ASSESSMENT OF MOLYBDENUM AND BORON STATUS OF SOILS OF JUNNER AND HAVELI TAHASIL OF PUNE DISTRICT

By

AJIT NARAYAN PURI
Reg. No. 02223

A thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH,
RAHURI- 413 722, DIST. AHMEDNAGAR,
MAHARASHTRA STATE. (INDIA)

in partial fulfil ment of the requirements for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

SOIL SCIENCE

DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL SCIENCE,
COLLEGE OF AGRICULTURE, PUNE - 411 005,
MAHARASHTRA STATE
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Approved by

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DEPARTMENT OF AGRICULTURAL CHEMISTRY AND SOIL SCIENCE,
COLLEGE OF AGRICULTURE, PUNE- 411 005,
MAHARASHTRA STATE.
2004

DEDICATION

Dedicated to family members, friends

whose high expectations,

constant inspiration

and everlasting

love form the

base of my

progress.

... AJIT

CANDIDATE'S DECLARATION

I hereby declare that this thesis entitled " **Assessment of molybdenum and boron status of soils of Junner and Haveli Tahasil of Pune District"**, or part there of has not been submitted by me or any other person to any other University or Institute for Degree or Diploma.

Place: Pune

Date: 10 / 12/2004

(A.N. Puri)

Dr. S.P. Surve,
Chairman and Research Guide,
Soil Scientist, Operational Research Project
For Dryland Agriculture, Solapur
Maharashtra State (India).

CERTIFICATE

This is to certify that the thesis entitled, "**ASSESSMENT OF MOLYBDENUM AND BORON STATUS OF SOILS OF JUNNER AND HAVELI TAHSILS OF PUNE DISTRICT** ", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE**, embodies the results of a piece of *bona-fide* research work carried out by **Mr. PURI AJIT NARAYAN,** under my guidance and supervision, and that no part of the thesis has been submitted for any other Degree or Diploma.

The assistance and the help received during the course of this investigation have been acknowledged.

Place : Pune

Date : 10 / 12 / 2004

(S. P. Surve)

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Associate Dean,
College of Agriculture,
Pune- 411 005.
Maharashtra, India.

CERTIFICATE

This is to certify that the thesis entitled, " **Assessment of molybdenum and boron status of soils of Junner and Haveli Tahasil of Pune District**", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **SOIL SCIENCE**, embodies the results of a piece of *bona-fide* research work carried out by **Mr. AJIT NARAYAN PURI**, under the guidance and supervision of **Dr. S.P. Surve**, Soil Chemist, Dryland Research Station, Solapur and no part of the thesis has been submitted for any other Degree or Diploma.

Place : Pune
Date : / /2004
10 DEC 2004

(D.L. Sale)

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While traveling on this path of education many hands pushed me forth, learned hearts put me on right track lightened by their knowledge and experience, I ever rest thankful indebt of them all.

Place: Pune

Date: 10/12/2004

(Ajit N. Puri)

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LIST OF ABBREVIATIONS

%	per cent
@	At the rate of
^0C	Degree Celsius
cm	centimeter
Co	Cobalt
dS m^{-1}	deci Siemens per meter
EC	Electrical conductivity
et al.	*et alli* (and others)
Fig.	Figure
g	gram (s)
ha	hectare
i.e.	That is
K	Potassium
kg ha^{-1}	Kilogram per hectare
Kg	Kilogram
mg kg^{-1}	Milligram per kilogram
mg L^{-1}	Milligram per liter
N	Nitrogen
NS	non significant
P	Phosphorus
Viz.,	Videlicet (namely)

ABSTRACT

ASSESSMENT OF MOLYBDENUM AND BORON STATUS OF JUNNER AND HAVALI TAHSIL OF PUNE DISTRICT

by

PURI AJIT NARAYAN

A candidate for the degree

of

MASTER OF SCIENCE (AGRICULTURE)

in

SOIL SCIENCE

2004

Research Guide	:	**Dr. S. P. Surve**
Department	:	**Agril. Chemistry and Soil Science**

In order to study the molybdenum and boron status of soil of Junner and Haveli tahsil of Pune district, the present investigation was carried out during the year 2003-2004. Two hundred surface soil samples (0-20 cm) were collected from thirty seven dominant soil series. The soil samples collected were analysed for available molybdenum and available boron. The soil samples were also analysed for chemical properties i.e. pH, EC, $CaCO_3$, available nitrogen, available phosphorus and available potassium content. The results obtained revealed that most of the soil samples of the each series were saline to slightly alkaline in nature. Out of thirty seven soil series, seventeen soil series were moderately calcareous and other twenty were non-calcareous.

According to the data in respect of nutrient status of soil, available nitrogen ranged from 201 to 303 kg ha^{-1} with average value 256 kg ha^{-1}, according to six tier system about 69 per cent soil samples were low in available nitrogen, while 31 per cent were medium in available nitrogen.

Available P content ranged from 7.99 to 11.37 kg ha^{-1} with an average value 9.27 kg ha^{-1}, according to six tier system all soil samples comes under low category.

Available K content in thirty seven soil series ranged from 291.18 to 385.21 kg ha^{-1} with an average value 341.08 kg ha^{-1}, according to six tier system available K content was high in 23.5 per cent and very high in 76.5 per cent.

In respect of micronutrients status, available boron content of the soil series varied from 0.19 to 0.67 ppm with average value 0.41 ppm.

For available boron about 21 per cent soil samples comes under 0.1 to 0.3 fraction, 65.5 per cent comes under 0.31 to 0.6 fraction and 13.5 per cent under 0.61 to 1.0 fraction.

Available molybdenum content of the soil series varied from 0.08 to 0.541 ppm with an average value 0.291 ppm.

For available molybdenum about 60 per cent soil samples comes under 0.05 to 0.3 fraction, 33.5 per cent comes under 0.31 to 0.5 fraction, and 6.5 per cent under more than 0.5 fraction.

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INTRODUCTION

1. INTRODUCTION

Intensive cropping and increased use of NPK fertilizers generally devoid of micronutrients though increase in the production tremendously but this also resulted in heavy turnover of other nutrients from soil simultaneously. There is a continuous decline in soil fertility and productivity due to exploitation of soil resource base. Imbalanced and indiscriminate use of fertilizers and emergence of micronutrient deficiencies have been identified as the most important factors for declining crop productivity growth (Kanwar and Randhawa, 1967; Takkar and Randhawa, 1978).

Due to use of hybrid vigours for higher yields, the demand for plant nutrients increased spectacularly. However, use of imbalanced fertilizers, micronutrients deficiencies seems to be appeared in most of the soils. Unlike the major nutrients, micronutrients are also equally important for boosting the agricultural production. Application of micronutrient in combination with major nutrients and provision of adequate irrigation facilities have a prime importance under sustainable farming system and there by maintaining the soil health and stability of soil productivity.

Among the various trace elements, boron has assumed greater significance due to wide occurrence of its deficiency and also due to its importance in deciding the quality and quantitative aspect of production. The crop failures and plant diseases arising from the deficiency and excess of available boron in the soil, has led to numerous studies for assessing the status of soils and plants, as well as in knowing the factors which governs its availability in soil. Very meager information is available on assessment of boron under adverse condition of agro-climatic situation.

Boron is one of four essential elements occurring in soils as anion and is the one which plant need in smallest quantity. Boron exist in soil in two forms *viz.,* water soluble and total boron. Water soluble boron is considered to be a most useful source for the plant (Berger and Trough, 1947). The contents of boron in different soils depend upon the nature of parent material from which they are derived and characteristics of soil types.

Boron has major importance in crop production. Plants cannot attain full maturity in the absence of traces of this element. Boron was first shown to be essential micronutrient for plant growth more than six decades ago. Maize crop was first to report that boron was essential for the normal growth of corn. Boron is known to play many important functions in plant metabolism in salt absorption and water relations in plant. It is also required for the translocation of sugar in plant and development of cell-wall. Further, it is regarded as a buffer in plant tissue acting as a some kind of regulator for other substances.

The problem regarding the general status of Indian soils in respect of boron and the degree of its availability in different soils has no doubt received some attention in our country.

Molybdenum deficiency is not common in Indian soils. Therefore very few and sporadic studies have been made on its management.

Molybdenum, a second transition series element occurs in aqueous solution mainly as the molybdate oxyanion. Molybdenum requirement of plant is low as compare to other mineral nutrients except nickel. Molybdenum has assumed great importance in plant nutrition in recent years. In long distance transport in plant, molybdenum is readily mobile in xylem and phloem (Kannan and Ramanis, 1978). The form in which molybdenum is translocated is unknown, but its chemical properties indicate that it is most likely transported as molybdate oxyanion rather than in complexed form.

The molybdenum content of lithosphere is estimated at 2.3 mg kg^{-1}, whereas the common range for soils is 0.2 to 5 mg kg^{-1} (Lindsay, 1979).

The available molybdenum content of Indian soils varie from traces to 1.65 mg kg^{-1}. Molybdenum occurs in soils in extremely small quantities and it is generally recorded in concentrations of less than 1 mg kg^{-1} in plants. On the basis of critical limit of molybdenum in soil as 0.05 mg kg^{-1} (Grigg, 1953), most of the Indian soils have been found to be deficient in the element.

In Maharashtra, very limited work has been carried out to assess the boron and molybdenum status of soils. The present studies were, therefore undertaken to assess the relative status of boron and molybdenum in Junner and Haveli tahasils of Pune district of Maharashtra state, which will help in locating the areas where probable deficiency of these elements would be predicated.

Objectives :

1. To study chemical properties of soils of Junner and Haveli tahasil.
2. To study molybdenum status of soils of Junner and Haveli tahasil.
3. To study boron status of soils of Junner and Haveli tahasil.

Chapter Opener Page

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Micronutrients play an active role in the plant metabolic processes starting from cell wall development to respiration, photosynthesis, chlorophyll formation, enzyme activity, nitrogen fixation and reduction etc. Micronutrient requirement of crops are relatively small and ranges between their deficiencies and toxicities in plants and soils are rather narrow. The decreased content of micronutrients in soils and their uptake by plants to such a critical level which shows their deficiency symptoms in different crops. Therefore, an attempt was made to review the important information required to know the boron and molybdenum status of soil.

2.1. Geochemistry of boron

Boron occurs in low concentrations in the earth's crust and in most igneous rocks and soils. It's concentration in earths crust is 10 mg kg^{-1} and it ranges from 5 to 15 mg kg^{-1} in igneous rocks. Among the usual sedimentary rocks, shales have the highest boron concentration up to 100 mg kg^{-1}.

Soil boron available to crop is less than 5% of total soil boron (Bokade, 1963).

Marine shales and glauconitic sandstones are commonly high in boron (Hodgson, 1963).

Most soil boron unavailable to plants, the available boron fraction ranging from 0.4 to 5 mg kg^{-1} (Gupta, 1979).

Gupta (1979) reported that soils in high rainfall areas are often deficient in boron. Boron is mainly contributed from tourmaline and fluorine borosilicate minerals.

Total boron in Indian soils varies from 7 to 630 mg kg^{-1} as reported by (Kanwar and Randhawa, 1974; Katyal and Sharma, 1979).

Boron is found in soil in different forms like boric acid (H_3BO_3) and borate ions (H_2BO_4).

Ullaha and Jabbar (1981) reported that hot water soluble, HCl soluble and leachable boron concentrations were maximum in surface soil and tends to decline with depth.

2.2 Distribution of boron

2.2.1 Distribution of boron in India

Boron is non metal and it belongs to the third periodic group. The total concentration of boron in most soils varies from 2 to 200 mg kg^{-1} and less than 5% of the total soil boron is generally available to plants.

Total boron content of most of the soils in the world ranges from 2 to 100 ppm (Swaine, 1955).

Total boron content in soils of Uttar Pradesh is in high to excess range (Agarwal, 1964).

The critical limits of available boron have been reported to be 0.1 to 0.5 ppm (Raychaudhary and Biswas, 1964).

Total amount of boron in soils depends largely on the soil parent material (Anonymous, 1967).

Jackson (1967) reported that total boron in soil ranged from 4 to 98 ppm and fine textured humid soils showed a range of 30 to 60 ppm and sandy soils as low as 2 to 6 ppm.

Chavan (1974) reported that the total boron content of Maharashtra soils varies from 8.57 to 37.14 ppm with an average value of 19.34 ppm.

Available boron content of soils, which are loamy sand to loam in texture of Ferozepur and Faridkot districts of Punjab ranged between 0.22 to 2.4 mg kg^{-1} and 0.20 to 3.85 mg kg^{-1} respectively (Singh and Nayyar, 1999).

The distribution of available boron status of different states of India, reported by researchers is given in Table 1.

2.2.2 Distribution of Boron in Maharashtra

Bendale *et al.* (1951) found that soils from Deccan trap of Maharashtra contain total boron ranging from 1.2 ppm to 16.6 ppm, while water soluble boron was found to ranging from 0.10 to 0.60 ppm which is in the safe limit for both the fractions of boron.

Atre (1960) reported that the water soluble boron in Vidarbha soils varied between 0.3 to 3.0 ppm in the surface soil samples. While in subsequent studies, the water soluble boron was observed to be low in some typical soil profiles of Nagpur (Raut, 1962).

The total boron in different districts of Maharashtra ranged from 2.75 to 20.90 ppm. The soils from districts like Solapur, Satara, Aurangabad, Yeotmal and Nagpur contain a fairly high proportion of total boron than the soils from Ahmednagar, Thane, Nanded, Pune and Dhule. The average total boron content in soils of different districts of Maharashtra is 9.21 ppm. The lowest value observed 0.10 ppm was in soils of Ahmednagar district while highest value of 0.92 ppm was observed in soils of solapur district. The soil from districts like Thane, Colaba, Kolhapur, Nasik, Beed, Akola and Nagpur were found to be rich in this fraction than the soils from other districts (Mahabari, 1970).

Chavan (1974) reported that the total boron content of Maharashtra soils varied from 8.57 to 37.14 ppm with an average value of 19.34 ppm. Water soluble boron constitutes a very small portion of total B (4.33%) and it varied from 0.18 to 1.97 ppm with an average value of 0.83 ppm.

2.3 Forms of boron in soil

Among the two forms of boron, namely H_2BO_3 and H_2BO_4 are the most common geological forms, of which H_2BO_3 (boric acid) predominates in soil and soil solutions over a wide range of pH, while H_2BO_4 predominates only above pH 9.2 (Lindsay, 1973).

Qertli and Grugurevic (1975) have shown that boric acid is the form of boron that plant roots absorb most efficiently.

Boric acid, however, undergoes hydrolysis and forms borate ion, $B(OH)_4^-$ reversively at above pH 7.0 (Baes and Mesmer, 1976).

Boron occurs in aqueous solution as boric acid, B $(OH)_3$ that acts as an electron acceptor or as a lewis acid (Parfitt, 1978).

Tourmaline and fluorine borosilicate are the best known boron containing minerals. Boron is also contributed by organic matter, irrigation water and boron containing fertilizer (Katyal and Sharma, 1979).

2.4 Factors affecting boron availability in soil

There are various factors influencing the availability of boron in soils *viz.*, soil texture, soil pH, electrical conductivity, calcium carbonate, organic matter, irrigation water, salt concentration, soil clay content and inter relationship with other element.

Several researchers studied these factors which are being reviewed below.

2.4.1 Soil texture

Gandhi and Mehta (1958) reported that no relationship existed between finer fraction and available boron content of the Gujarat soils.

Singh and Singh (1976) also reported a positive significant correlation between water soluble boron and finer fraction in saline alkali areas of southwest tracts of Bihar.

2.4.2 Soil pH

In alkaline susceptible plants, the severity of lime induced boron deficiency depends on the moisture status of soil and the nature of crop

(Bradford, 1966). The availability of native and applied boron was not significantly affected by $CaCO_3$ content of soils (Bhattacharjee, 1956; Gandhi and Mehta, 1958 and Singh and Singh, 1967).

There was no correlation betn soil pH and water soluble boron in soils of Gujarat (Gandhi and Mehta, 1958).

2.4.3 Electrical Conductivity

Electrical conductivity has a positive relationship with water soluble boron content in soil (Bingham, 1973; Paliwal and Anjameyulu, 1967).

While negative relationship between EC with boron has also been reported by many investigators (Parks and White, 1952; Bhumbla *et al.*, 1980).

2.4.4 Calcium Carbonate

Baser and Saxena (1967) reported that there was significantly adverse effect of $CaCO_3$ on boron availability.

Singh and Singh (1967) reported that availability of native and applied boron was not significantly affected by $CaCO_3$ content of the soils.

The positive significant relationship between water soluble boron and $CaCO_3$ content of soils was demonstrated by Singh and Randhawa, 1977.

2.4.5 Organic matter

The amount of boron adsorbed on organic matter is much higher than those on soils (Keren and Mezuman, 1981). Available boron significantly increased with increasing in organic matter content of arid soils in Western Rajasthan and Bhuna soils in Haryana (Lodha and Baser, 1971 and Sharma and Shukla, 1972). A negative relationship between organic matter and available boron was observed in saline alkali soils in Punjab and Uttar Pradesh (Singh and Singh, 1967 and Singh and Randhawa, 1977).

2.4.6 Irrigation water

The occurrence of boron in high concentration in the irrigation water frequently develops soil salinity and continuous use of such irrigation water build up boron in a toxic level (Chauhan and Power, 1978 and Verma, 1983). Fine textured soils generally have more water soluble boron than coarse textured soils (Singh and Singh, 1976).

2.4.7 Salt concentration

Boron exists in the form of Na and Ca salts, in dry land soils which are highly soluble. Boron moves up along with other salts and is deposited at the surface. Agarwal *et al.* (1964) found that in general change in exchangeable sodium percentage (E.S.P.) did not affect the amount of water soluble boron.

2.4.8 Soil clay content

More clay content responsible for the fixation of applied boron. Fine textured soils generally have more water soluble boron than coarse textured soils (Singh and Singh, 1976).

Kaolinite has the lowest boron adsorption capacity. There is no relationship between water soluble boron and clay content (Mathur *et al.*, 1969). With increase in fineness of soil texture, boron adsorption also increases (Ullah and Jabbar, 1981).

2.4.9 Interrelationship with other elements

In alkaline soils where free Ca^{2+} ions are present, the availability of boron is much less.

Berger (1949) considered that the Ca/B interaction is more fundamental than the K/B.

2.5 Role of boron in plant nutrition

Boron is an important essential micronutrient, which is required in very small amounts for the crop production.

The role of boron in crop production and nutrition was discussed by Lal and Srivastava (1948).

Raut (1962) observed that the absorption of boron by rice plants run parallel with dry matter production. There is heavy demand for the element at flowering stage.

Kouchi and Kumazawa (1976) reported that boron complexes strongly with cell wall constituents.

According to Lewis (1980) high boron levels in the stigma and style are required for physiological inactivation of callose from the pollen tube walls by the formation of borate callose complexes.

Agarwal *et al.* (1981) reported that boron affects fertilization by increasing the pollen producing capacity of the anthers and pollen grain viability.

Oil content of rai (*Brassica juncea*) was found to be significantly improved due to application of boron (Sukla *et al.*, 1983).

Takkar *et al.* (1989) reported that activity of polyphenol oxidase strikingly increased with an increasing supply of boron.

Mandal (1990) also reported that the grain filling of wheat did not occur due to failure of pollen tube growth on the stigma and fertilization resulting from the boron deficiency.

Application of boron significantly increased the pod yield (Singh *et al.* 1991, Patel and Kolakiya, 1986).

Sinha *et al.* (1991) reported that 1.5 kg B ha^{-1} appeared to be the optimum level for all the crops. The maximum yield responses of groundnut, mustard, winter maize, sunflower, onion and lentil at optimum B level were 2.4, 3.1, 8, 7, 3.2, 28.3 and 2.4 q ha^{-1}, respectively, but higher doses of molybdenum and boron depressed the yield.

Table 1. Average value of available boron content (mg kg^{-1}) in Indian soils

States	Districts/Orders	Available boron (mg kg^{-1})
Assam	Jorhat	1.66
	Darrange	1.72
	Nagaon	2.15
	Kamrup	1.61
	Goalpara	1.37
	Saharsa	1.59
	Bhagalpur	1.05
		Ali (1992)
Bihar	Katihar	1.05
	Bhojpur	1.15
	Muzaffarpur	0.89
	Morena	0.96
		AR, Pusa Centre, (1982)
Orissa	Mayurbhanj	0.47
	Inceptisols	1.00
	Entisols	0.57
		Ali (1992)
Punjab	Aridisols	1.70
	Vertisols	0.59
	Alfisols	1.06
	Girjapuri	1.60
	Kulaguri	2.10
		Katyal *et al.* (1982)

Uttar Pradesh	Bagulia Pathaguri	1.5 1.8
		AR, Lucknow centre (1980)
	Coochbehar Jalpaiguri	0.36 1.02
		Mandal (1991)
West Bengal	Bankura Purulia Midnapore	0.43 0.28 0.37
		Ali (1992)

2.6 Geochemistry of Molybdenum

Among the essential nutrients for plants, molybdenum is required in the smallest quantity. It is used by plants in the form of MoO_4^- ions and its availability is high in the alkaline pH range.

Molybdenum content in lithosphere on an average is 1 to 2 ppm. It's content is highest in clays and schists which is an available form depending on pH and phosphorous status (Davis, 1956).

Molybdenosis has been observed as an endemic nutritional problem of ruminants, primary in wet, poorly drained neutral to alkaline soils. Accumulations of molybdenum in toxic concentration (>10 mg molybdenum kg^{-1}) in the forage grown in flood plains of six districts of Punjab was recorded (Nayyar *et al.*, 1977).

Molybdenum is readily mobile in xylem and phloem (Kannan and Ramani, 1978).

Molybdenum is found to occurs in primary minerals in silicate structures in feldspar and micas or in association with sulphur as molybdenite. Minerals such as powellite, wulfenite and ferromolybdite contain molybdenum which is not easily soluble (Fleming, 1980).

2.7 Distribution of molybdenum in India

Molybdenum a second transition series element. It was discovered by Carl William Scheele (Sweden) in 1778. Molybdenum occurs in aqueous solution mainly as the molybdate oxyanion. Common range of molybdenum availability in soil is 0.2 to 5 mg kg^{-1}.

On the basis of critical limit of molybdenum in soil as 0.05 mg kg^{-1} (Grigg, 1953) most of the Indian soils have been found to be deficient in the element.

Patil *et al.* (1972) reported that available molybdenum content in soils of Maharashtra State was found to be ranged from trace to 4 ppm. Lower values of available molybdenum were reported from Zone I receiving heavy rain fall and where the soils were acidic in reaction. Increased available molybdenum content was found in alkali soils.

Rai *et al.* (1972) reported that the molybdenum content of deep black soils of Madhya Pradesh, they

varied from 0.05 to 0.14 ppm.

Mali and Badhe (1974) studied the total and available forms of molybdenum in soils of Parbhani district which ranged from 1.1 to 11.6 ppm.

Kanwar and Randhawa (1978) reported that if we consider 0.05 ppm as a critical limit for soils above pH 6 then 59 per cent of the soils may be rated deficient in available molybdenum.

An accepted average for soil is 2 mg kg^{-1}, which provides $10^{-3.68}$ M, molybdenum if it was to dissolve completely in the soil solution at 10% moisture (Lindsay, 1979).

Mitra *et al.* (1993) reported that the available molybdenum content of all the soils varied from 0.01 (lateritic) to 0.2 (saline) mg kg^{-1} in Orissa.

Vinay Singh *et al.* (1995) reported that the soils from Agra district of Uttar Pradesh were neutral to alkaline in reaction having variation in salt concentration and calcium carbonate, the soils are generally poor in organic matter, the available molybdenum content of soils varied from traces to 0.7 mg kg^{-1} soil with mean value of 0.15 mg kg^{-1} soil, the soils from Lucern growing sites contained a maximum amount of available molybdenum.

Available molybdenum content of most of the Indian soils varied from 0.07 to 7.67 mg kg^{-1} (Singh, 1999).

The available molybdenum content in some of the Indian soils is given in Table 2.

2.8 Forms of molybdenum in soil

Molybdenum occurs in soils as associated with primary minerals clay minerals, sesquioxides, organic matter and water soluble forms.

In primary minerals molybdenum known to exhibit both chalcophile and lithophile properties.

Davis (1956) reported that molybdenum is found to be held as the anion, MoO_4^{2-} on the surface of clay or secondary mineral. Sesquioxides are the most important constituents present in acid laterite soils which bound several essential nutrients especially micronutrients including molybdenum.

The nature of binding of molybdenum by sesquioxides has been studied by many workers (Fleming, 1980; Jones, 1957 and Reisenauer *et al.,* 1962)

Organically bound molybdenum was recorded to be higher in plant under acid soil condition (Mitchell, 1964). Concentration of molybdenum in the soil solution is largely controlled by the adsorption of MoO_4^{2-} on Fe_2O_3 and only under alkaline conditions molybdenum availability in water soluble form ranged between 0.8 to 3.9 mg kg^{-1} (Fleming, 1980).

2.9 Factors affecting molybdenum availability

Availability of molybdenum in soil is affected by various factors like liming, soil reaction, organic matter, effect of other ions, moisture regimes and microorganisms.

2.9.1 Liming

Nayyar (1972) studied the effect of graded doses of $CaCO_3$ on molybdenum availability in soils and found that all levels of lime significantly increased the extractable molybdenum content.

It is an evident that liming in acid soils increases molybdenum availability (Fleming, 1980).

The response to lime in the case of soil application of molybdenum may be attributed to its enhanced availability in soil (Gupta and Lipsett, 1981 and Kotur, 1990).

2.9.2 Soil reaction

It is well known fact that molybdenum becomes increasingly available with increasing pH.

Several workers reported the correlation between pH and available molybdenum but could not find the significant relationship (Ghosh *et al.*, 1961; Kavimandan *et al.*, 1964; Balguru and Dhanpalan, 1973).

Rai *et al.* (1972) studied the available molybdenum status of deep black soils of Madhya Pradesh and found that molybdenum was correlated positively with soil pH.

Chavan (1974) also observed positive significant correlation between soil pH and available molybdenum in Maharashtra.

More (1976) studied the soils from Parbhani (Maharashtra) for molybdenum content and they observed that available molybdenum showed a positive significant correlation with pH.

Mandal *et al.* (1991) studied the available molybdenum content in some alluvial acidic soils of North Bengal districts in West Bengal and reported non significant negative correlations (r - 0.16) between pH and available molybdenum.

2.9.3 Organic matter

The role of organic matter in increasing the availability of molybdenum, especially in acid soils, may be due to protection of molybdenum from adverse soil reaction.

Kavimandan *et al.* (1964) reported that there is significant positive relationship between available molybdenum and organic carbon content of Vidharbha soils.

Balguru and Dhanapalan (1973) found that available molybdenum was more in alluvial soils owing to its higher organic matter content.

Chavan (1974) also reported a positive significant correlation between organic matter and available molybdenum in soils of Maharashtra State.

On the other hand More (1976) reported a negative significant correlation with organic carbon and available molybdenum in soils from Parbhani district of Maharashtra.

2.9.4 Effect of other ions

Very little information is available on transformation of molybdenum in soils and its interactien with other ions.

The specific effect of sulphate ion on the molybdate ion is an antagonistic one but in certain soils the application of sulphur as gypsum actually increased molybdenum availability (Fleming, 1980).

Basak *et al.* (1982) reported that the application of phosphatic fertilizers was effective in enhancing molybdenum availability in acid soils which may vary with soil properties.

2.9.5 Moisture regimes

Moisture content of soil may affect the availability and uptake of molybdenum by the plants.

Nayyar (1972) studied effect of 50 per cent field capacity, field capacity and saturation conditions on molybdenum availability in soils and found that the highest amount of extractable molybdenum was recorded in treatments at field capacity moisture regimes followed by 50 per cent field capacity and saturated soil moisture regimes.

The relatively more amount of extractable molybdenum under submerged soil conditions may be due to reduction of ferric iron to more soluble ferrous iron forms resulting from the intense soil reduction as well as increased soil pH of an acid soil due to submergence (Ponnamperuma, 1975).

2.9.6 Micro-organisms

The extent to which microorganisms affect molybdenum availability has only recently been recognized.

Donald *et al.* (1952) demonstrated that in a medium of acid washed quartz-crystals, micro-organisms could fix a number of nutrient elements including molybdenum.

Mosse (1957) reported that mycorrhizal apple seedlings contained higher levels of molybdenum than non mycorrbizal plants.

Mitchell (1964) suggested that the formation of organic complexes prevents the fixation of molybdenum by other soil components. The possibility exists that part of this organic complex is composed of microbial cells.

Rhizosphere organisms exert a greater influence on molybdenum availability that those not connected with plant roots (Fleming, 1980).

2.10 Role of molybdenum in plant nutrition

For the growth and development of plant iron, manganese, copper, zinc, boron and molybdenum requires in very less amount.

Among this microelement, molybdenum acts as coenzyme in most of the metabolic activities of plant system. Similarly it is very much useful in translocation of biologically fixed nitrogen from root nodules to vegetative part of plant.

Gorlach and Gorlach (1970) noticed that the application of 2 kg Mo ha^{-1} as ammonium molybdate before sowing to lucern grown on a alluvial soil (pH 5.4) with available molybdenum of 0.16 ppm and receiving 90 kg P_2O_5 and 150 kg K_2O annually, increased the dry matter yields by 73 per cent due to molybdenum application.

Murlidharan and George (1971) reported that the molybdenum application @ 1062 g ha^{-1} increased the plant height and number of leaves of groundnut plant.

Singh (1971) found that the application of 680 g ha^{-1} of molybdenum to *dhaincha* significantly increased the branches per plant and leaf dry weight as compared to 340 g ha^{-1} molybdenum and control.

Sharma and Minhas (1986) reported that 105 g Mo ha^{-1} was better than 140 g Mo ha^{-1} for soybean grain yield. Higher dose of Mo depressed the yield from 28.5 to 26.3 q ha^{-1}.

Wankhede *et al.* (1991) reported that seed treatment of groundnut cv. JL-24 and SB-11 with *rhizobium* + molybdenum increased dry matter accumulation and weight of dry pods per plant over control.

Among different rates tried, soil application of 0.4 kg Mo ha^{-1} produced the optimum yield of maize, groundnut and soybean. The increased yield over control was 1.02, 0.62 and 0.40 t ha^{-1}, respectively. (Sakal *et al.,* 1993).

Dwivedi *et al.* (1996) carried out a field investigation during *kharif* season of 1990-91 to study the influence of phosphorous and molybdenum application on nutrient status in various plant parts (leaf, stem and seeds) at pre flowering (45 days), general flowering (60 days) active pod filling (75 days) stages and maturity. Maximum nitrogen and potassium content in stems were estimated at pre flowering and phosphorous and sulphur at general flowering, while in leaf all the nutrients were higher at pre flowering stages after which their content reduced sharply. The application of 100 kg P_2O_5 and 1 kg Mo ha^{-1} enhanced the absorption of all the nutrients and their accumulation in various plant parts including seeds.

Singh *et al.* (1996) reported that field trials in acidic red loam soils of Kanke with graded levels of molybdenum indicate significant increase in grain yields of maize, soybean and of groundnut pods at 0.4 kg Mo ha^{-1} applied as ammonium molybdate.

Bhattacharya *et al.* (1997) in a field study reported that a combined application of sulphur, zinc and molybdenum increased groundnut plant height by 28 per cent and dry matter by 117 per cent.

Noor *et al.* (1997) reported that the application of boron and molybdenum increased nodulation and seed oil content as compared to control.

Dubey (1999) reported that the mean nodule count and nodule dry weight per plant of soybean increased by 22.9 to 44.3 per cent and 17.4 to 39.6 per cent, respectively.

On molybdenum deficient soils application of 1 kg ha^{-1} molybdenum increased the molybdenum content of black gram and residual sunflower and raised the available molybdenum status of the soil (Rattan *et al.*, 1999).

Pattanayak *et al.* (2000) conducted a field experiment to study seed treatment of green gram with micronutrients (0.16 mg Mo and 0.008 mg Co g^{-1} of seed as sodium molybdate and cobalt chloride) and *rhizobium* culture. The results showed significant increase in nodule number, nodule weight, N concentration leg hemoglobin content, grain yield, N uptake and total biomass production over uninoculated treatment in a moderately acid soils.

Table 2. Average value of available molybdenum mg kg^{-1} in Indian soils

States	Districts/Blocks	Available Mo (mg kg^{-1})
Bihar	-	0.13-0.92
		Verma and Jha (1970)
Punjab	Saline alkali soils	0.012-0.44
		Pasricha and Randhawa (1971)
Gujarat	Valsad	0.23
	Surat	0.18
	Bhamch	0.19
	Vadodara	0.08
	Panchmahals	0.10
	Kheda	0.06
	Sabarkantha	0.11
	Mehsana	0.07
	Ahmedabad	0.10
	Junagadh	0.10
	Bhavnagar	0.10
	Amreli	0.09
	Jamnagar	0.06
	Rajkot	0.07
	Surendranagar	0.10
	Kutch	0.06
	Bans Kantha	0.06
	Raipur	0.08
	Narsinghpur	0.38
		AR., Jabalpur Centre (1981)

West Bengal	**Bankura**	
	Khatra	0.15
	Kotalpur	0.18
	Onda	0.15
	Midnapore	
	Binpur I	0.10
	Egra II	0.24
	Salboni	0.16
	Jhargram	0.05
	Purulia	0.48
	Balarampur	0.32
	Kashiur	0.09
	Purulia-I	0.20
	Puncha	0.065
	Coochbehar	0.086
	Jalpaiguri	0.063
Nandi *et al.* (1992), Mandal *et al.* (1991)		

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MATERIAL AND METHODS

3. MATERIAL AND METHODS

The present investigation was undertaken to study the available molybdenum and boron status of soils of Junner and Haveli tahasils of Pune district. Total two hundred representative soil samples were collected from thirty seven soil series of Junner and Haveli tahsils.
Five to seven soil samples are collected from each series.

3.1 Materials

3.1.1 Soils

Predominant soils of Junner and Haveli tahasils of Pune district belonging to thirty seven dominated soil series were selected for the study.

Among which, twenty one series comes under Haveli and sixteen comes under Junner tahasil. The total area of Pune district is 15.40 lakh ha out of which 1·30 lakh ha contributed by Haveli which is 8.5 percent of the total and 1·38 lakh ha contributed by Junner tahasil which is 8.8 per cent of the total. A brief description of these soil series is given below.

3.1.1.1 Kusmod series: (16348 ha)

The soils of kusmod series belongs to very shallow, sandy loam, gently sloping with severe erosion.

3.1.1.2 Kurkumbh series (70290 ha)

The soils of Kurkumbh series belongs to shallow, sandy loam soils which have been formed on very gently sloping land with moderate erosion.

T-5739

3.1.1.3 Bhendwade series: (51782 ha)

The soils of Bhendwade series belongs to shallow, sandy clay loam which have been formed on very gentle sloping land, with moderate erosion.

3.1.1.4 Malshiras series (28385 ha)

The soils of Malshiras series belongs to shallow, clay soils. They are formed on very gentle slope and have moderate to normal erosion.

3.1.1.5 Palasdev series: (41259 ha)

The soils of this series belongs to moderately deep, sandy clay loam soils. They are formed on very gentle slope and moderate erosion.

3.1.1.6 Tulapur series: (42139 ha)

The soils of this series belongs to moderately deep, clay soils, which have been formed on very gentle slope and have moderate to normal erosion.

3.1.1.7 Rastapur series (1857 ha)

The soils of this series belongs to very deep clay soils. They are formed on very gentle slope with moderate to normal erosion. Mostly the soils are saline.

3.1.1.8 Yesdara series: (2221 ha)

The soils of this series belongs to shallow sandy loam soils. They are formed on very gentle slope and have moderate to severe erosion. The lime concentration is moderate.

3.1.1.9 Patewadi series: (1230 ha)

The soils under this series are moderately deep, clay soils with moderate to normal lime content. Also they are slight to moderately erosionated.

3.1.1.10 Kusgaon series: (37477 ha)

The soils under this series are highly shallow, clay soils. They have been formed on steeply sloping land with severe erosion.

Also they are well drained with moderate lime concentration.

3.1.1.11 Patas series: (16078 ha)

The soils comes under this series are moderately deep, clay to sandy clay loam soils. The slope is very gentle and high amount of free lime is observed with moderate erosion.

3.1.1.12 Vadgaon Amli series: (19590 ha)

The soils under this series are very deep, clay soils with very gentle slope and moderate drainage. The lime content is moderate and erosion is normal.

3.1.1.13 Urawade series: (1624 ha)

The soils under this series are shallow, sandy loam with steep slope. There is no lime and erosion is severe.

3.1.1.14 Nimgiri series: (4383 ha)

The soils under this series are very shallow, sandy clay loam with moderate slope. There is no lime and erosion is very severe.

3.1.1.15 Javal series: (26743 ha)

The soils under this series are shallow, sandy clay loam with moderate slope. There is no lime with very severe erosion.

3.1.1.16 Mandoshi series: (1480 ha)

The soils under this series are moderately deep, sandy clay loam with moderate slope and erosion is severe with no lime content.

3.1.1.17 Sathesai series: (12502 ha)

The soils of this series belongs to shallow, sandy clay loam, which have been formed on very gentle slope with moderate erosion and no lime content.

3.1.1.18 Nune series: (2735 ha)

The soils of this series belongs to moderately deep, sandy loam soils with gentle slope and no lime content. The erosion is moderate.

3.1.1.19 Hadshi series: (7021 ha)

The soils under this series are moderately deep, clay soils with gentle slope and no lime content. The erosion is moderate.

3.1.1.20 Nandgaon series: (3414 ha)

The soils under this series are deep, sandy clay loam with gentle slope and no lime content. Erosion is normal.

3.1.1.21 Washinge series: (245 ha)

The soils under this series are deep, clay soils with gentle slope and no lime content. The erosion is moderate to normal.

The soil series mentioned above found in the Haveli tahasil out of which eight soil series namely Malshiras, Palasdev, Tulapur, Nimgiri, Mandoshi, Sathesai, Nune and Nandgaon are also found in Junner tahasil. The remaining are discussed below.

3.1.1.22 Sawargaon series: (827 ha)

The soils under this series are moderately deep, clay soils with gentle slope and weak drainage. The erosion is slight.

3.1.1.23 Otur series: (1468 ha)

The soils of this series belongs to very deep, clay soils with moderate drainage and moderate erosion. Lime content is normal.

3.1.1.24 Dongargaon series: (7699 ha)

The soils under this series are shallow, sandy loam with very gentle slope and no lime content. Erosion is moderate to severe.

3.1.1.25 Tokawade series: (523 ha)

The soils under this series are moderately deep sandy clay loam with very gentle slope and no lime content. The erosion is moderate to severe.

3.1.1.26 Ambegaon series: (1456 ha)

The soils of this series belongs to shallow clay soils with gentle slope and no lime content. Erosion is moderate.

3.1.1.27 Anjavale series: (909 ha)

The soils under this series are very shallow, sandy clay loam soils with gentle slope and no lime content. The erosion is moderate.

3.1.1.28 Kashig series: (1713 ha)

The soils of this series belongs to deep, clay soils with gentle slope and no lime content.The erosion is moderate to slight.

3.1.1.29 Hadsar series: (147 ha)

The soils which belongs to this series are very deep, sandy clay loam soils with gentle slope and no lime content. The erosion is moderate to slight.

The collected soil samples were air dried in shade. After air drying the samples were crushed with wooden mortar and pestle and passed through appropriate sieve as per requirements. Maximum care was taken to avoid the contamination while digging, filling and transportation and also during preparation of soil samples for analysis.

3.2 Methods of analysis

The collected soils samples were analyzed for different properties by following standard methods which are discussed below.

3.2.1 Soil pH

The pH was determined by potentiometric method by means of glass electrode given by Richards (1968).

3.2.2 Electrical Conductivity

The electrical conductivity was measured by using conductivity meter as described by Richards (1968).

3.2.3 Calcium Carbonate Content

Free lime was estimated by Rapid titration method given by Piper (1966).

3.2.4 Available Nitrogen

Available nitrogen was estimated by alkaline permagnate method described by Subbiah and Asija (1956).

3.2.5 Available Phosphorous

Available phosphorous was estimated by extracting phosphorous with 0.5 M $NaHCO_3$ having pH 8.5 as described by Watanabe and Olsen (1965).

3.2.6 Available Potassium

Available potassium was estimated by using neutral normal ammonium acetate extractant as described by Knudsen *et al.* (1982).

3.2.7 Available Boron

The 0.01M $CaCl_2$ extractable boron was determined calorimetrically by using Azomethine (Bingham, 1982).

3.2.8 Available Molybdenum

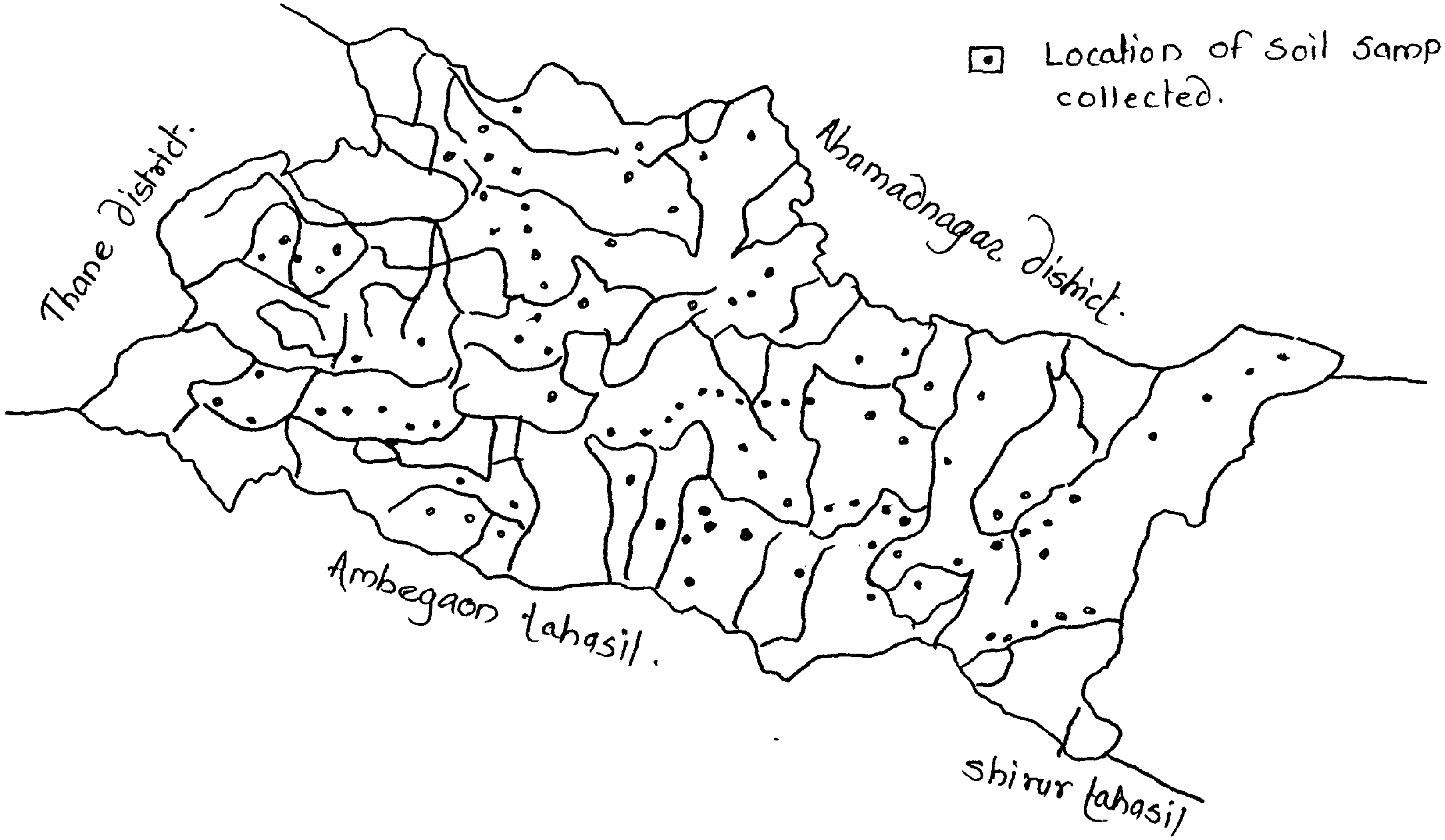
Available molybdenum was determined by using ammonium oxalate (pH 3.3), (Purvis and Peterson, 1956).

Fig: **Location** of Junner and Haveli Tahsil in Pune district.

References :

- ⊙ District H.Q.
- o Tahasil H.Q.
- ▨ selected tahasil.

fig : Layout map of Junner tahasil



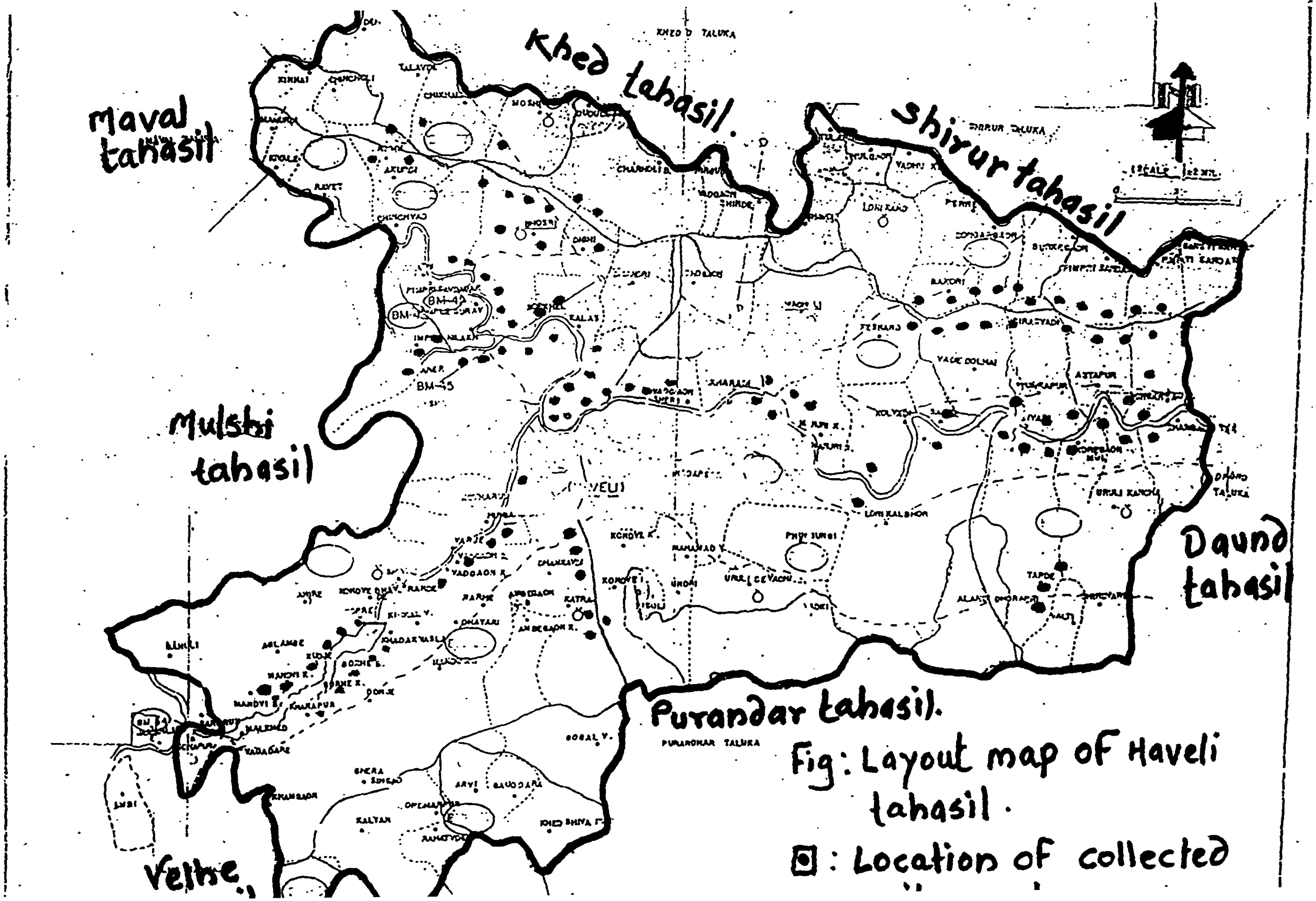


Fig: Layout map of Haveli tahasil.

◙ : Location of collected

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RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The present studies were undertaken with a view to assess the boron and molybdenum status in soil series encountered in Pune district. The results obtained are presented and discussed in this chapter.

The purpose of collecting the data in respect of boron and molybdenum content of soils according to the soil series of Pune district was to get a general picture of the status of boron and molybdenum, which will be useful for other parts of Maharashtra State, wherever the same series are encountered. It was considered intrinsinic to analyse large number of soil samples from the various soil series so as to get a more realistic picture for adopting a suitable fertilizers.

Two hundred surface soil samples (0-20 cm) were analysed for available boron and molybdenum content. The soils were also analysed for chemical properties. The results obtained have been presented and discussed under appropriate headings.

4.1 Chemical properties of soil

4.1.1 Soil reaction (pH)

The data represented in Table 3 indicated that the pH of soil ranged from 7.65 to 8.31 with an average value of 8.04. The highest pH of soils was observed at Rastapur (8.31) and the lowest value of pH was observed at Kusgaon (7.65) series. It was observed that most of the soils were saline to slightly alkaline in nature. This might be due to low rainfall with moderate to poor drainage of soil due to dominance of montmorillonite clay mineral. The soils could not leach soluble salts from the solum and accumulation of salts causing higher pH values.

Table 3 : Status of available boron and available molybdenum along with chemical properties of different soil series of Haveli and Junner tahsil of Pune district

Name of soil series	Tahsil	No. of samples collected	Average pH	Average EC (dSm^{-1})	$CaCO_3$ (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	Available B (ppm)	Available Mo(ppm)
Kusmod	H	4	8.10	2.10	5.92	242.37	10.07	330.90	0.61	0.334
Kurkumbh	H	5	8.21	2.37	6.81	273.50	11.37	369.15	0.38	0.412
Bhendwade	H	5	8.25	2.31	6.07	265.13	8.98	371.06	0.29	0.167
Malshiras	H	5	8.04	1.98	6.42	286.29	9.55	293.89	0.37	0.416
Palasdev	H	4	7.96	1.82	5.61	221.13	8.13	363.45	0.39	0.246
Tulapur	H	5	8.24	2.12	5.85	281.78	9.07	347.51	0.49	0.246
Rastapur	H	5	8.31	2.74	6.92	303.30	8.91	385.21	0.61	0.207
Yesdara	H	4	7.81	1.77	5.02	278.05	8.92	291.18	0.33	0.166
Palewadi	H	5	8.27	2.27	4.83	260.20	10.41	371.85	0.67	0.332
Kusgaon	H	5	7.65	1.17	4.97	281.17	9.31	369.72	0.30	0.249
Patas	H	4	8.07	2.11	7.04	262.42	10.47	359.74	0.47	0.166
Vadgaon Amli	H	5	8.27	2.77	4.98	289.39	9.13	381.08	0.54	0.256
Urawade	H	4	7.81	1.81	0.51	234.08	8.29	334.23	0.36	0.083
Nimgiri	H	5	8.11	1.81	0.57	213.91	10.31	293.27	0.21	0.207
Javal	H	5	8.19	1.71	0.62	227.37	8.54	298.11	0.49	0.246

Table 3 contd...

Name of soil series	Tah-sil	No. of samples collected	Average pH	Average EC (dSm^{-1})	$CaCO_3$ (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available B (ppm)	Available Mo (ppm)
Mandoshi	H	5	8.20	2.42	0.51	235.17	9.81	295.77	0.29	0.156
Sathesai	H	5	8.08	2.12	0.49	213.92	8.11	341.55	0.30	0.498
Nune	H	5	7.91	1.93	0.46	251.48	9.12	337.18	0.42	0.249
Hadashi	H	5	8.24	2.18	0.56	289.05	8.98	349.14	0.19	0.267
Nandgaon	H	5	8.02	2.34	0.50	302.14	8.93	380.24	0.54	0.167
Washinge	H	5	8.23	2.40	0.61	239.77	9.06	336.21	0.49	0.246
Malshiras	J	6	8.10	1.99	6.45	290.11	8.98	294.16	0.25	0.498
Palasdev	J	6	7.94	1.80	5.56	222.13	8.20	360.13	0.35	0.249
Tulapur	J	6	8.23	2.18	5.81	275.91	9.00	339.05	0.43	0.167
Sawargaon	J	7	7.92	2.07	5.08	281.15	9.32	370.39	0.37	0.207
Otur	J	6	8.12	2.19	4.71	201.25	8.79	362.15	0.62	0.332
Dongargaon	J	6	7.84	2.02	0.56	221.19	9.29	294.27	0.39	0.208
Tokawade	J	7	8.11	1.98	0.49	242.31	9.77	349.38	0.43	0.332
Nimgiri	J	6	8.13	1.91	0.67	212.68	10.21	322.18	0.23	0.498
Mandoshi	J	6	8.19	2.38	0.47	235.06	9.77	298.17	0.39	0.249

Table 3 contd…

Name of soil series	Tah-sil	No. of samples collected	Average pH	Average EC (dSm^{-1})	$CaCO_3$ (%)	Available N ($kg\ ha^{-1}$)	Available P ($kg\ ha^{-1}$)	Available K ($kg\ ha^{-1}$)	Available B (ppm)	Available Mo(ppm)
Anjavale	J	6	7.91	1.92	0.52	265.07	9.81	333.41	0.49	0.541
Sathesai	J	6	8.00	2.14	0.47	211.58	7.99	342.07	0.33	0.332
Ambegaon	J	6	8.02	2.11	0.67	235.17	8.92	351.22	0.38	0.416
Nune	J	6	7.93	2.03	0.43	248.47	9.00	299.07	0.44	0.498
Nondgaon	J	7	8.10	2.29	0.49	301.37	8.95	381.25	0.44	0.249
Kashig	J	7	8.23	2.32	0.54	301.08	9.88	367.17	0.63	0.541
Hadsar	J	6	7.99	2.01	0.50	277.81	9.89	355.67	0.41	0.166
Total		200	298.73	77.59	108.39	9473.96	343.24	12620.18	15.32	10.799
Average			8.037	2.097	2.929	256.052	9.276	341.085	0.414	0.291

H : Haveli tahsil

J : Junner tahsil

Kibe (1956) while reviewing the work done on paddy soils of former Bombay State observed that medium black soils formed on Deccan trap were moderately alkaline in reaction. The results obtained for different soil series under irrigated condition are in agreement with the above observation.

4.1.2 Electrical Conductivity (EC)

The electrical conductivity of surface soils ranged from 1.17 to 2.27 dS m^{-1} (Table 3) with an average value of 2.097 dS m^{-1}. The lowest and the highest values of electrical conductivity were observed in Kusgaon (1.17dS m^{-1}) and Vadgaon Amli (2.77dS m^{-1}) series, respectively. From the data presented in Table 3, it is noticed that soil from Rastapur(2.74 dS m^{-1}), Mondoshi (2.42 dS m^{-1}), Washinge (2.40 dS m^{-1}) and Kurkumbh (2.37 dSm^{-1}) series showed the highest values of electrical conductivity. While, soils from Javal (1.71 dSm^{-1}), Yesdara (1.77 dS m^{-1}), Palasdev (1.80 dS m^{-1}),Urawade (1.81 dS m^{-1}) and Nimgiri (1.81 dS m^{-1}) series showed the lowest values. It might be due to more amount of salts present in upper layer of soils, as a result of continual moisture extraction by plant roots and evaporation. Qureshi *et al.* (1996) observed the same trend of electrical conductance in problematic soils of Bharatpur (Rajasthan).

4.1.3 Calcium carbonate

Data on calcium carbonate content of 37 soil series of Haveli and Junner tahasils of Pune district presented in Table 3. Results showed that calcium carbonate content of soils ranged from 0.43 to 7.04 per cent, with mean value of 2.92 per cent. Minimum and maximum values of calcium carbonate content of soils were obtained at Nune series (0.43 %) of Junner tahasil and Patas series (7.04%) of Haveli tahasil, respectively.

Out of 37 soil series 17 series were moderately calcareous in nature and other 20 were non calcareous.

In general, the soils of arid and semiarid region were calcareous in nature because of combined effect of climate and parent material of soils. As such soils are developed from basaltic alluvium under semiarid climatic condition and high pH condition similar observations were also recorded by Durgude (1999) in problematic soils of MPKV, Rahuri.

4.1.4 Nutrient status of soil

The data in respect of available N, P, K and available micronutrients are presented in Table 3.

4.1.4.1 Available N, P and K

The categorization of fertility constituents of irrigated soils as per the six tier system is presented in Table 4.

Table 4 : Categorisation of fertility constituents of soils as per the six tier system

Class	Available Nitrogen	Available Phosphorous	Available Potassium
Very low	Nil	Nil	Nil
Low	138 (69%)	200 (100%)	Nil
Medium	62 (31%)	Nil	Nil
Moderately high	Nil	Nil	Nil
High	Nil	Nil	47 (23.5%)
Very high	Nil	Nil	153 (76.5%)

Note : 1. Figures without parentheses indicate number of soil samples.

2. Figures in parentheses indicate percentage of soil samples.

4.1.4.1.1 Available N

The available nitrogen ranged from 201 to 303 kg ha^{-1} with an average value 256 kg ha^{-1} (Table 3). It is higher in Nandgaon (302.14 kg ha^{-1}), Kashig (301.08 kg ha^{-1}), Vadgaon Amli (289.39 kg ha^{-1}) and Malshiras (290.11 kg ha^{-1}) series. While it is highest in Rastapur (303.30 kg ha^{-1}). It is lower in Otur (201.0 kg ha^{-1}), Sathesai (211.58 kg ha^{-1}) and Nimgiri (212.68 kg ha^{-1}) series.

According to six tier system about 69 per cent, soil samples were low in available nitrogen while 31 per cent were medium in available nitrogen. Similar observations were recorded by Paliwal and Maliwal (1975) and Durgude (1999).

4.1.4.1.2 Available P

The available P content ranged from 7.99 to 11.37 kg ha^{-1} with an average value 9.276 kg ha^{-1} (Table 3). The higher availability of phosphorous observed in Kurkumbh (11.37 kg ha^{-1}), Patas (10.47 kgha^{-1}), Palewadi (10.41 kg ha^{-1}) and Nimgiri (10.31 kg ha^{-1}) series. While the lower values observed in Sathesai (7.99 kg ha^{-1}), Palasdev (8.13 kg ha^{-1}) and Uranade (8.29 kg ha^{-1}) series.

4.1.4.1.3 Available K

The available K content in 37 soil series ranged from 291.18 to 385.21 Kg ha^{-1} with an average value 341.08 Kg ha^{-1} (Table 3). The available potassium content was higher in Rastapur (385.08 Kg ha^{-1}), Nandgaon (381.25 Kg ha^{-1}), Vadgaon Amli (381.08 Kg ha^{-1}), Paliwadi (371.85 Kg ha^{-1}) and Bhendwade (371.06 Kg ha^{-1}) series. The available of potassium was lower in some series like Yesdara (291.18 Kg ha^{-1}), Nimgiri (293.27 Kg ha^{-1}), Malshiras (293.89 Kg ha^{-1}) and Dongargaon (294.27 Kg ha^{-1}). According to the six tier system the available K content was high (251 to 300 Kg ha^{-1}) in 23.5 per cent of total soil samples and very high (> 301 Kg ha^{-1}) in 76.5 per cent of total soil samples. The available potassium content was higher due to more release of potassium from non exchangeable to exchangeable form due to hydrolysis of K bearing minerals. Similar observations were also recorded by (Gupta *et al.*, (1970) and Bhalerao, (1999).

4.1.4.2 Micronutrient status (available boron and available molybdenum)

An attempt was made to determine the available boron and available molybdenum status of soils of Junner and Haveli tahasils of Pune district. Data on available boron and available molybdenum status in different soils series are presented in Table 3 and depicted in Fig. 1 to 4.

4.1.4.2.1 Available Boron

The available boron content of the soils varied from 0.19 to 0.67 ppm with an average value of 0.41 ppm (Table 3). The lowest and the highest values of available boron were noticed in respect of soils of Hadashi (0.19 ppm) and Palewadi (0.67 ppm) series, respectively.

Table 5 Rating of soil samples in different categories for available boron

Fraction of boron	0.1- 0.3 (ppm)	0.31-0.6 (ppm)	0.61-1.0 (ppm)
Available boron (% samples)	21	65.5	13.5
Number of samples	42	131	27

Data presented in Table 5 and Fig. 5 indicated that 21 per cent of total soils studied in the present investigation fall in the range of 0.1 to 0.3 ppm, 65.5 per cent of soil samples showed a status of 0.31 to 0.6 ppm while 13.5 per cent of soils contain more than 0.6 ppm available boron. Data from the present study on available boron indicated that similar pattern as reported by Bendale *et al.* (1951) for soils of Bombay State and by Mahabari (1970) and Chavan (1974) for Maharashtra soils.

4.1.4.2.2 Available Molybdenum

The available molybdenum content of the soils varied from 0.08 to 0.541 ppm with an average value of 0.291 ppm (Table 3). The lowest and the highest values of available molybdenum were noticed in respect of soils of Urawade (0.08 ppm) and Anjavale (0.541 ppm) and Kashig (0.541 ppm) series, respectively.

Table 6: Rating of soil samples in different categories for available molybdenum

Fraction of molybdenum	0.05- 0.3 (ppm)	0.31-0.5 (ppm)	> 0.5 (ppm)
Available molybdenum (% samples)	60	33.5	6.5
Number of samples	120	67	13

Data presented in Table 6 and Fig. 6 indicated that 60 per cent of total soils studied in the present investigation fall in the range of 0.05 to 0.3 ppm,

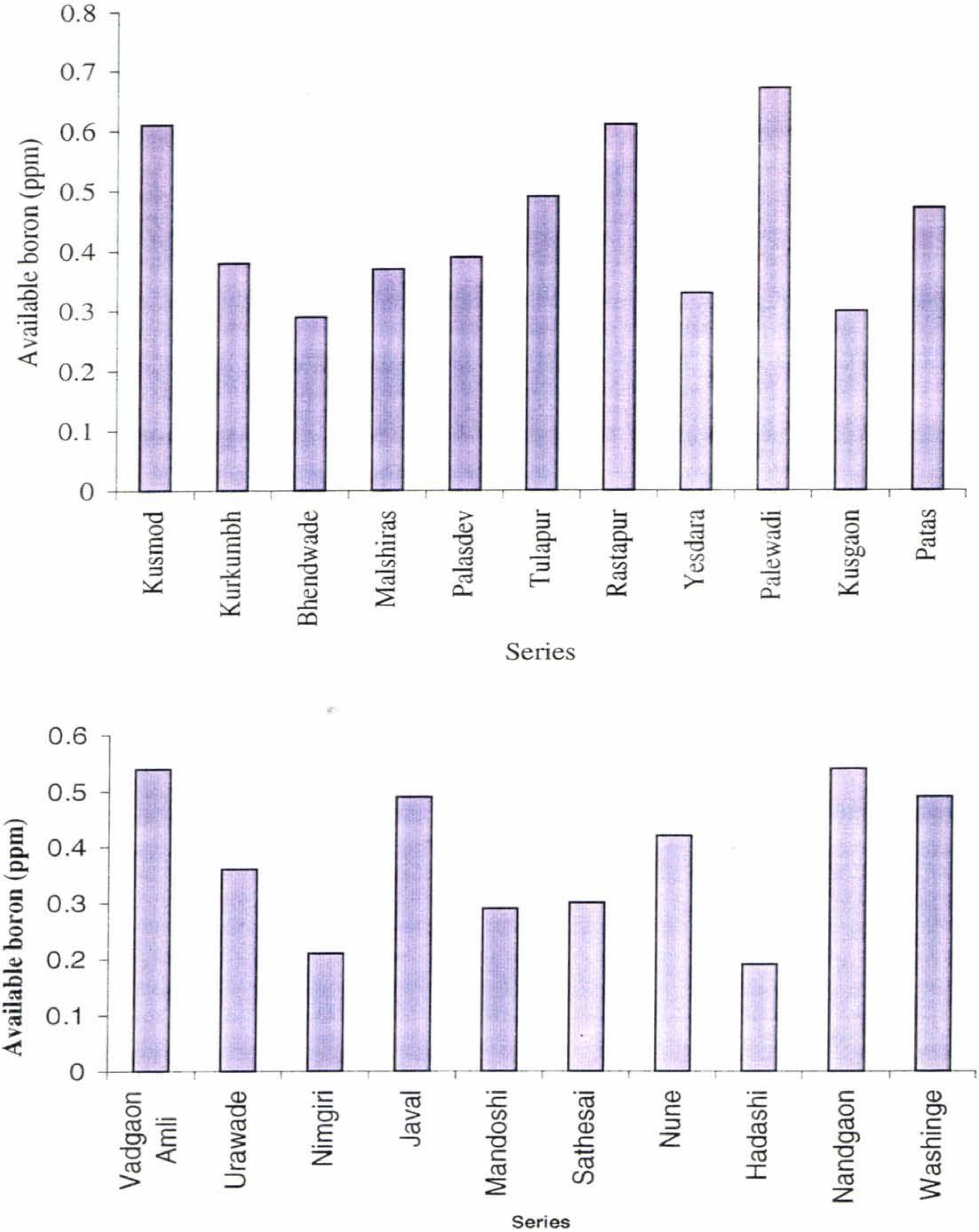
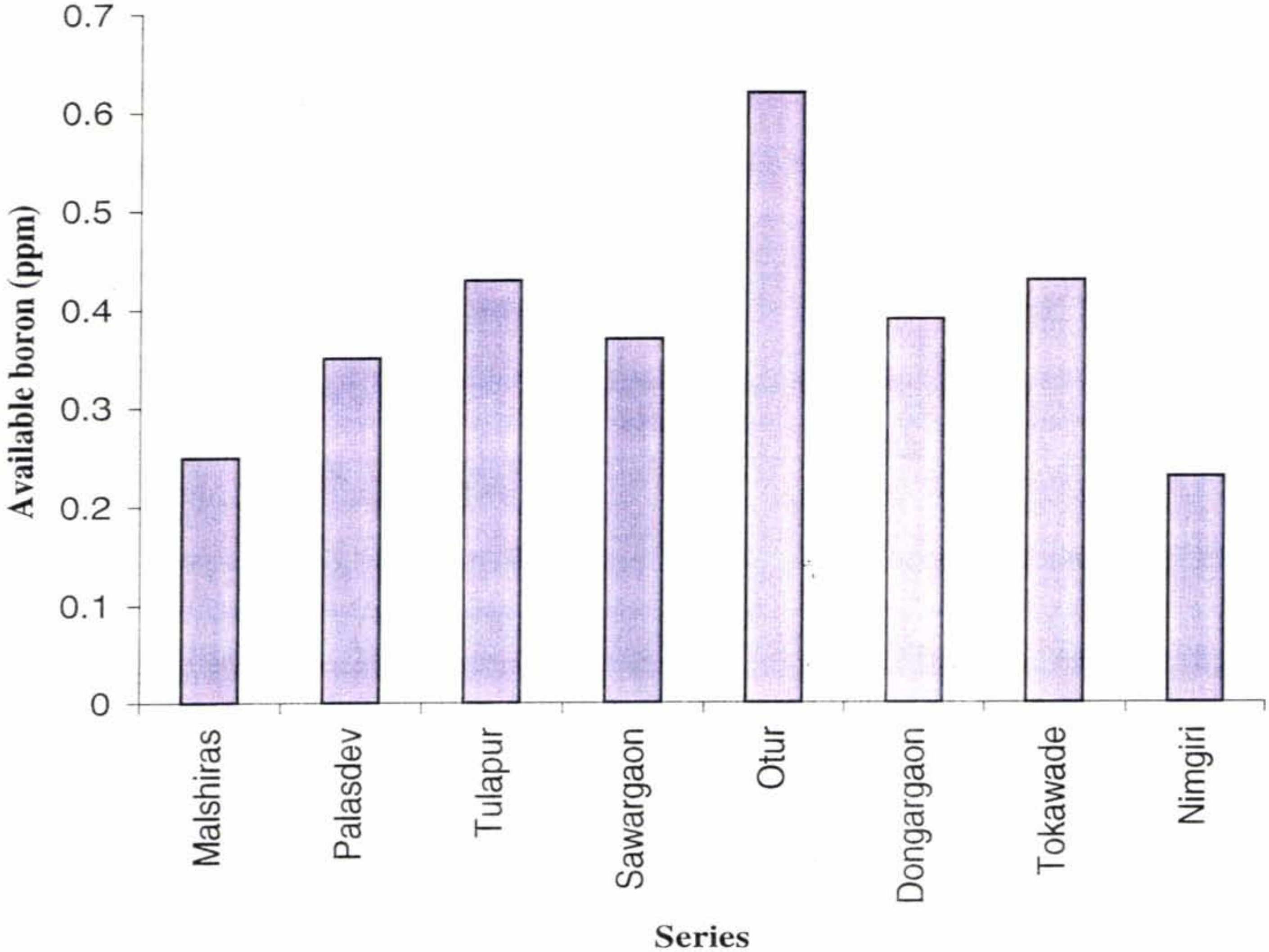


Fig. 1 Available boron status of different soil series of Haveli tahsil of Pune district



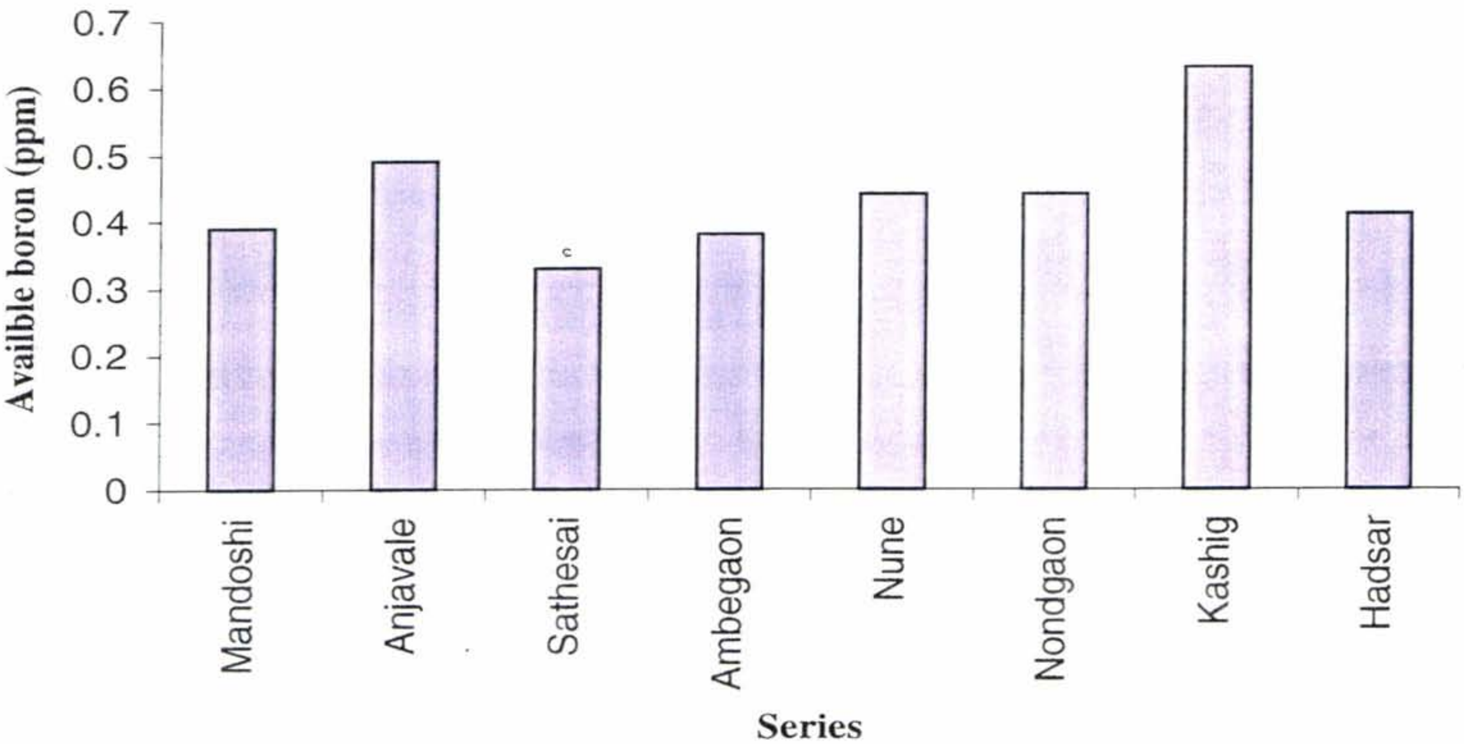
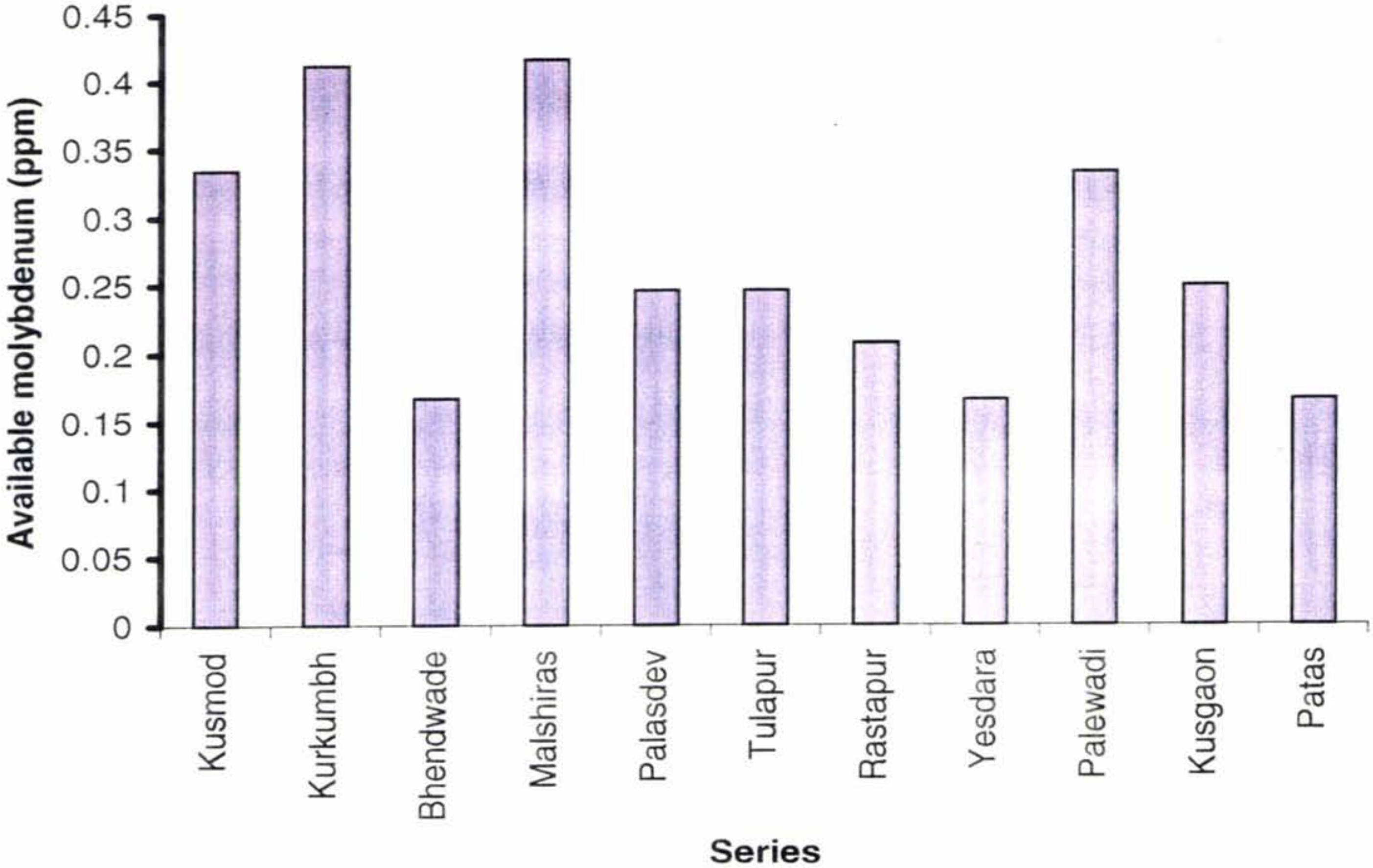


Fig. 2 Available boron status of different series of Junner tahsil of Pune district



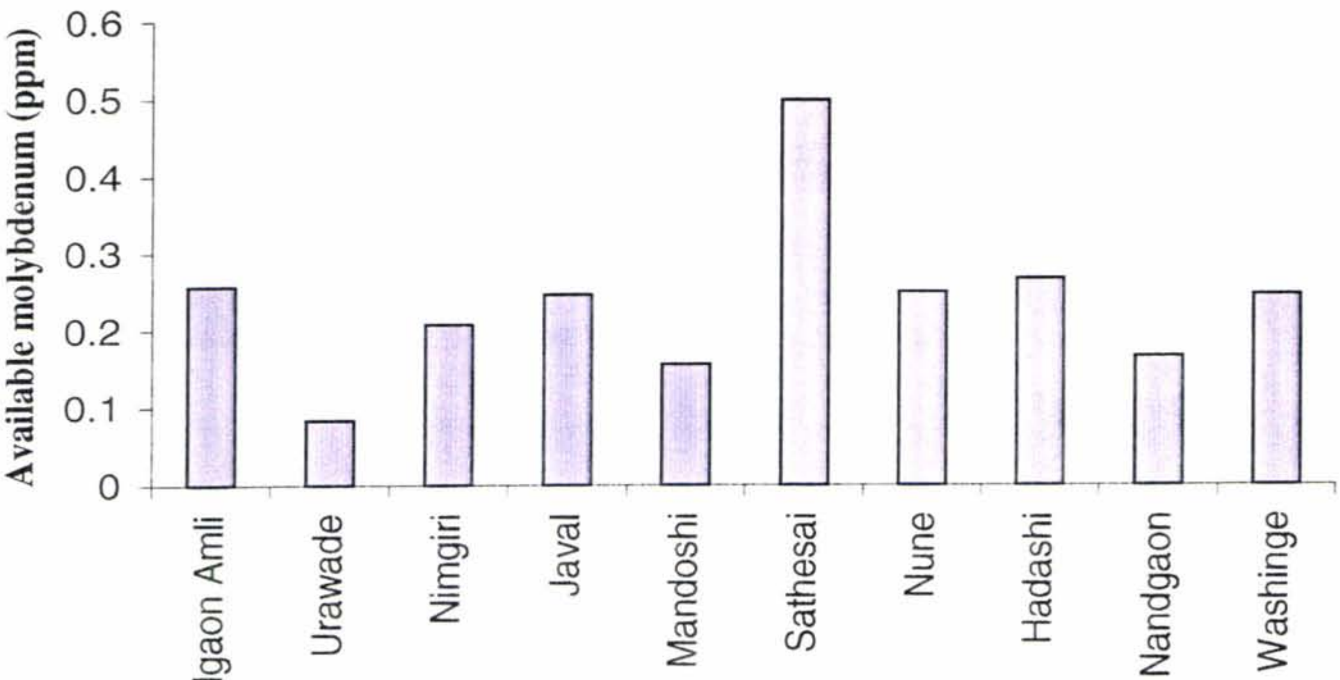
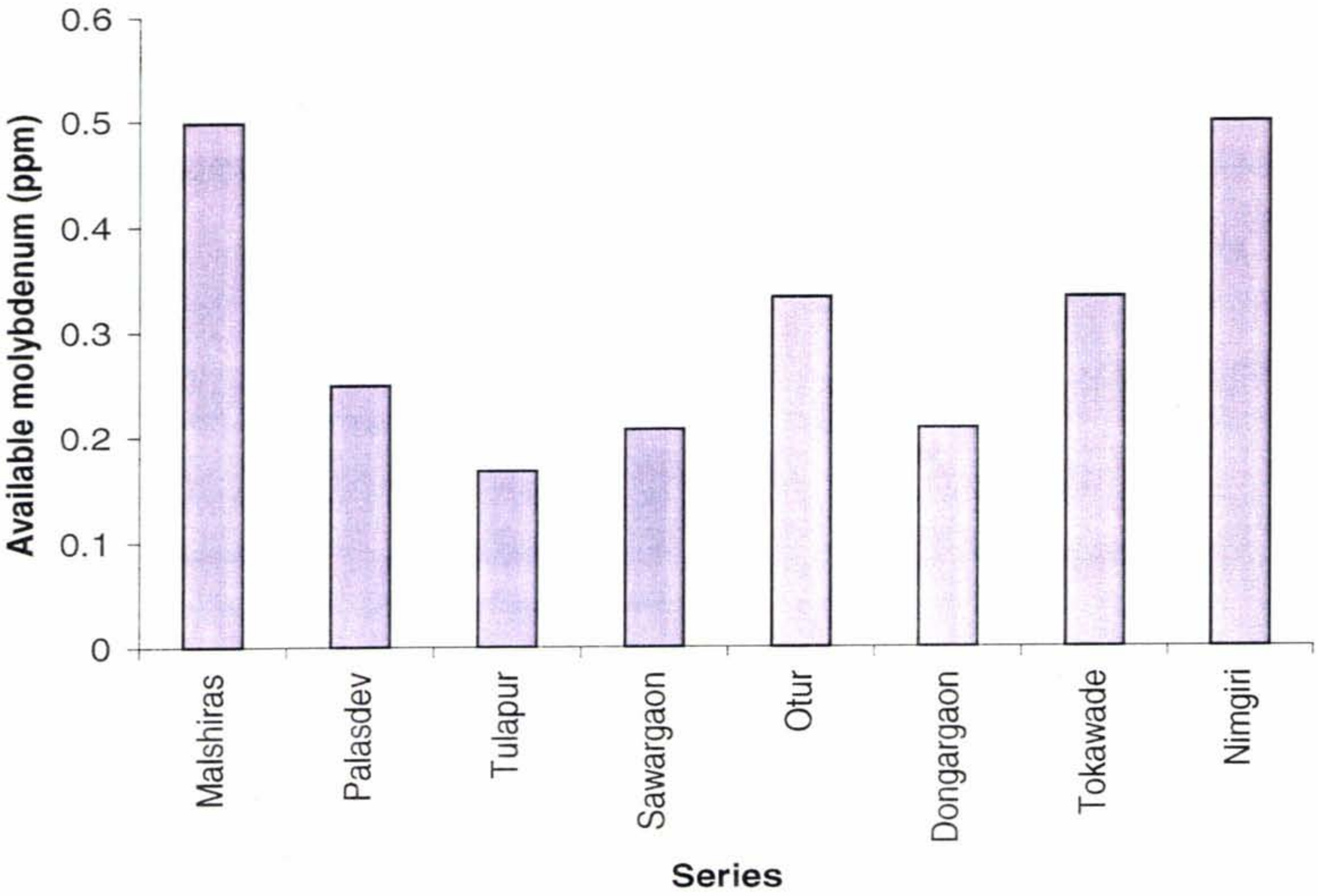


Fig. 3 Available molybdenum status of different soil series of Haveli tahsil of Pune district



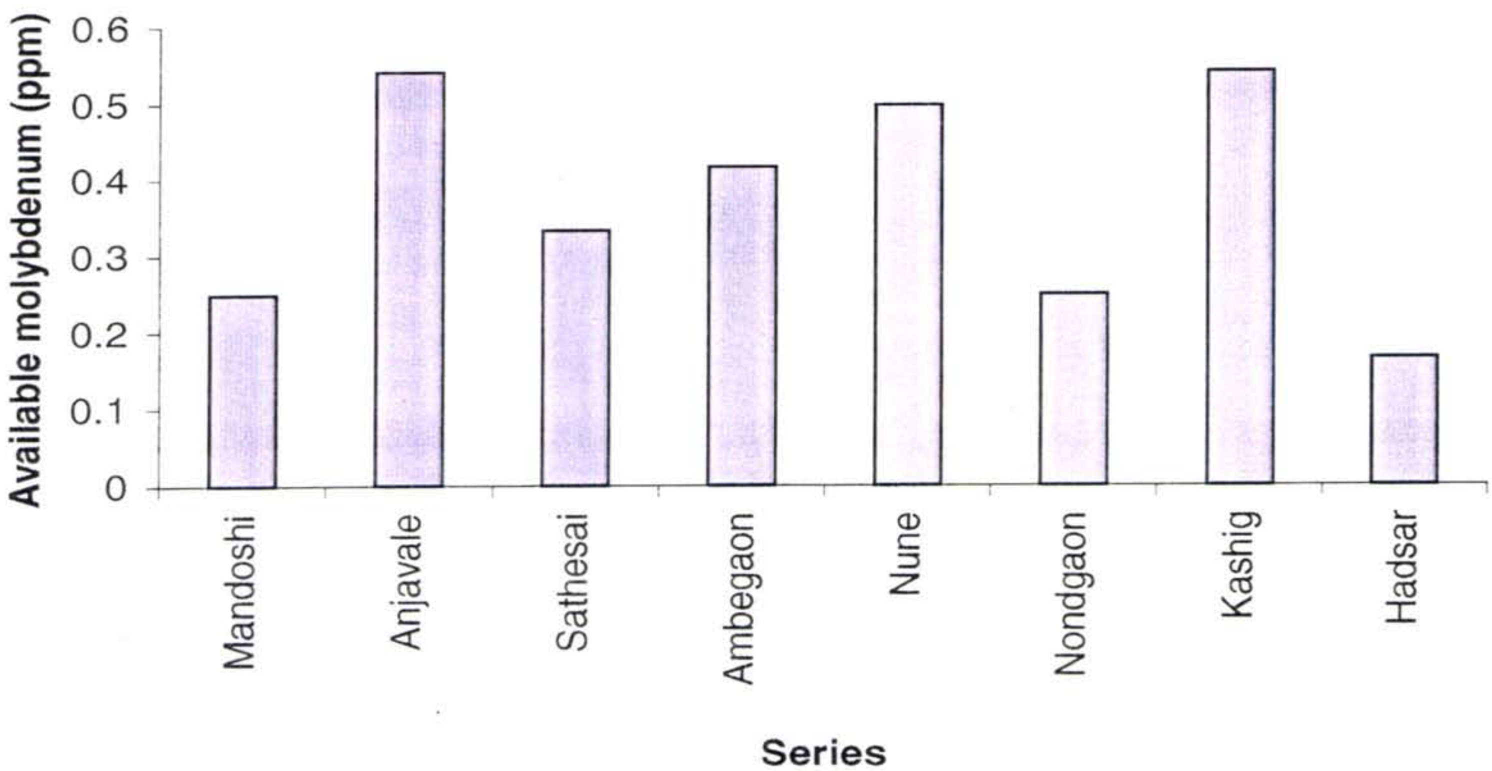


Fig. 4 Available molybdenum status of differnt soil series of Junner tahsil of Pune district

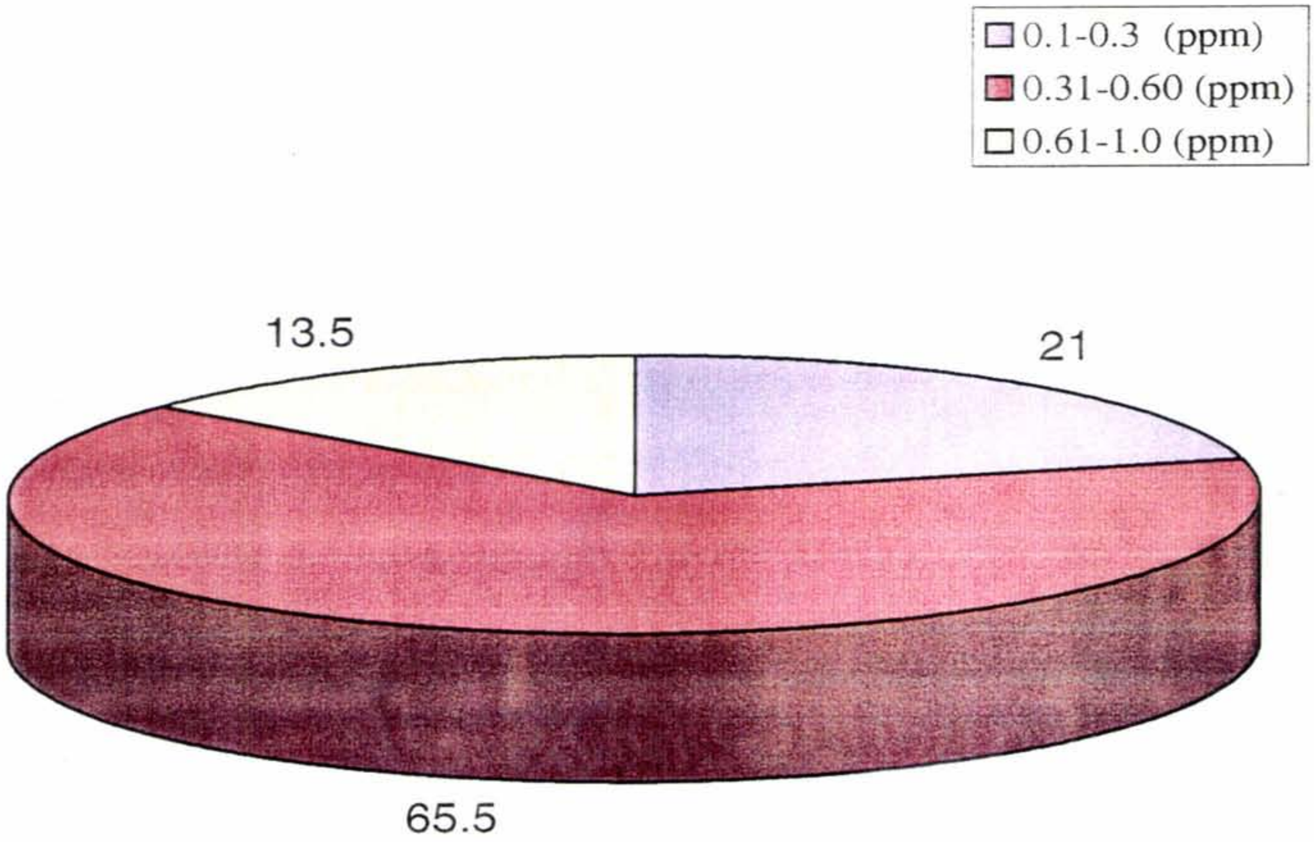


Fig. 5 Per cent distribuition of soil samples in different categaores of available boron

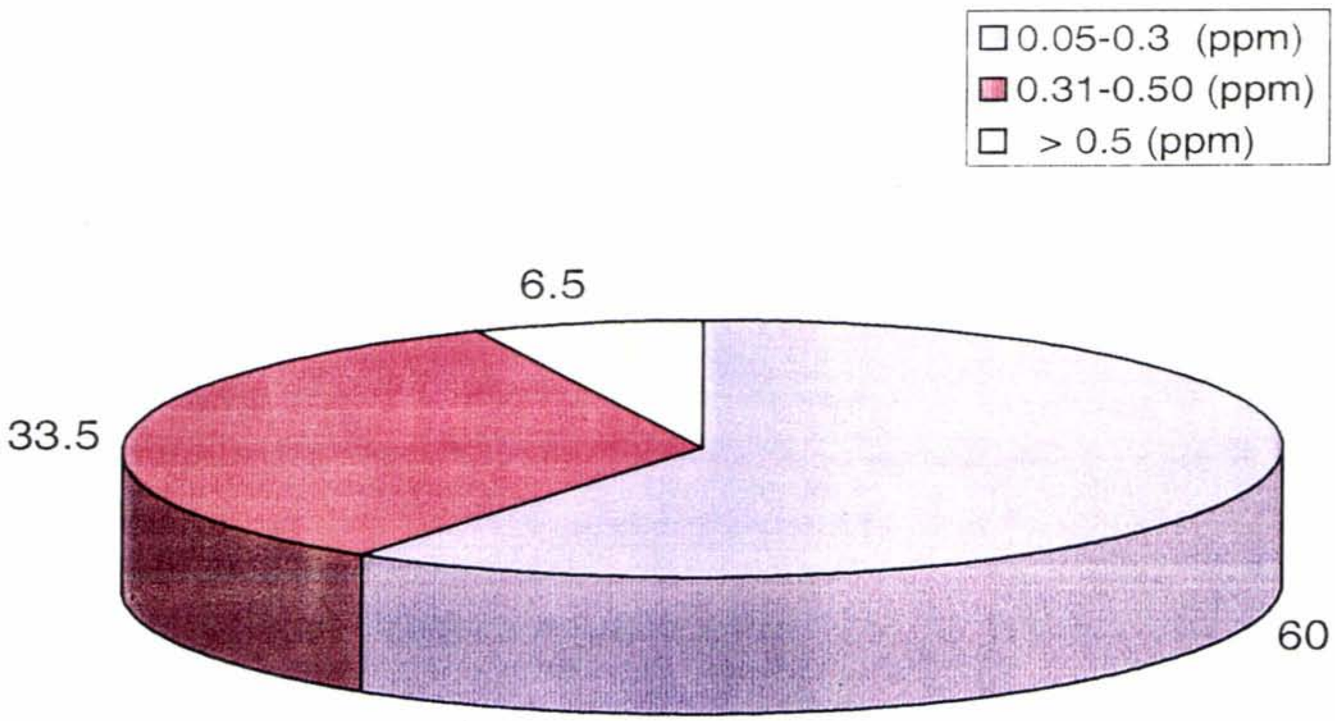


Fig. 6 Per cent distribution of soil samples in different categories of available molybdenum

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SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

The present investigation was undertaken to study molybdenum and boron status of soil series encountered in Junner and Haveli Tahsils. Total two hundred soil samples were collected from thirty-seven soil series and analysed for their contents of available boron and available molybdenum. Soil samples were also analysed for chemical properties like pH, $CaCO_3$, EC, available nitrogen, available phosphorous and available potassium.

On the basis of observations recorded in these studies laid to following conclusions, which are summarized in brief.

5.1 Soil analysis

5.1.1 Chemical properties of soil

5.1.1.1 pH

The pH of soil was moderately alkaline and ranged from 7.65 to 8.31 with an average value of 8.04.

5.1.1.2 Electrical conductivity

Electrical conductivity of surface soil samples ranged from 1.17 to 2.27 dS m^{-1} with an average value of 2.097 dS m^{-1}.

5.1.1.3 $CaCO_3$ content

The calcium carbonate content of soils ranged from 0.43 to 7.04 per cent, with an average value of 2.92 per cent.

5.1.2 Nutrient status of soil

5.1.2.1 Available N, P and K

5.1.2.1.1 Available nitrogen

The available nitrogen ranged from 201 to 303.3 kg ha^{-1} with an average value of 256 kg ha^{-1}.

5.1.2.1.2 Available phosphorous

Available phosphorous content ranged from 7.99 to 11.37 kg ha^{-1} with an average value 9.276 kg ha^{-1}.

5.1.2.1.3 Available potassium

Available potassium content ranged from 291.18 to 385.21 kg ha^{-1} with an average value of 341.08 kg ha^{-1}.

5.1.2.2 Available micronutrient (available molybdenum and available boron)

5.1.2.2.1 Available boron

The available boron content of the soils varied from 0.19 to 0.67 ppm with an average value of 0.41 ppm.

5.1.2.2.2 Available molybdenum

The available molybdenum content of the soils varied from 0.08 to 0.541 ppm with an average value of 0.291 ppm.

5.2 Conclusions

The pH of soil samples was saline to slightly alkaline in nature. The electrical conductivity of these soils was fairly good. Out of 37 soil series 17 series were moderately calcareous in nature and other 20 were non calcareous. Among the macronutrients, the available N was low to moderate, available P was low and available K was high to very high. Among the micronutrients, available boron content of soil was categoriesed in 0.1 – 0.3 ppm (low), 0.31 – 0.6 ppm (medium) and 0.61 - 1 ppm (high). As per the observations recorded 65.5 per cent samples fall in the range of 0.31-0.6 ppm, 21 per cent in 0.1-0.3 ppm and 13.5 per cent in 0.61-1 ppm. Available molybdenum content of soil was categorized in 0.05 – 0.3 ppm (low), 0.31 – 0.5 ppm (medium) and more than 0.5 ppm (high). As per the observations recorded 60 per cent soil samples fall in the range at 0.05 - 0.3 ppm, 33.5 per cent samples fall in 0.31 - 0.5 ppm and 6.5 per cent were more than 0.5 ppm.

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7. VITA

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