.

4.2.7 Total boron

Total boron content of the soil depends upon the parent material (Aubert and Pinta, 1977) of soil derived from sedimentary rocks or those of arid and semi-arid climatic conditions contain higher content of total boron.

The data given in Table 4.10 and 4.11 indicate that the minimum content (25.80 mg kg^{-1}) of total boron was recorded in village Jharna (D_2) of Dudu tehsil and maximum (38.50 mg kg^{-1}) in village Basdi Kalan (P_6) of Phulera tehsil. The total boron content of soil samples varied from 26.80 to 36.80 mg kg^{-1} in Amber, 28.40 to 36.31 mg kg^{-1} in Chomu, 25.80 to 36.70

mg kg^{-1} in Dudu, 28.10 to 34.90 mg kg^{-1} in Jaipur and 26.20 to 38.50 mg kg^{-1} in Phulera. The overall total boron content ranged from 25.80 to 38.50 mg kg^{-1} with the mean value of 32.37 mg kg^{-1}. The magnitude of total boron in the present study appears to be quite comparable to those reported earlier Singh and Randhawa (1977) reported that total boron in the saline-alkali soils of Punjab varied from 14.0 to 81.3 mg kg^{-1}. The total boron content in arid soils of Rajasthan was found to vary between 25.78 to 35.01 mg kg^{-1} (Choudhary and Shukla, 2004).

As evident from Table 4.14 the soils under groundnut cultivation had highest traction of residual boron (92.11 per cent) followed by organically bound boron (2.60 per cent), specifically adsorbed boron (2.27 per cent), readily soluble boron (1.87 per cent) and oxide bound boron (1.13 per cent) of the total boron content indicating the major fraction in soils was the residual boron. Similar results were also reported by Choudhary and Shukla (2004a) and Moafouryan and Shukla (2004).

Table 4.14 Percentage of different forms of boron to total boron

Forms of boron	Percentage
Readily soluble boron	1.87
Specifically adsorbed boron	2.27
Oxide bound boron	1.13
Organically bound boron	2.60
Residual boron	92.11

A positive and significant correlation (Table 4.12) between total boron and EC (r=0.417**) and residual boron (r= 0.999**) was existed but negative and significant correlation between total boron and pH (r= -0.942**), $CaCO_3$ (r= -0.776**), readily soluble boron (r= -0.941**), specifically bound boron (r =-0.909**), oxide bound boron (r= -0.857**) and organically bound boron (r= - 0.883**) was existed.

The results suggest a dynamic equilibrium among them and thus, any decrease or increase in the level of one form will influence the level of the other forms in these soils (Hadwani *et al.* 1989 and Tsadidas, 1994). The total boron content was correlated positively with OC, CEC, silt and clay content of soil but non-significantly. This shows that total boron was poorly associated with finer fractions of the soil. Although total boron does not affect the plant growth and its contribution is low as compared to other forms of boron but it helps in knowing its potential reserve in soil. Similar results were also reported by Choudhary and Shukla (2004a), Moafpouryan and Shukla (2004) and Arora and Chahal, 2007).

For the variation in the amount of total boron, pH_2 and $CaCO_3$ content of soil were the best predicators. Simple linear regression equation (Table 4.13) indicate that pH_2 of soil showed negative and significant correlation with total boron. The highest relationship was observed with pH_2 (R^2 = 0.887) followed by $CaCO_3$ (R^2 = 0.602) *i.e.* 88.7 and 60.2 per cent variation in total boron content, respectively. These three soil characteristics jointly contributed 90.6 per cent variation in total boron. But inclusion of CEC, OC, silt and clay could not improve the prediction value remarkably (R^2 = 0.911).

Table 4.12 Correlation among soil physico-chemical properties and different forms of Boron

	pH_2	EC_2 (dSm^{-1})	$CaCO_3$ (%)	CEC (Cmol (p+) kg^{-1}	OC (%)	Sand (%)	Silt (%)	Clay (%)	Av. boron (mg kg^{-1})	Readily (mg kg^{-1})	Specifically (mg kg^{-1})	Oxide (mg kg^{-1})	Organically (mg kg^{-1})	Residual (mg kg^{-1})	Total (mg kg^{-1})
pH	1.000	-0.455**	0.724**	-0.147	-0.032	0.134	-0.158	-0.102	0.016	0.901**	0.941**	0.873**	0.914**	-0.950**	-0.942**
EC		1.000	-0.290*	0.051	0.097	-0.120	0.109	0.132	0.127	-0.492**	-0.342**	-0.326*	-0.324**	0.416**	0.417**
$CaCO_3$			1.000	-0.155	0.090	-0.117	0.113	0.121	0.177	0.706**	0.688**	0.644**	0.651**	-0.771**	-0.776**
CEC				1.000	0.650**	-0.604**	0.592**	0.611**	0.597**	-0.140	-0.108	-0.127	-0.112	0.174	0.181
OC					1.000	-0.847**	0.821**	0.869**	0.956**	-0.066	0.009	0.006	-0.019	0.044	0.048
Sand						1.000	-0.996**	-0.993**	-0.819**	0.152	0.131	0.086	0.158	-0.137	-0.134
Silt							1.000	0.979**	0.794**	-0.172	-0.163	-0.107	-0.186	0.160	0.157
Clay								1.000	0.839**	-0.125	-0.090	-0.059	-0.122	0.105	0.104
Av. boron (mg kg^{-1})									1.000	-0.024	0.058	0.055	0.020	-0.013	-0.010
Readily (mg kg^{-1})										1.000	0.900**	0.860**	0.874**	-0.949**	-0.941**
Specifically (mg kg^{-1})											1.000	0.932**	0.978**	-0.929**	-0.909**
Oxide (mg kg^{-1})												1.000	0.919**	-0.878**	-0.857**
Organically (mg kg^{-1})													1.000	-0.905**	-0.883**
Residual (mg kg^{-1})														1.000	0.999**
Total (mg kg^{-1})															1.000

* significant at 5 per cent level of probability

** significant at 1 per cent level of probability

4.3 Nutrient concentration in plant at peg initiation stage

4.3.1 Nitrogen

The data presented in Table 4.15 and 4.16 indicate that the minimum N content in plant was recorded as 1.22 per cent in Devguda (A_7) of Amber tehsil and maximum as 1.62 per cent in village Atal Biharipura (A_4) of Amber tehsil. The N content varied from 1.22 to 1.62 per cent in Amber, 1.25 to 1.52 per cent in Chomu, 1.29 to 1.48 per cent in Dudu, 1.28 to 1.42 per cent in Jaipur and 1.25 to 1.52 per cent in Phulera. The overall N content ranged from 1.22 to 1.62 per cent with the mean value of 1.37 per cent.

A perusal of data in Table 4.17 indicate a positive and significant correlation of plant N with plant P (r=0.558**), K (r= 0.578**), Ca (r=0.631**), Mg (r=0.637**), S (r= 0.564**) and soil available boron (r= 0.648**) and pod yield (r = 0.281*) but positive and non significant correlation was existed with readily soluble boron (r= 0.017), specifically adsorbed boron (r= 0.030), oxide boron (r= 0.019), organically (r= 0.002) while it related negatively and non significantly with residual boron (r=-0.008) and total boron (r=-0.006).

4.3.2 Phosphorus

It is evident from the Table 4.15 and 4.16 and that the minimum P was recorded in 0.10 per cent in Jahota (A_6) of Amber tehsil and maximum as 0.32 per cent in village Kuchchaywas (P_{14}) of Phulera tehsil. The P content ranged from 0.10 to 0.19 per cent in Amber, 0.12 to 0.26 per cent in Chomu, 0.17 to 0.27 per cent in Dudu, 0.20 to 0.26 per cent in Jaipur and 0.15 to 0.32 per cent in Phulera. The overall phosphorus content ranged from 0.10 to 0.32 per cent with the mean value of 0.20 per cent.

Table 4.15 Nutrient concentration in plant at pegging stage and pod yield of groundnut

S.No.	Name of village	Sample Code	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (mg kg^{-1})	Pod yield (kg ha^{-1})
1	2	3	4	5	6	7	8	9	10	11
	Amber Tehsil									
1	Raithal	A_1	1.42	0.16	1.65	136.00	27.60	0.12	19.20	2650
2	Pratappura	A_2	1.29	0.12	1.40	122.00	24.00	0.11	30.20	1650
3	Jalsu	A_3	1.39	0.13	1.55	168.00	33.60	0.13	20.20	2550
4	Atal Biharipura	A_4	1.62	0.19	1.60	184.00	37.20	0.15	21.20	2700
5	Moudi	A_5	1.38	0.19	1.57	114.00	24.00	0.09	26.30	2300
6	Jahota	A_6	1.28	0.10	1.54	120.00	24.00	0.08	27.30	2200
7	Devguda	A_7	1.22	0.13	1.46	126.00	26.40	0.11	27.90	2300
8	Mohanpura	A_8	1.42	0.15	1.50	102.00	19.20	0.07	15.60	2600
9	Anoochpura	A_9	1.32	0.12	1.46	130.00	22.80	0.10	21.20	2350
10	Mukandpura	A_{10}	1.30	0.14	1.42	112.00	21.60	0.08	26.20	2300
11	Anopura	A_{11}	1.35	0.15	1.55	104.00	20.40	0.09	24.20	2350
	Chomu									
12	Gulabbadi	C_1	1.32	0.13	1.53	104.00	21.60	0.09	23.60	1800
13	Tankarda	C_2	1.42	0.17	1.55	122.00	25.20	0.11	26.20	2320
14	Jai Singhpura	C_3	1.29	0.15	1.43	130.00	25.20	0.12	23.50	2100
15	Devpura	C_4	1.30	0.14	1.54	136.00	24.00	0.10	12.50	2000
16	Loharwara	C_5	1.25	0.12	1.42	104.00	19.20	0.08	16.50	1920
17	Naya bas	C_6	1.45	0.19	1.62	140.00	27.60	0.14	23.50	2640
18	Udaipuriya	C_7	1.40	0.22	1.60	158.00	32.40	0.15	22.50	2680
19	Kanarpura	C_8	1.31	0.18	1.57	128.00	25.20	0.11	26.80	2320
20	Kaladera	C_9	1.32	0.21	1.65	130.00	26.40	0.11	14.20	2620
21	Bai Ka Bas	C_{10}	1.52	0.26	1.60	170.00	33.60	0.14	20.10	3400
22	Thodsar	C_{11}	1.45	0.21	1.60	148.00	28.80	0.12	14.10	2950
23	Bada ki Badi Dhanni	C_{12}	1.42	0.20	1.50	134.00	27.60	0.10	25.80	2620

Contd....

1	2	3	4	5	6	7	8	9	10	11
	Dudu Tehsil									
24	Devala	D_1	1.30	0.17	1.52	128.00	25.20	0.10	16.30	2200
25	Jharna	D_2	1.37	0.19	1.58	134.00	26.40	0.11	26.80	2150
26	Kesari Singhpura	D_3	1.36	0.21	1.60	130.00	25.20	0.08	27.60	2350
27	Begus	D_4	1.30	0.17	1.46	116.00	20.40	0.08	20.50	1980
28	Mehala	D_5	1.29	0.18	1.45	126.00	26.40	0.12	19.50	2120
29	Kharaniya Ki Dhani	D_6	1.36	0.20	1.48	130.00	26.40	0.11	22.00	2150
30	Surpura	D_7	1.48	0.27	1.60	162.00	30.00	0.15	15.00	2720
31	Chandramanpura	D_8	1.32	0.19	1.58	124.00	25.20	0.12	22.10	2100
32	Aydan Ka bas	D_9	1.30	0.20	1.52	128.00	26.40	0.10	14.60	2150
33	Kheri Alufa	D_{10}	1.47	0.27	1.57	134.00	26.40	0.11	20.10	2300
	Jaipur Tehsil									
34	Lalpura	J_1	1.42	0.25	1.62	150.00	30.00	0.13	19.60	2550
35	Mandabhopawas	J_2	1.40	0.26	1.57	136.00	27.60	0.12	17.50	2500
36	Pachar	J_3	1.35	0.20	1.51	130.00	24.00	0.11	20.30	2200
37	Ramsinghpura	J_4	1.28	0.24	1.52	150.00	30.00	0.13	19.60	2450
38	Ramkui	J_5	1.25	0.23	1.48	140.00	26.40	0.11	23.50	2400
39	Mehraya Ka Bas	J_6	1.40	0.24	1.52	148.00	30.00	0.13	25.30	2670
40	Fathehpura	J_7	1.37	0.23	1.46	126.00	27.60	0.11	20.50	2400
41	Himmatpura	J_8	1.33	0.24	1.40	122.00	25.20	0.10	23.00	2420
42	Kalwar	J_9	1.39	0.21	1.42	122.00	26.40	0.11	16.60	2200
43	Ramla Ka Bas	J_{10}	1.40	0.25	1.52	134.00	28.80	0.12	22.60	2400

Contd....

1	2	3	4	5	6	7	8	9	10	11
	Phulera Tehsil									
44	Dhakawala	P_1	1.38	0.21	1.57	142.00	27.60	0.12	11.50	2350
45	Kalkh	P_2	1.40	0.22	1.55	148.00	28.80	0.13	10.50	2420
46	Murlipura	P_3	1.45	0.25	1.51	146.00	28.80	0.12	22.60	2670
47	Math	P_4	1.48	0.23	1.55	148.00	30.00	0.13	10.20	2550
48	Kesha ka bas	P_5	1.44	0.26	1.54	146.00	26.40	0.11	11.20	2350
49	Basdi Kalan	P_6	1.25	0.15	1.46	106.00	20.40	0.08	11.60	2100
50	Dungari Kalan	P_7	1.35	0.30	1.57	162.00	31.20	0.13	20.10	2580
51	Kheerava	P_8	1.42	0.29	1.58	166.00	33.60	0.14	23.30	2700
52	Hingonia	P_9	1.35	0.20	1.60	138.00	25.20	0.10	19.80	2350
53	Bobas	P_{10}	1.36	0.20	1.51	136.00	26.40	0.11	13.80	2400
54	Gokulpura	P_{11}	1.42	0.30	1.58	146.00	27.60	0.12	16.30	2450
55	Ghatolai	P_{12}	1.38	0.23	1.54	120.00	25.20	0.10	10.00	2000
56	Kalkh	P_{13}	1.45	0.27	1.65	158.00	31.20	0.13	16.50	2670
57	Kuchchaybas	P_{14}	1.52	0.32	1.65	154.00	30.00	0.12	30.00	2520
58	Josibas	P_{15}	1.28	0.18	1.35	124.00	24.00	0.10	23.20	1400
59	Bassi Nagan	P_{16}	1.41	0.24	1.46	130.00	25.20	0.11	23.00	2100

Table 4.16 Tehsil wise range and mean value of nutrient concentration in groundnut plant at peg initiation

S.No.	Sample site	N (%)	P (%)	K(%)	Ca (%)	Mg (%)	S (%)	B ($mgkg^{-1}$)	Pod yield ($kg\ ha^{-1}$)
1	**Amber**								
	Minimum	1.22	0.10	1.40	0.51	0.16	0.07	15.60	1650.00
	Maximum	1.62	0.19	1.65	0.92	0.31	0.15	30.20	2700.00
	Mean	1.36	0.14	1.52	0.64	0.21	0.11	23.59	2359.09
	CV	7.77	19.76	5.10	19.93	21.55	23.48	18.79	10.44
2.	**Chomu**								
	Minimum	1.25	0.12	1.42	0.52	0.16	0.08	12.50	1800.00
	Maximum	1.52	0.26	1.65	0.85	0.28	0.15	26.80	3400.00
	Mean	1.37	0.18	1.55	0.67	0.22	0.11	20.78	2447.50
	CV	.04	22.86	4.65	14.48	15.38	18.47	24.79	16.43
3	**Dudu**								
	Minimum	1.29	0.17	1.45	0.58	0.17	0.08	14.60	1980.00
	Maximum	1.48	0.27	1.60	0.81	0.25	0.15	26.80	2720.00
	Mean	1.36	0.21	1.54	0.66	0.22	0.11	20.45	2222.00
	CV	5.14	17.85	3.76	9.15	9.11	18.93	21.79	7.59
4.	**Jaipur**								
	Minimum	1.28	0.20	1.40	0.61	0.20	0.10	16.60	2200.00
	Maximum	1.42	0.26	1.62	0.75	0.25	0.13	25.30	2670.00
	Mean	1.36	0.24	1.50	0.68	0.23	0.12	20.85	2419.00
	CV	4.17	7.83	4.38	8.08	7.67	9.05	13.12	5.03
5.	**Phulera**								
	Minimum	1.25	0.15	1.35	0.53	0.17	0.08	10.00	1400.00
	Maximum	1.52	0.32	1.65	0.81	0.28	0.14	30.00	2700.00
	Mean	1.40	0.24	1.54	0.71	0.23	0.12	17.10	2350.63
	CV	4.97	19.75	4.84	11.21	11.88	13.39	36.15	14.04
	Mean	**1.37**	**0.20**	**1.53**	**0.67**	**0.22**	**0.11**	**20.26**	2361.69

A perusal of data in Table 4.17 also indicate a positive and significant correlation of plant P with plant N (r=0.558**), K (r= 0.414**), Ca (r=0.584**), Mg (r=0.585**), S (r= 0.542**) and soil available boron (r= 0.447**) and yield (r= 0.418**), but positively and non significantly correlated with readily soluble boron (r= 0.014), oxide bound boron (r= 0.010), while, negatively non-significantly related with specifically adsorbed boron (r=-0.035), organically bound boron (r=-0.051), residual boron (r=-0.029), total boron (r= -0.038), boron content in plant (r= -0.164) and pod yield (r= -0.059).

4.3.3 Potassium

Data presented in Table 4.15 and 4.16 indicate that the minimum K content in groundnut plant was recorded as 1.35 per cent in Josibas (P_{15}) of Phulera tehsil and maximum as 1.65 per cent village Raithal (A_1), Kaladera (C_9), Kalkh (P_2) of Amber, Chomu and Phulera tehsil, respectively. The K content in plant varied from 1.40 to 1.65 per cent in Amber, 1.42 to 1.65 per cent in Chomu, 1.45 to 1.60 per cent in Dudu, 1.40 to 1.62 per cent in Jaipur and 1.35 to 1.65 per cent in Phulera. The overall K content in plant ranged from 1.35 to 1.65 per cent with the mean value of 1.53 per cent.

Data in Table 4.17 indicate a positive and significant correlation of K content in plant with N (r=0.578**), P (r= 0.414**), Ca (r=0.531**), Mg (r=0.507**), S (r= 0.453**), content in plant and soil available boron (r= 0.591**) and pod yield (r= 0.305*) but it correlated positively and non significantly with residual boron (r= 0.072), total boron (r= 0.077), while, negatively and non-significantly related with readily soluble boron (r=-0.034), specifically adsorbed boron (r= -0.034), oxide bound boron (r=-0.004), organically adsorbed boron (r= -0.069) and boron content in plant (r= -0.125).

4.3.4 Calcium

The data shown in Table 4.15 and 4.16 indicate that the minimum Ca content in plant was recorded as 0.51 per cent in village Mohanpura (A_8) of Amber tehsil and maximum as 0.92 per cent in village Atal Biharipura (A_4) of Amber tehsil. The Ca content varied from 0.51 to 0.92 per cent in Amber, 0.52 to 0.85 per cent in Chomu, 0.58 to 0.81 per cent in Dudu, 0.61 to 0.75 per cent in Jaipur and 0.53 to 0.81 per cent in Phulera. The overall Ca content ranged from 0.51 to 0.92 per cent with the mean value of 0.67 per cent.

The correlation coefficient (Table 4.17) were worked between Ca content with other nutrient concentration and different forms of boron (Table 4.21). Positive and significant correlation was existed between Ca content and of N (r=0.631**), P (r= 0.584**), Mg (r=0.941**), S (r= 0.859**), K (r= 0.531**) content in plant and soil available boron (r= 0.647**) but it was positively and non significantly correlated with readily soluble boron (r= 0.019), residual boron (r= 0.011), total boron (r=0.012) and pod yield (r= 0.143), while, negative non-significant correlation was noted with specifically adsorbed boron (r= -0.001), oxide bound boron (r=-0.019), organically bound boron (r= -0.025) and boron content in plant (r= -0.111).

4.3.5 Magnesium

The data given in Table 4.15 and 4.16 indicate that the minimum Mg was recorded as 0.16 per cent in village Mohanpura (A_8) of Amber tehsil and maximum as 0.31 per cent in village Atal Biharipura (A_4) Amber tehsil. The Mg varied from 0.16 to 0.31 per cent in Amber, 0.16 to 0.28 per cent in Chomu, 0.17 to 0.25 per cent in Dudu, 0.20 to 0.25 per cent in Jaipur and 0.17 to 0.28 per cent in Phulera. The overall Mg content ranged from 0.16 to 0.31 per cent with the mean value of 0.22 per cent.

Correlation coefficient (Table 4.17) further indicate a positive and significant correlation of plant Mg with N (r=0.637**), P (r= 0.585**), K (r=0.507**), Ca (r = 0.941**) and S content in plant (r= 0.885**) and available boron content in soil (r= 0.648**), but positive and non significant was noted with readily soluble boron (r= 0.057), specifically bound boron (r= 0.050), oxide bound boron (r= 0.038), organically bound boron (r= 0.033) and boron content in plant (0.068), while, negatively and non-significantly related with residual boron (r= -0.040) and total boron (r= -0.039).

4.3.6 Sulphur

It is evident from the data given in Table 4.15 and 4.16 that the minimum S in plant was recorded as 0.07 per cent in village Mohanpura (A_8) of Amber tehsil and maximum as 0.15 per cent in village Atal Biharipura (A_4), Udiapuriya (C_7), Surpura (D_7) of Amber, Chomu and Dudu tehsil, respectively. The S content in plant varied from 0.07 to 0.15 per cent in Amber, 0.08 to 0.15 per cent in Chomu, 0.08 to 0.15 per cent in Dudu, 0.10 to 0.13 per cent in Jaipur and 0.08 per cent to 0.14 per cent in Phulera teshil. The overall S content ranged from 0.07 per cent to 0.15 per cent with the mean value of 0.11 per cent.

A perusal of data given in Table 4.17 further indicates a positive and significant correlation of plants S with N (r=0.564**), P (r= 0.542**), K (r=0.453**), Ca (r = 0.859**) and Mg content in plant (r= 0.885**) and available boron content in soil (r=- 0.579**). Positive but non significant correlation was obtained between S and readily soluble boron (r= 0.033), specifically bound boron (r= 0.020), oxide bound boron (r= 0.025) and pod yield (r= 0.094), while, negative and non-significant correlation was noted between organically bound boron (r= -0.005), residual boron (r= -0.047), total boron (r= -0.052) and boron content in plant (r= -0.088).

4.3.7 Boron

The data given in Table 4.15 and 4.16 indicate that the B content in groundnut plant varied from 15.60 to 30.20 per cent in Amber, 12.50 to 26.80 per cent in Chomu, 14.60 to 26.80 per cent in Dudu, 16.60 to 25.30 per cent in Jaipur and 10.00 to 30.00 per cent in Phulera. The highest mean value of 23.59 per cent was noted in Amber tehsil and lowest 17.10 per cent in Phulera tehsil. The overall B content in plant ranged from 10.00 to 30.00 per cent with the mean value of 20.26 per cent.

The minimum B content was recorded as 10.00 per cent in village Ghatolai (P_{12}) of Phulera tehsil and maximum as 30.00 per cent in village Kuchchaybas (P_{14}) of Phulera tehsil. The mean value of B content was found to be 20.26 per cent.

Data on simple correlation coefficient (r) given in Table 4.17 further indicate a positive and significant correlation of plant boron with readily soluble boron (r= 0.841**), specifically bound boron (r=0.866**), oxide bound boron (r = 0.779**), organically bound boron (r= 0.839**), but it was negatively and significantly correlated with soil available boron (r=0.350*) residual boron (r= -0.881**) and total boron (r = -0.875**). Negative and non-significant correlation was noted between N (r= -0.114), P (r= -0.164), K (r= -0.125), Ca (r=-0.111), Mg (r= -0.036), S (r= -0.088) content and pod yield (r= 0.148). Positive correlation value was obtained between boron content in plant and available boron in soil. Kushawaha and Singh (1981) also reported significant and positive correlation between soil boron and boron content in sweet orange in Agra region. Similar results were also reported by Kher and Isher (2006), Mahapatra and Sahu (1996).

4.3.8 Pod yield

The data presented in Table 4.15 and 4.16 indicate that the minimum yield (1400 kg ha^{-1}) was recorded in village Josibas (P_{15}) of Phulera tehsil and maximum (3400 kg ha^{-1}) in village Bai ka bas (C_{10}) of Amber tehsil . The pod yield varied from 1650 to 2700 kg ha^{-1} in Amber, 1800 to 3400 kg ha^{-1} in Chomu, 1980 to 2720 kg ha^{-1} in Dudu, 2200 to 2670 in Jaipur and 1400 to 2700 kg ha^{-1} in Phulera teshil. The overall pod yield ranged from 1400 to 3400 kg ha^{-1} with the mean value of 2361.69 kg ha^{-1}.

A perusal of data in Table 4.17 further indicate a positive and significant correlation of pod yield with plant N (r=0.281**) and K (r= 0.305*) content but non significant positive correlation with available boron (r=0.221), residual boron (r= 0.103) and total boron (r =0.103), while, a negative but non-significant correlation was noted with readily available boron (r=-0.140), specifically adsorbed boron (r=-0.071), oxide bound boron (r=-0.102) and organically bound boron (r=-0.070).

In general, soil pH is one of most important factor affecting the availability of boron plant. Generally, boron becomes less available to plants with increasing soil pH. Boron uptake was also reduced when the Ca content of the medium was increased. Leaf tissue Ca/B ratio have also been considered as indicator of the boron status of crops. The Ca/B ratios of groundnut plant responsible for flower setting, peg initiation and pod formation varied from 307 to 510 in the present investigation. Considering the optimum ratio between 218 to 224 in groundnut plant (Golakiya and Patel, 1988), all the samples appeared to boron deficient as the higher Ca/B ratio as indicative of boron deficiency are probably related to the higher Ca concentration in the leaf tissue. (Gupta, 1979). This higher Ca/B ratio in plant is cause of lower mean pod yield (2361.69 kg ha^{-1}) obtained from farmers field than potential yield (2800 kg ha^{-1}) of the region.

Table 4.17 Correlation among forms of boron and nutrient concentration in groundnut plant

	Available boron	Readily (mg kg⁻¹)	Specifically (mg kg⁻¹)	Oxide bound (mg kg⁻¹)	Organically bound (mg kg⁻¹)	Residual (mg kg⁻¹)	Total (mg kg⁻¹)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (mg kg⁻¹)	Pod yield
Available boron	1.000	-0.024	0.058	0.055	0.020	-0.013	-0.010	0.648**	0.447**	0.591**	0.647**	0.648**	0.579**	0.350*	0.221
Readily		1.000	0.900**	0.860**	0.874**	-0.949**	-0.941**	0.017	0.014	-0.034	0.019	0.057	0.033	0.841**	-0.083
Specifically			1.000	0.932**	0.978**	-0.929**	-0.909**	0.030	-0.035	-0.034	-0.001	0.050	0.020	0.866**	-0.089
Oxide				1.000	0.919**	-0.878**	-0.857**	0.019	0.010	-0.004	-0.019	0.038	0.025	0.779**	-0.154
Organically					1.000	-0.905**	-0.883**	0.002	-0.051	-0.069	-0.025	0.033	-0.005	0.838**	-0.126
Residual						1.000	0.999**	-0.008	-0.029	0.072	0.011	-0.040	-0.047	-0.881**	0.154
Total							1.000	-0.006	-0.038	0.077	0.012	-0.039	-0.052	-0.875**	0.159
N								1.000	0.558**	0.578**	0.631**	0.637**	0.564**	-0.114	0.281*
P									1.000	0.414**	0.584**	0.585**	0.542**	-0.164	-0.059
K										1.000	0.531**	0.507**	0.453**	-0.125	0.305*
Ca											1.000	0.941**	0.859**	-0.111	0.143
Mg												1.000	0.885**	-0.036	0.068
S													1.000	-0.088	0.094
B														1.000	-0.148
Pod yield															1.000

* significant at 5 per cent level of probability

** significant at 1 per cent level of probability

Further, there exists a relationship between available boron and exchangeable Ca in soil with respect to boron content in plant (Table 4.6). Earlier studied have shown that when plants have access to increasing amounts of Ca, they require more boron for growth (Reeve and Shive, 1944). Tanaka (1967) reported that boron uptake by radish was reduced when the Ca content of the medium increased.

The organic matter influenced the availability of boron in soil as well to plant. This contention got support from the close association of available boron in present study (Table 4.6). The availability of boron influenced by adsorbing more boron than mineral constituents (Gu and Lowe, 1990) and coating the boron fixing mineral surfaces. Also it is well established that much of the boron in soil is associated with organic matter in tightly bound compounds, which is released in available form by microbial action (Berger and Pratt, 1963). Simple correlation showed that boron content in groundnut plants was significantly correlated with readily soluble, specifically adsorbed, oxide bound and organically bound forms of boron. These findings are in agreement with these obtained by Jin *et al.* (1987), Tsadilas *et al.* (1994), Wojcik (2000) and Moafpouryan and Shukla (2004). Jin *et al.* (1987) concluded that water soluble and non-specifically adsorbed forms of boron were readily available to maize and considered as intensity factor and specifically adsorbed and Mn oxides-bound boron forms were considered quantity factor of boron supply of soil to plant.

4.5 Delineation of boron deficient and sufficient area

It is evident from the data given in Table 4.19 that the soil under study may be classified as low (< 0.5 mg B kg^{-1}), medium (0.5-2.0 mg B kg^{-1}) and high (> 2.0 mg B kg^{-1}) category as per categorisation given by Tandon (1992). According to these category, out of 59 surface soil

Table 4.18 Nutrient status of groundnut leaves at peg initiation (per cent samples) as per critical range given by Tandon (1992)

Nutrient	Range	Deficient	Sufficient	Toxic
N (%)	1.57-2.42	98.38	1.69	-
P (%)	0.31-0.39	98.38	1.69	-
K (%)	1.75-2.24	-	100	-
Ca(%)	1.10-1.50	100	-	-
Mg (%)	0.60-0.75	100	-	-
S (%)	0.20-0.25	100	-	-

Table : 4.19 Available boron status in soil (Tandon,1992) under groundnut cultivation

Tehsil	Number and percentage of samples			
	Low (< 0.5 mg kg^{-1})	Medium (0.5-2.0 mg kg^{-1})	High (> 2.0 mg kg^{-1})	Total
Amber	11 (100)	-	-	11
Chomu	11 (91.66)	1 (8.34)	-	12
Dudu	10 (100)	-	-	10
Jaipur	10 (100)	-	-	10
Phulera	16 (100)	-	-	16
Total	58 (98.30)	1 (1.70)	-	59

Figures in parenthesis are percentage of samples

Table 4.20 Boron status in groundnut plants at peg initiation stage (Tandon, 1992)

Tehsil	Number and percentage of samples			
	Deficient (< 28 mg kg^{-1})	Sufficient (28-50 mg kg^{-1})	Toxic (> 50 mg kg^{-1})	Total
Amber	10 (90.90)	1 (9.10)	-	11
Chomu	12 (100)	-	-	12
Dudu	10 (100)	-	-	10
Jaipur	10 (100)	-	-	10
Phulera	15 (93.75)	1 (6.25)	-	16
Total	**57 (96.60)**	**2 (3.40)**	**-**	**59**

Figures in parenthesis indicate percentage of samples

samples, about 98.3 per cent samples were found under low category and 1.7 per cent samples were under medium category. None of the sample was found under high category. Almost all samples (100 per cent) of all tehsil were rated as low except Chomu tehsil in which only one soil sample rated as medium. This indicate that soils under ground cultivation were deficient in boron content.

The boron content in groundnut plant ranged from 10.00 to 30.00 mg B kg^{-1}. Considering 28.0 to 50.0 mg B kg^{-1} as sufficient range for boron deficiency in groundnut plant (Tandon, 1992), 96.60 per cent groundnut plant samples were in deficient range and only 3.40 per cent samples were in sufficient range. None of the sample was found in toxic range in all soils under study (Table 4.20).

Almost all plant samples (100%) of all tehsils were deficient in boron content except Amber and Phulera tehsil in which only one sample of each was in sufficient range (Table 4.20). The study indicate that the application of boron in groundnut growing area maintained the higher availability of boron without any effect on availability of other nutrient.

The N, P, Ca, Mg and S were also deficient in groundnut plant (Table 4.18) and all were correlated positively with available boron content in soil.

From the study, it is clear that to meet the immediate need of crop, there is a need for application of boron fertilizer to maintain sufficient concentration of boron in the soil to satisfy the requirement of plants. The investigation emphasizes on adequate application of boron in these soils and maintain good amount of organic matter by local farmers growing groundnut. The study will help in formulating the recommendations for N, P, K, Ca, Mg, S and B fertilization in these soils for optimizing groundnut production.

5 Summary and Conclusion

Fifty nine surface soil (0-15 cm) and fifty nine groundnut plant samples at peg initiation stage from fifty nine village of 5 tehsil of Jaipur district of Rajasthan were collected in the month of August, 2009. Soil samples were analysed for determining mechanical composition, physico-chemical characteristics and nutrient status and different forms of boron. Plant samples were analysed for estimation of nutrient contents. The results have been summarized as follows:

5.1 Soil analysis

5.1.1 Soil texture

5.1.1.1 The textural classes of soils under investigation were loamy sand, sandy loam and sand. In general, sand is a predominant fraction in these soils.

5.1.1.2 The property of sand has reverse to silt and clay content of soil.

5.1.2 Physico-chemical properties

5.1.2.1 The calcium carbonate content of soils varied from 1.00 to 5.30 per cent.

5.1.2.2 Calcium carbonate content decreased significantly with increase in pH_2.

5.1.2.3 The organic carbon content of these soils had generally been low.

5.1.2.4 The organic carbon content of soils increased significantly with increase in silt, clay and CEC of soils, whereas, it decreased significantly with sand content of soils.

5.1.2.5 The pH_2 and EC_2 values of soils under study varied from 7.80 to 8.70 and 1.03 to 4.33 dS m^{-1}, respectively.

5.1.2.6 The pH_2 of soils enhanced significantly with increased in $CaCO_3$ and sand content while decreased significantly with increased in EC_2, silt, clay and organic carbon contents of soils.

5.1.2.7 The EC_2 values of soils had non-significant relationship with most of the soil properties.

5.1.2.8 The cation exchange capacity of these soils varied between 2.00 to 6.80 cmol (p^+) kg^{-1}. These values indicated that CEC of soils was low.

5.1.2.9 The cation exchange capacity of soils increased significantly with increase in silt, clay and organic carbon contents and decreased significantly with sand, $CaCO_3$ and pH_2 of soil.

5.1.3 Available nutrients

5.1.3.1 The content of available nitrogen in soils of the tract ranged from 110.80 to 140.00 kg ha^{-1}. In general, 100 per cent soils were deficient in available nitrogen.

5.1.3.2 The availability of nitrogen in soils increased significantly with increase in CEC, OC, silt and clay content of soil whereas, decreased significantly with increase in sand content of soils.

5.1.3.3 There was positive significant correlation between available nitrogen and nutrients like P_2O_5, K_2O, Ca, Mg, S and B.

5.1.3.4 The content of available phosphorus in these soils varied from 12.60 to 30.11 kg ha^{-1}. Most of the soils of the tract were found deficient in available P_2O_5.

5.1.3.5 Similar to the available phosphorus, the availability of phosphorus increased significantly with increase in silt, clay, organic carbon, CEC and $CaCO_3$ of soils. Its availability decreased significantly with increase in sand and EC_2 of soils.

5.1.3.6 There was positive significant correlation between available phosphorus and other nutrients like N, K_2O, Ca, Mg, S and B.

5.1.3.7 The content of available potassium in soils of Jaipur district ranged between 190.80 to 230.80 kg ha^{-1}. Soils of Jaipur district were found medium in available potassium.

5.1.3.8 The availability of potassium significantly increased with increase in silt, clay, organic carbon and CEC; while, its availability decreased significantly with increase in silt content and pH_2 of soils.

5.1.3.9 The magnitude of available calcium in soils varied between 340.00 to 616.00 mg kg^{-1}. In general, 100.00 per cent soils samples were medium.

5.1.3.10 The availability of calcium enhanced significantly with finer fractions (silt and clay), organic carbon and CEC. On the other hand, it was found to decrease with increase in sand and pH_2 of soils.

5.1.3.11 The content of available magnesium in soils of Jaipur district ranged between 124.00 to 166.00 mg kg^{-1} and soils were rated as medium in available magnesium.

5.1.3.12 The available magnesium significantly increased with increase in CEC, OC, silt and clay content while, its availability decreased significantly with increase in sand of soils.

5.1.3.13 The content of available sulphur in these soils ranged between 5.30 to 12.50 mg kg^{-1}. Most of the soils under study were found deficient in available sulphur.

5.1.3.14 There was positive and significant correlation between available sulphur and other nutrients like N, P_2O_5, Ca, Mg and B.

5.1.3.15 The availability of sulphur significantly increased with increase in CEC, OC, silt and clay content, while, its availability decreased significantly with increase in sand content of soil.

5.1.3.16 About 3.39 per cent soil samples of the study area were found sufficient and 96.61 per cent soil samples were deficient in available boron content. Its content in soils varied from 0.25 to 0.55 mg kg^{-1}.

5.1.3.17 The content of available boron in soils increased significantly with increase in CEC, OC, silt and clay and decreased significantly with increase in sand content in soils.

5.2 Status of different forms of boron

5.2.1 The readily soluble boron content of soils ranged from 0.35 to 0.95 mg kg^{-1}. The highest mean value (0.65 mg kg^{-1}) of readily soluble boron was noted in Amber tehsil.

5.2.2 The readily soluble boron in soils increased significantly with increase in $CaCO_3$, whereas, decreased significantly with increase in EC_2 of soils.

5.2.3 The content of specifically adsorbed boron varied from 0.25-1.02 mg kg^{-1}.

5.2.4 Similar to readily soluble boron, the specifically adsorbed boron content in soil increased significantly with soil characteristics, like pH_2 and $CaCO_3$ but reduced significantly with increase in EC_2 of soil.

5.2.5 The oxide bound boron content of soil varied from 0.12 to 0.55 mg kg^{-1}.

5.2.6 The oxide bound boron in soils increased significantly with increase in pH_2 and $CaCO_3$ and decreased significantly with increase in EC_2 of soil.

5.2.7 The content of organically bound boron ranged from 0.35 to 1.15 mg kg^{-1}.

5.2.8 The content of organically bound boron increased significantly with pH_2 and $CaCO_3$ and decreased significantly with increase in EC_2 of soil.

5.2.9 The residual boron content of soil ranged from 22.13 to 37.34 mg kg^{-1}. It had highest contribution (92.11) in total boron content in soil.

5.2.10 The residual boron increased significantly with increase in pH_2 and $CaCO_3$ while decreased significantly with increase in EC_2.

5.2.11 The content of total boron ranged from 25.80-38.50 mg kg^{-1}.

5.2.12 Similar to all other forms of boron, it increased significantly with increase in pH_2 and $CaCO_3$ of soil, while, decreased with increase in EC of soil.

5.2.13 The soils of Jaipur district had highest fraction of residual boron (92.11 per cent) followed by organically bound boron (2.60 per cent), specifically adsorbed boron (2.27 per cent), readily soluble boron (1.87 per cent) and oxide bound boron (1.13 per cent).

5.2.14 The readily soluble boron were found to correlated positively with rest of forms.

5.3 Plant Analysis

5.3.1 The nitrogen contents in groundnut plants varied from 1.22 to 1.62 per cent.

5.3.2 The contents of nitrogen in groundnut plant had positive significant correlation with available boron, readily soluble boron, specifically adsorbed boron, oxide bound boron, while, had negative correlation with residual boron, total boron contents of soils.

5.3.3 The phosphorus contents in groundnut plant varied from 0.10 to 0.32, per cent.

5.3.4 Similar to nitrogen content, the phosphorus content in groundnut plant had positive significant correlation with available boron, readily soluble boron and oxide bound boron but had negative correlation reduced with increase in specifically adsorbed boron, organically bound boron, residual boron and total boron of soils.

5.3.5 The potassium content in groundnut plants ranged from 1.35 to 1.65 per cent.

5.3.6 The potassium content in plant had positive significant correlation with forms of boron like available boron, residual boron and total boron but had negative correlation with readily soluble boron, specifically adsorbed boron, oxide bound boron and organically bound boron content of soils.

5.3.7 The calcium contents in groundnut plants varied from 0.51 to 0.92 per cent.

5.3.8 Its, content in groundnut plants enhanced with increase in available boron, readily soluble boron, residual boron and total boron of soils. Besides, it also reduced with specifically adsorbed boron and oxide bound boron and organically bound boron content of soils.

5.3.9 Magnesium content in groundnut plant varied from 0.16 to 0.31 per cent.

5.3.10 Its content in groundnut plant had positive significant correlation with available boron, readily soluble boron, specifically adsorbed boron, oxide bound boron and organically bound boron but had negative correlation residual boron and total boron content of soils.

5.3.11 Sulphur content in groundnut plant varied form 0.07 to 0.15 per cent.

5.3.12 Sulphur content in groundnut plant had plant had positive significant correlation with available boron, readily soluble boron, specifically adsorbed boron and oxide bound boron but had negative correlation with organically bound boron, residual boron and total boron of soils.

5.3.13 Boron content in groundnut plant varied from 0.25 to 0.55 mg kg^{-1}.

5.3.14 Similar to the contents of other nutrients, boron content in plant had positive significant correlation with available boron, readily soluble boron, specifically adsorbed boron, oxide bound boron and organically bound boron and but had negative correlation with residual boron and total boron content.

5.3.15 The pod yield varied from 1650 -3400 kg ha^{-1}.

5.3.16 The pod yield enhanced positively and non-significantly with increase in available boron, residual boron and total boron, but decreased with increase in readily soluble boron, specifically adsorbed boron, oxide bound boron and organically bound boron.

Conclusion

The soils of Jaipur district were loamy sand in texture. These soils were found low in organic carbon, available nitrogen, P_2O_5, sulphur and boron and medium in K_2O, Calcium and magnesium content. The groundnut plants were also found deficient in boron content.

Thus, groundnut cultivation determines the economy of this region, it is expected that the results obtained on boron deficiency may be helpful to the cultivators/planners for effective and judicious application of boron fertilizers in order to obtain high yield of groundnut.

Bibliography

Afrifa, A.A., Ofori-Frimpong, K. and Abekoe, M.K. 2009. Boron levels in soils cropped to coffee and their relationship to some soils properties of Ghanna, *Ghann Journal of Science*.

Ahmed, I.U., Uddin, M.J. and Sarwar, K.S. 2003. Distribution of nutrient status under different parent materials in some brown hill soils of Bangladesh. *Bulletin of the Institute of Tropical Agriculture, Kyushu University,* 26 : 39-44.

Akbari, K.N., Karan, F. and Pandey, H.R. 1993. Distribution of available phosphorus and potash and organic carbon in mewar region. *Annals of Arid Zone,* 32 : 251-252.

Al-Busaidi, A.S., Cookson, P. 2003. Salinity-pH relationship in calcarious soils. *Sultan Quboos University Journal for Scientific Research- Agricultural Sciences,* 8 : 41-46.

Al-Qawasmi, W., Badwan, R., Al-Nsour, A. 2003. Heavy metals content and soil fertility in irrigated agriculture Deir Alla area. Jordan Valley, *Bulgarian Journal of Agricultural Sciences,* 9 : 357-362.

Anonymous, 2006. Economic survey, Govt. of India (Division Finance) New Delhi, pp. 16-18.

Anonymous, 2006-07. Vital Agriculture, Govt. of Rajasthan. pp.68.

Arain, M.A.; Mubarik Ahmed; Khan, M.A. 2000. Some physico-chemical characteristics of soil in sugarcane cultivated areas of Nawabshah, Sindh Pakistan. *Pakistan Journal of Botany.* 32 : 93-100.

Arora, S. and Chahal, D.S. 2009. Boron desorption kinetics in inceptisols representing Benehmark soils of Punjab. *Journal of the Indian Society of Soil Science,* 57 : 145-153.

Arora, Sanjay and Chahal, D.S. 2005. Available boron content in benchmark soils of Punjab under different moisture regimes in relation to soil charactersticitics *Agropedology,* 15 : 90-94.

Arora, Sanjay and Chahal, D.S. 2007. Profile distribution of different forms of Boron in typic Haplustalfs of Punjab. *Journal of the Indian Society of Soil Science,* 65 : 248-253.

Arora, Sanjay and Chahal, D.S. 2007b. Soil boron extraction in relation to its availability for clover grown in semi arid soils of Punjab *Agrochemicals*, 51 : 76-85.

Aubert, H. and Pinta, 1977. Trace elements in soils, Elsevier, New York.

Babel, M. 2007. Available Micronutrient Status and their Relationship with Soil Properties of Jhunjhunu Tehsil, district Jhunjhunu (Rajasthan). *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Balpande, H.S., Challa, O. and Jagadish Prasad. 2007. Characterization and classification of Grape-growing soils in Nasik district, Maharastra. *Journal of the Indian Society of Soil Science,* 55 : 80-83.

Bansal, R.L., Nayyar, V.K. and Takkar, P.N. 1991. Availability of B, Co and S in ustochrepts. *Journal of the Indian Society of Soil Science,* 39 : 181-182.

Bansal, R.L., Nayyar, V.K., Brar, J.S. 2003. Available boron status of soils in central plain region of Punjab. *Journal of PAU,* 40 : 172-176.

Barala, R. 2005. Available micronutrient status and their relationship with soil properties of Shahpura tehsil of Jaipur district. *M.Sc. (Ag.) Thesis*, RAU, Bikaner

Basker, A., Ammal, U. B., Sanker, R., Vembu, G. and Valliammal, K. 2006. Impact of *tsunami* on soil quality and reclamation strategies in the Union Territory of Pondicherry. *Journal of Indian Society of Coastal Agricultural Research*, **24** :375-377.

Berger, K.K.C. and Pratt, P.F. 1963. Advances in secondary and micronutrient fertilization, In: technology and usage (M.H. Mevicker, G.L. Bridger and L.B. Nelson, Eds.) pp- 281-340, *Soil Science Society of America*, Madison, WI.

Bhargava, G.P. and Sharma, R.C. 1982. Saline soils of Indo-Gangatic alluvial plain (North Bihar) and their characteristics and genesis. *Journal of the Indian Society of Soil Science*, 30 : 234-241.

Bhatnagar, P., Chandra Atul and Gupta, P.K. 2006. Nutrient status of Ber orchards in Bikaner district. *Annals of Arid zone*, 45 : 219-221.

Bhogal, N.S., Sakal, R., Singh, A.P. and Sinha, R.B. 1993. Micronutrient status in aquic Usifluvents and Udifluvents as related to certain properties, *Journal of the Indian Society of Soil Science*, 41 : 75-78.

Bingham, F.T., Page, A.L., Coleman, A.L. and Flach, K 1971. Boron adsorption characterstics of selected amorphous soils from mexico and Hawai. *Soil Science Society of America Proceedings*, 35 : 546-550.

Bremner, J.M. and Mulvaney, C.S. 1982. In : Methods of soil analysis, part 2, (Page, A.L. *et al.*, .eds) *ASA, SSSA, Modison, Wis., USA*, pp. 595.

Chapman, H.D. and Pratt, P.F. 1961. Methods of analysis for soils, plant and waters. *Division of Agricultural Sciences, California USA.*

Choudhary, D. R. and Shukla, L. M. 2002. Sulphur status of soils of western Rajasthan. *Annals of Agricultural Research,* **23**: 371-376.

Choudhary, D.R. and Shukla, L.M. 2003. Availability of soil boron fractions to mustard (*Brassica juncea*) in arid soils of Rajasthan (India). *Agrochimica* XLVII (5-6), 173-179.

Choudhary, D.R. and Shukla, L.M. 2004a. Boron forms and their relationships with characteristics of arid soils of western Rajasthan. *Journal of the Indian Society of Soil Science*, Vol. 52 : 197-199.

Choudhary, D.R. and Shukla, L.M. 2004b. Boron status of arid soils of westerns Rajasthan in relation to their characteristics. *Journal of the Indian Society of Soil Science*, Vol. 52 : 194-196.

Cristobal, Camacho, Rexach, J.J., Gonzalez, J. and Fontes, A. 2008. Boron in plants: deficiency and toxicity, *Journal of Integrative Plant Biology*, 50 : 1247-1255.

Das, D.K. 2000. Micronutrients : *Their Behaviour in soils and plants.* Kalyani Publishers, Ludhiana.

Datta, M. and Ram, Munna 1993. Status of micronutrients in some soil series of Tripura. *Journal of the Indian Society of Soil Science*, 41 : 776-777.

Datta, S.P., Rattan, R.K., Suribabu, K. and Datta, S.C. 2002. Fractionation and colorimetric determination of boron in soils. *Journal of Plant Nutrition and Soil Science,* 165 : 179-184.

Dhir, R.P., Singh, N. and Sharma, B.K. 1979. Nature and incidence of soil salinity in Pali block, western Rajasthan. *Annals of Arid Zone,* 18: 27–34.

Dhir, R.P., Singh, N. and Sharma, B.K. 1979. Nature and indices of salinity in Pali block, Western Rajasthan, *Annals of Arid Zone*, 18 : 27-34.

Dubey, D.D.; Sharma, O.P. and Shila, P.K. 1984. Formation and taxonomy of salt affected Aridosols. *Journal of the Indian Society of Soil Science,* 32 : 146-149.

Duin, M.Van., Peters, J.A., Kieboom, A. P. G. and Bekkum, H. Van 1985. Studies on borate esters II. Structure and stability of borate esters of polyhydroxycarboxlates and related polyols in aqueous alkaline media as studied by 11B NMR. *Tetrahedron*, 16 : 3411-3421.

Gagnesh Sharma, Shavma, K.L. and Sharma, C.M. 2001. Nutrient status of tea gardens of Himachal Pradesh Zone I. *Journal of Plantation Crops*. 29 : 44-48.

Gathala, M. K., Yadav, B.L. and Singh, S.D. 2004. Mineral nutrient status of pomegranate orchard in Jaipur district of Rajasthan. *Journal of the Indian Society of Soil Science,* 52 : 206-208.

Gharu, Amita and Tarafdar, J.C. 2004. Influence of organic acids on mobilization of inorganic and organic phosphorus in soil. *Journal of the Indian Society of Soil Science,* 24 : 248-253.

Goldberg, S. 1997. Reaction of boron with soil, *Plant and Soil*, 193 : 35-38.

Goldberg, S. and Forster, H.S. 1991. Boron sorption on calcareous soils and reference calcites, *Soil Science,* 152 : 304-310.

Goldberg, S. and Glaubig, R.A. 1985. Boron adsorption on aluminum and iron oxide minerals. *Soil Science Society of America Journal,* 49 : 1374-1379.

Goldberg, S., Forster, H.S. and Heick, E.L. 1993. Boron adsorption mechanisms on oxides, clay minerals and soils inferred from ionic strength effects. *Soil Science Society of America Journal,* 57 : 704-708.

Goldberg, S., Foster, H. S., Lesch, S.M. and Heick, E.L.1996. Influence of anion competition on boron adsorption by clay and soils. *Soils Science,* 161 : 99-103.

Golkiya, B.A. and Patel, M.S. 1986. Effect of calcium and boron application on yield components densities for rainfed groundnut. *Indian Journal of Physiology,* 29 : 28-29.

Golkiya, B.A. and Patel, M.S. 1988. Effect of ca/B ratio on yield attributes and yield of groundnut. *Journal of the Indian Society of Soil Science,* 36 : 287-290.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for Agricultural Research, 2nd edition, Jhon Wiley and Sons, New York.

Goswami, D. and Karmarkar, R.M. 2002. Fertility status of soils of citrus research station, Tinsukia, A.A.U., Assam. *Annals of Agriculture and Biology Research,* 7 : 139-142.

Gu, B., and L.E. Lowe, 1990. Studies on the adsorption of boron on humic acids. *Candian Journal of Soil Science,* 70 : 305-311.

Gupta, U.C. 1967. A simplified method for determining hot water soluble boron in podsols. *Soil Science,* 103 : 224-229.

Gupta, U.C. 1968. Relationship of total and hot water soluble boron and fixation of added B to properties of podzol soils. *Soil Science Society of America Proceeding,* 32 : 45-48.

Gupta, U.C. 1979. Boron nutrition of crop. *Advances in Agronomy*, 31 : 273-315.

Gupta, U.C., Jame, Y.W., Campbell, C.A., Leyshon, A.J. and Nicholaichuk, W. 1985. Boron toxicity and deficiency : A review, *Canadian Journal of Soil Science*, 65 : 381-395.

Hatcher, J.T., and Wilcox, L.V. 1950. Colorimetric determination of boron using carminal. *Analytical Chemistry*, 22 : 567-569.

Hingston, F.J. 1964. Reactions between boron and clays. *Australian Journal of Soil Research,* 2 : 83-95.

Hou, J., Evans, L.J. and Spirers, G.A. 1994. Boron fractionation in soils. *Communication in Soil Science and Plant Analysis*, 25 : 1841-1853.

Hou, J., Evans, L.T. and Spirers, G.A. 1996. Chemical fractionation of soil boron, I method development. *Canadian Journal of Soil Science,* 76 : 485-491.

Hundal, H.S., Kumar, Raj, Singh, D. and Manchanda J.S. 2006. Available nutrient and heavy metal status of soils of Punjab, North-West India, *Journal of the Indian Society of Soil Science,* 54 : 50-56.

J.M. Xu, K. Wang, R.W. Bell, Y.A. Yang and I.B. Belang 2001. Soil boron fractions and their relationship to soil properties. *Soil Science Society of America Journal,* 65 : 133-138.

Jackson, M.L. 1973. Soil Chemical Analysis. *Prentice Hall of* India Pvt., Ltd. New Delhi.

Jolivet, C., Arrcuays, D., Andreux, F. and Leveque, J. 1997. Soil organic carbon dynamics in cleared temperate forest spodosols converted to maize cropping. *Plant and Soil,* 191 : 225-231.

Jat, J.R. and Yadav, B.L. 2006. Different forms of S and their relationship with properties of Entisols of Jaipur district (Rajasthan) under mustard cultivation. *Journal of the Indian Society of Soil Science,* 54 : 208-212.

Jin, J., D.C. Martens and L.W. Zelazny 1988. Plant availability to applied and native boron in soils with diverse properties. *Plant and Soil,* 105 : 127-132.

John, M.K., Chuah, H.H. and Neufeld J.H. 1975. Application of improve azomethine-H method to the determination of boron in soils and plants. *Analytical letter* 8 : 559-568.

Joshi, D.C. and Dhir, R.P. 1995. Characteristics and genesis of lime segregation in Thar desert of India. National Seminar on "Development in Soil Science, "held from Nov., 2-5-1995 pp. 177-178.

Kameriya, P.R. 1995. Characterization of soils of Agro climatic zone of Transitional plain of inland drainage (Zone IIIA) of Rajasthan. *Ph.D. Thesis*, RAU, Bikaner.

Kanthaliya, P.C. and Bhatt, P.L. 1991. Relation between organic carbon and available nutrients in some soils of sub-humid zone. *Journal of the Indian Society of Soil Science,* 42 : 100-104.

Kareen, R., Gross, P.R. and Sparks, D.L. 1994. Equilibrium and kinetics of borate adsorption-desorption on pyrophyllite in aqueous suspensions. *Soil Science Society of America Journal*, 58 : 1116-1122.

Kaushik, R.N. and Shukla, U.G. 1977. A study on the development of salt affected soils in a typical area. *Journal of the Indian Society of Soil Science,* 25 : 276-283.

Keren, R. and Bingham, F.T. 1985. Boron in water, soils and plants. *Advances in Soil Science* 1 : 229-276.

Kher, D. and Isher, M.S. 2006. Distribution of boron in relation to soil properties in citrus orchard soils of Jammu region. *Journal of the Indian Society of Soil Science,* 54 : 354-358.

Kolarkar, A.S., Jain, S.V., Dhir, R.P. and Singh, M. 1989. Distribution morphology and land use in Rajasthan. International symposium on "Managing sandy soil". 6-10 Feb., pp. 1-20.

Kour, J. and Jalali, V.K. 2008. Forms of sulphur and their relationship in soils of different Agro-climatic zones of Jammu region *Journal of the Indian Society of Soil Science,* 56 : 309-312.

Kumar, R. 2005. Available micronutrient status and their relationship with soil properties of Parbatsar Soil Series. *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Kumar, V. and Seth, S.P. 1983. Studies on soil fertility status of Sriganganagar district. *Annals of Arid Zone*, 22 : 71-81.

Kundu, M. C., Chakrabortty, S. and Mukhopadhyay, P. 2005. Soil fertility status of rice growing soils of four villages of Haringhata block under Nadia district of West Bengal. *Environment and Ecology*, 23 : 922-925

Kushawaha, J.P.S. and Singh, Vinay, 1981. Boron content of soils and leaves of sweet orange (*Citrus senensis* (L.) osbeck) orchards in Agra region of Uttar Pradesh. *Current Agriculture Journal*, 164-168.

Lal, P. and Singh, K.S. 1974. A comparative study of effects of quality of irrigation water on different soils. *Journal of the Indian Society of Soil Science*, 22 : 19-25.

Lehto, T., and Malkonen.1994.Effect of liming and boron fertilization on boron uptake of *Picea Abies*. *Plant and Soil* 163;55-64

Lingaiah., and Sanaulla, H. 2000. Fertility status of mulberry growing soils of Siddlaghtta Taluk of Kolar District, Karnataka. *Bulletin of Indian Academy of Sericulture*, 4 : 46-49.

Lodha, B.K. and Seth, S.P. 1970. The relationship between different forms of potassium and particles size in different soil groups of Rajasthan. *Journal of the Indian Society of Soil Science*, 18 : 121-127.

Mahapatra, P.K. and Sahu, S.K. 1996. Relationship between some major, secondary and micronutrient status of soils growing groundnut and their contents in groundnut plants, *Journal of the Indian Society of Soil Science*, 44 : 100-103.

Malewar, G.U. 1991. Annual progress report, Department of Agriculture chemistry and Soil Science, MAU, Parbhani,

Mandal, B.T.K., Adhikari, and D.K. De, 1993. Effect of lime and organic matter application on the availability of added boron in acidic alluvial soil, *Communication, Soil Science and Plant Annals,* 24 : 1925-19.

Marzadori. C., Vittori, A. L., Ciavatta, C. and . Sequi, P. 1991. Organic matter influence on adsorption and desorption of boron. *Soil Science Society of America Journal*, 55 : 1582-1585.

Mathur, C.M., Mehta, K.M. and Sharma, V.C. 1968. Soil and land classification in Rajasthan. *Journal of the Indian Society of Soil Science,* 16 : 249-254.

Mathur, G.M., Ramdev and Yadav, B.S. 2006. Status of zinc in irrigated North-West plain soils of Rajasthan. *Journal of the Indian Society of Soil Science,* 54 : 359-361.

Meena, B.L. 2006. Available micronutrient status and their relationship with soil properties of Sawai Madhopur Tehsil (Rajasthan). *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Meena, H.B., Sharma, P.R. and Rawat, U.S. 2006. Status of macro-micronutrients in some soils of Tonk district of Rajasthan. *Journal of the Indian Society of Soil Science,* 54 : 508 - 512.

Mehra, J.R. 2007. To delineate the areas of sufficiency and deficiency of micronutrients and their relationship with soil properties of Mokala soil series. *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Moafpouryan, G.R. and Shukla, L.M. 2002. Status of available boron in major soil series of Delhi. *Annals of Agricultural Research*, 23 : 554-557.

Moafpouryan, G.R. and Shukla, L.M. 2004. Forms of boron in inceptisols of Delhi and their relationship with soil characteristics and sunflower plant parameters. *Journal of the Indian Society of Soil Science*, 52 : 109-111.

More, S.D., Shinde, J.S. and Malewar, G.U. 1988. Characterization of some salt affected soils of Purha command area of Maharashtra, *Journal of the Indian Society of Soil Science,* 36 : 146-150.

Muhr, G.R., Datta, N. P., Shankara, Subramoney, H., Laley, V.K. and Donahue, R.L. 1965. Soil Testing in India, U.S.D.A. Publication, pp. 120.

Murthy, I.Y.L.N. 2006. Boron studies in major oilseed crops. *Indian Journal of Fertilizers.* 1(II) : 11-20.

Nair, K.M. and Chamuah, G.S. 1988. Characteristics and classification of some pine forest soils of Meghalaya, *Journal of the Indian Society of Soil Science,* 36 : 142-145.

Niskanen, R.; Dris, R. 2002. Nutritional status of straw berry fields. In; proceedings of the fourth inernational strawberry symposium, Tompere, Finland. July, 9-14, 2000 vol. 2.

Nitharwal, S.S. 2007. Available Micronutrient Status and their Relationship with Soil Properties of Amber Tehsil, District Jaipur (Rajasthan). *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Nourbakhsh, F.; Jalalian, A.; Shariatmadari, H. 2003. Estimation of CEC from soil physical and chemical properties. *Journal of*

Science and Technology of Agriculture and Natural Resources, 3 : 107-118.

Olsen, S.R., Cole, R.V. Watanabe, F.S. and Lean, L.A. 1954. Estimation of available phosphorus in soil by extraction with sodium carbonate. *Circular ,USDA* No. 939.

Paliwal, K.V. 1972. Irrigation with saline water *IARI mcnugram,* No. 2 (New Series), WTC, IARI, New Delhi.

Paliwal, M.L. 1996. Studied on major and micronutrient status of soils of panchayat samiti Bhinder (District Udaipur), *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Pandey, R.N. and Girish, B.H. 2007. Extractants and critical limits of available soil sulphur for maize (*Zea mays* L.). *Journal of the Indian Society of Soil Science,* 55: 304-312.

Piper, C.S. 1950. Soil and Plant analysis. *The University of Adelade Australia*

Prasad, N. and Jangra, K.K. 2007. Sulphur in balanced fertilization in Rajasthan. *Indian Journal of Fertilizer,* 3 : 41-47.

Qureshi, F.M., Singh, S.K., Choudhary, and S.K. and Das, K. 1996. Genesis and taxonomy of some saline and sodic soils in Bharatpur (Raj.) *Journal of the Indian Society of Soil Science,* 44 : 130-135.

Qureshi, S.J., Khan, M. A., and Qureshi, R.A. 2001. Potassium status of Gujar Khan teshil. *Sarhad Journal of Agriculture*. 17 : 249-252.

Raj, Kumar, 1995. Characterization, classification and management of Aridisols in Punjab National Seminar on "Development in soil Science "held from Nov., 2-5 1995 pp. 176-177.

Reddy, H.T., Prabhuraj, D.K., Bangale, U.D., Mahadevappa, L., Lingaiah; Sanaulla, H. 2000. Fertility status of mulberry growing soils of siddlaghatta taluk of Kolar district, Karnataka. *Bulletin of Indian Academy of Sericulture,* 4 : 46-49.

Reeve, E and Shive, J.E. 1944. Potassium-boron and calcium-boron relationship in plant nutrition. *Soil Science,* 57 :1-14.

Richards, L.A. 1954. Diagnosis and improvement of saline and alkali soils. USDA Handbook No. 60.

Sahu, S.K., Mitra, G.N. and Misra, U.K. 1990. Relationship between available micronutrient status of soils growing rice and micronutrient contents of rice plants. *Journal of the Indian Society of Soil Science*, 38 : 82-88.

Sakal, R., Singh, S.P., Singh, A.P. and Bhogal, N.S. 1993. Evaluation of soil test methods for response of chickpea to boron in calcarious soil. *Annals of Agricultural Research,* 14 : 377-387.

Sanwal, R.C. 2008. Available micronutrient status and their relationship with soil properties of Srimadhopur Tehsil, District-Sikar (Rajasthan). *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Sarkar, M., Ghosh, S. K., Mukhopadhyay, P. and Pal, S. K. 2007 Distribution of sulphur and its relationship with properties in some soil series (Alfisols) of West Bengal.*Agropedology,*17 :113-117

Sellamuthu, K.M., Nartarajan, S., Sivasamy, and R. Mani, S. 2000. A study on the soil fertility status of sugarcane growing areas of Kancheepuram district, Tamil Nadu, *Madras Agricultural Journal*. 87 : 428-431.

Sharma, D.L., Moghe, V.B. and Mathur, C.M. 1968. Salinity and alkalinity problem and fertility status of soils of Pali district of Rajasthan. *Journal of the Indian Society of soil Science.* 16 : 263-269.

Sharma, H.C. and Bajwa, M.S. 1989. Different forms of boron in salt affected soils. *Journal of the Indian Society of Soil Science,* 37 : 470-474.

Sharma, J.C. and Chaudhary, S. K. 2007. Vertical distribution of micronutrient cations in relation to soil characteristics in lower shiwaliks of solan inNorth-west Himalayas. *Journal of the Indian Society of Soil Science,* 55 : 40-44.

Sharma, Y.K. and Gangawar, M.S. 1997. Distribution of different forms of sulphur and their relationship with some soil properties in Alfisols, Inceptisols and Molisols of Moradabad district U.P. *Journal of the Indian Society of Soil Science*, 45 : 480-485.

Shrotriya, G.C. and Philips, M. 2002. Boron in Indian Agriculture Retrospect and Prospect. Fertilizer News, 47 : 95-102.

Simard, R. R., G. Charron and D. Pageau 1996. Field calibration boron soil test for barley. Communication, *Soil Science and Plant Analysis*, 27 : 1631-1646.

Sims, J.R. and Bingham, F.T. 1967. Retention of boron by layers silicates, sesquioxides and soil minerals. *I layer silicates Soil Sciences Society of America Proceeding*, 31 : 728-732.

Singh, B. and Randhawa, N.S. 1977. Distribution of boron in soil, water and plant samples of malerkotla block of sangrur district (Punjab). *Journal of the Indian Society of Soil Science,* 25, 47-53.

Singh, B.K. 2006. Available Micronutrient Status and their Relationship with Soil Properties of Sangaria Tehsil of Hanumangarh District (Rajasthan). *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Singh, C.P., Gupta, S.P. and Gupta, V.K. 1997. Determination of micro and secondary nutrients in ber (*Zizyphus mauritana* L.) orchard soil profiles. *Haryana Journal of Horticulture Science*, 26 : 199-202.

Singh, D.P. 2007. Available Micronutrient Status and their Relationship with Soil Properties of Pushkar Sub-Tehsil of Ajmer District (Rajasthan). *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Singh, G.; Sharma., K.N. and Arora, B.R. 2002. Fertility status of soils of different agro-climatic zones of Punjab. *Journal of Research. PAU.,* 39: 6-14.

Singh, H. and Singh, P. 2007. Fertility status of soils of the recent flood plains of Punjab. *Journal of Research, PAU*, 44 : 199-205.

Singh, Komal, Bansal, S.K.; Moinduddin; Pasricha, N.S. 2003. Indexing of potassium, phosphorus and Ca + Mg in wheat grown on six benchmark soil series of Northern India. *Journal of the Indian Society of Soil Science,* 51 : 540-544.

Singh, M.V. 2001. Evaluation of current micronutrients stocks in different agro-ecological zones of India for sustainable crop production. *Fertilizer News,* 46 : 25-42.

Singh, S. and Sharma, B.K. 1984. Some observations on the morphology and physico-chemical aspects of the sand dune in Jodhpur district (Rajasthan). *Annals of Arid Zone,* 23 : 31-38.

Singh, S.K., Baser, B.L., Shyampura, R.L. and Pratap Narayan, 2003. Genesis of lime nodules in Vertisols of Rajasthan. *Journal of the Indian Society of Soil Science,* 51 : 273-279.

Singh, S.K., Kumar, M. and Sharma, B.K. 2009. Change in soil properties in hot arid region of India. *Journal of the Indian Society of Soil Science,* 57: 24-30.

Singh, S.P. and Nayyar, V.K. 1999. Available boron status of some alluvium derived arid and semi-arid soils of Punjab. *Journal of the Indian Society of Soil Science,* 47 : 801-802.

Singh, Y.P., Singh, M. and Singh, R. 1985. Forms of soil potassium in western part of Haryana, *Journal of the Indian Society of Soil Science,* 33 : 285-291.

Snell, F.D. and Snell, C.T. 1949. Colorimeteric methods and analysis. 3rd Edn. Vol., 116, Van *North and Co., Inc.*, New Delhi.

Srivastava, A.K. and Srivastavaw, O.P. 1991. Cation exchange capacity in relation to pH in salt affected soils. *Journal of the Indian Society of Soil Science,* 39 : 355-357.

Srivastava, S.P.; Singh, A.K.; Sharma, M.L. 2001. Importance of soil testing for sugarcane production in western Uttar Pradesh. *Cooperative Sugar.* 32 : 1009-1011.

Su, C. and Suarez, D.L. 1994. Coordination of adsorbed boron. A FTIR spectroscopic study. *Environment Science and Technology.,* 29 : 302-311.

Subbiah, B.V. and Asija, G.L. 1956. A rapid procedure for estimation of available N in soils. *Current Science,* 25 : 259.

Tabatabai, M.A. and Bremner, J.M. 1969. Use of p-nitrophnyl phosphate for assay of soil phosphatase assay. *Soil Biology and Biochemistry,* 1 : 371-376.

Takkar, P.N. and Randhawa, N.S. 1978. Micronutrients in Indian Agriuclture, *Fertilizer News* 23 : 3-26.

Tanaka, H. 1967 Boron adsorption by crop plants as suggested by other nutrients of the medium. Soil Science and Plant Nutrition,13: 41-42

Tandon, H.L.S. 1992. Fertilizer guide. *Fertilizers Development and Consultation Organization*, New Delhi.

Tisdale, S.L., Nelson, W.L., Beatson, J.D. and Halvin, J.L. 1995. *Soil Fertility and Fertilizers* (Edition Fifth), Macillan Publishing Company, New York.

Tiwari, K.N., Nigam Vandana and Pathak, A.K. 1983. Evaluation of some soil test methods for diagnosing sulphur deficiency in rice in alluvial soils of Uttar Pradesh. *Journal of the Indian Society of Soil Science,* 31 : 245-249.

Tsadilas, C.D., N. Yassoglou, C.S. Kosmas and Kallianou C.H. 1997. The availability of soil boron fractions to olive trees and barley and their relationship to soil properties. *Plant and Soil,* 162 : 211-217.

Verma, L.P., Tripathi, B.R. and Sharma, D.P. 1980. Organics as an index to assess the nitrogen status of the soils. *Journal of the Indian Society of Soil Science,* 28 : 138-140.

Verma, V. K., Patel, L. B. and Toor, G. S. 2005. Special distribution of micronutrient in soil in arid tract of Punjab, India. *International Journal of Agricultural Biology,* 7 :295-297

Walkley, A. and Black, I.A. 1934. Rapid titration method of organic carbon of soils. *Soil Science*, 37 : 29-33.

Wang, K., Xu, J.M., Wel,Y.Z., Yang, Y.A. and Bell R.W. 1997. The influence of boron fertilizer on distribution of extractable boron in soil profiles in rape-rice rotation in Southeast China. In R.W. Bell and B. Rerkasem (ed.) Boron in soils and plants proceedings. Developments in Plant and Soil Science, 76. Kluwer Academic Publications Dordrecht the Netherlands. pp. 56-61.

Wang, Y. 1987. Manual of china cities and counties (In Chinese) Zhejiang Education Press. Hangzhou.

Williams, C.H. and Steinbergs, A. 1959. Soil sulphur interactions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research,* 10 : 340-352.

Wojcik, P. 2000. Availability of soil boron fraction to M-26 apple rootstock. *Journal of Plant Nutrition,* 23 : 1025-1035.

Wu, R. and Tiessen, H. 2002. Effect of land use on soil degradation in alpine grassland soil china, *Soil Science Society of the America Journal,* 66 : 1648-1656.

Xu-Zonylin, Gou-Xi, Li-Kun., Ye-Dexian 2008. Distribution and characteristics of cultivated soil nutrients and its dynamic change trend in sichuan province. *Southwest China Journal of Agricultural Sciences,* 21 : 718-723.

Yadav, B.L. and Vyas, K.K. 1998. Water retention characteristics of some soils of semi-arid Eastern plain of Rajasthan. *Journal of the Indian Society of Soil Science,* 46 : 439-442.

Yadav, R.L. 2005. Available micronutrient status and their relationship with soil properties of Degana soil series of Rajasthan. *M.Sc. (Ag.) Thesis*, RAU, Bikaner.

Yadav, R.L. and Meena, M.C. 2009. Available micronutrient status and their relationship with soil properties of Degana soil series of Rajasthan. *Journal of the Indian Society of Soil Science,* 57 (1) : 90-92.

Yener, H., Aydin, S., and Gulec, T. 2002. Nutrient status of kovakhdere vineyard in alasehir Province. Alsehir Yoresi Kavakhadere baglarinin beslenme durumu. *Anadolu*, 12 : 110-138.

Yermiyahu, U., R. Keren and Y. Chen. 1988. Boron Sorption on composted organic mater. *Soil Science Society of America Journal* 52 : 1309-1313.

Yermiyahu. U., R. Keren and Y. Chen 1995. Boron sorption by soil in the presence of composted organic matter, *Soil Science Society of the America Journal* 59 : 405-409.

Forms of boron in relation to soil properties under groundnut cultivation in Jaipur district of Rajasthan.

Pradeep Kumar*
(Scholar)

Dr. B.L. Yadav**
(Major Advisor)

ABSTRACT

Fifty nine soil and groundnut plant samples at peg initiation stage were collected from fifty nine villages of groundnut growing fields of five tehsils of Jaipur district. The soils were analysed for texture, physico-chemical properties, status of available nutrients and forms of boron. Plants were analysed for the determination of nutrient content.

The important findings of the present investigation are as follows:

1. The majority of soils of the tract were found loamy sand and their texture varied from sandy to sandy loam.
2. Majority of soils have low in organic carbon, available nitrogen, phosphorus, sulphur and boron and medium in potassium, calcium and magnesium.
3. The groundnut growing soils of the study area had major portion of their boron content in residual form boron followed by organically bound boron, specifically adsorbed boron, readily soluble boron and oxide bound boron of the total boron.
4. All the forms of boron gave significant positive correlation with pH_2 and $CaCO_3$ and all forms positively correlated to each other except residual and total boron whereas both were correlated negatively with all other forms of boron.
5. The content of all nutrients in groundnut plants positively and significantly correlated with available boron whereas, plant boron positively and significantly correlated with available boron, readily soluble boron, specifically adsorbed boron, oxide bound boron and organically bound boron but negatively and significantly with residual boron and total boron.
6. The present study indicates that groundnut growing soils of Jaipur district of Rajasthan are deficient in boron and thus, calls for an adequate application of boron alongwith organic matter for optimizing groundnut production.

---

* A Post Graduate Student, Department of Soil Science and Agricultural Chemistry S.K.N. College of Agriculture, Jobner (Jaipur-Rajasthan) - 303329.

** Associate professor, Department of Soil Science and Agricultural Chemistry, S.K.N. College of Agriculture, (Swami Keshwanand Rajasthan Agricultural University, Bikaner), campus- Jobner (Jaipur- Rajasthan).

राजस्थान के जयपुर जिले में मूंगफली उगायी जाने वाली मृदाओं के गुणों का बोरॉन के रूपों से संबंध

प्रदीप कुमार*
(शोधकर्त्ता)

डॉ. बी.एल. यादव**
(मुख्य सलाहकार)

अनुक्षेपण

जयपुर जिले की 5 तहसील के मूंगफली उगाने वाले 59 गांवों से मृदा एवं मूंगफली के नमूने कील उद्भव अवस्था पर एकत्रित किए। मृदाओं को उनके कणाकारों, भौतिक–रासायनिक गुणों, तत्वों के स्तर एवं बोरॉन के रूपों को ज्ञात करने के लिए विश्लेषित किया गया। पौधो का विश्लेषण तत्वों की पौधो में विद्यमान मात्रा को ज्ञात करने के लिए किया गया।

वर्तमान अनुसंधान के महत्वपूर्ण परिणाम निम्न प्रकार से है:–

1. अन्वेषण क्षेत्र की अधिकतर मृदाए दोमट बलुई पायी गयी एवं उनका कणाकार बलुई से बलुई दोमट विचरण करता है।
2. अधिकतर मृदाओं में जैविक कार्बन, प्राप्य नाइट्रोजन, फास्फोरस, गंधक एवं बोरॉन न्यून तथा पोटेशियम, कैल्शियम एवं मैगनीशियम मध्यम मात्रा में पाये गये।
3. मूंगफली उगाये जाने वाली मृदाओं के अध्ययन से पाया गया कि कुल बोरॉन में से सबसे अधिक भाग अवशिष्ट बोरॉन का उसके बाद क्रमशः कार्बनिक बाध्य बोरॉन, विशेष संगठित बोरॉन, शीघ्र घुलनशील बोरॉन एवं ऑक्सीकृत बाध्य बोरॉन का भाग, पाया गया।
4. बोरॉन के सभी रूपों का पी.एच कैल्शियम कार्बोनेट एवं बोरॉन के सभी रूप आपस में सार्थक धनात्मक सम्बन्ध पाया गया सिवाय अवशिष्ट एवं कुल बोरॉन को छोड़कर, वैद्युत चालकता के साथ असार्थक धनात्मक सम्बन्ध पाया गया।
5. मूंगफली पौधो में सभी पोषक तत्वों की मात्रा का सार्थक धनात्मक सम्बन्ध प्राप्य बोरॉन के साथ पाया गया जबकि पादप बोरॉन की सार्थक एवं धनात्मक सम्बन्ध प्राप्य बोरॉन, शीघ्र घुलनशील बोरॉन, विशेष संगठित बोरॉन आक्सीकृत बाध्य बोरॉन एवं कार्बनिक बाध्य बोरॉन के साथ पाया गया परन्तु अवशिष्ट बोरॉन एवं कुल बोरॉन के मध्य ऋणात्मक एवं सार्थक संबंध पाया गया।
6. वर्तमान अध्यान यह निर्देशित करता है कि जयपुर जिले की मूंगफली उगायी जाने वाली मृदाओं में बोरॉन की न्यूनता है, अतः मूंगफली के उपयुक्त उत्पादन के लिए बोरॉन के साथ जैविक पदार्थो की पर्याप्त मात्रा का अनुप्रयोग करे।

* स्नातकोतर छात्र, मृदा विज्ञान एवं कृषि रसायन विभाग, श्री क.न. कृषि महाविद्यालय, जोबनेर (जयपुर) – 303329

** सहआचार्य, मृदा विज्ञान एवं कृषि रसायन विभाग, श्री क. न. कृषि महाविद्यालय, जोबनेर (जयपुर) (स्वामी केश्वानन्द कृषि विश्वविद्यालय, बीकानेर)