I BORON STATUS OF SOILS OF MAHARASHTRA STATE

II BORON CONTENTS OF WELL WATERS FROM EASTERN MAHARASHTRA

by

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I INTRODUCTION :

Chapter I

I N T R O D U C T I O N

Unlike major nutrients, trace elements did not receive adequate attention in the past, in our Country. As the demand for higher yields increases and the plant requirements for major elements are more efficiently met with, other elements are more likely to become limiting. Like major nutrients, micronutrients are also equally important in boosting the agricultural production. Application of micronutrients in combination with major nutrients and provision of adequate irrigation facilities will go a long way in bringing the green revolution in the country which is of prime importance.

Amongst the various trace elements, boron has received considerable attention in recent years owning to its role as a nutrient and also due to its importance in deciding the quality of water. This together with instances of 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 it in soils and plants as well as in knowing the factors which govern its availability in soils.

Boron exists in soil in two forms namely - water soluble and total. Water soluble boron is considered to be a most useful source for the plant (Berger and Truog,1947).

The contents of boron in different soils depend upon the nature of parent material from which they are derived and the characteristic of the soil type.

Eventhough boron is considered to be a minor element, ...actice it is of major importance. It is of universal occurrence in living organisms and flowering plants cannot attain their full development in the absence of traces of this element (Anon. 1967). The necessity of boron to plants in small amounts was first established about two decades ago in connection with the Heartrot disease of Sugarbeet and Mangold. Maze (1915) working with maize, was the first to report that boron was essential for the normal growth of the corn.

Boron is known to play many important functions in plant metabolism. It is necessary for cell division, nitrogen and carbohydrate metabolism, in salt absorption and water relations in plants. It is also required for the transloca- tion of sugar in the plants and development of cell wall. Further, it is regarded as a buffer in plant tissues acting as some kind of regulator for other substances (Agarwal, 1965). The role of boron appears to be connected both with the uptake of calcium by the roots and its efficient use in the plant (Russell, 1961). Monocotyledans have a lower requirement for boron than the dicotyledans (Wear, 1957).

Irrigation is an essential practice in boosting the agricultural production for increasing the food supply. Even with the adequate irrigation facilities in some regions of the State of Maharashtra, there has been no remarkable increase in the crop yields which is mostly due to faulty irrigation practices and use of poor quality irrigation water. There is also a tendency to utilize all the available water which leads to the heavy accumulation of salts in the soil. In Maharashtra State, the major source of irrigation is through well waters and therefore, due consideration to its quality must be given.

The boron content of irrigation water is one of the major criteria used in deciding the quality of water. Many well waters contain boron which may be present in toxic amounts. Continuous use of such waters may render the soil unproductive. (U.S.D.A. 1947, Sing and Kanwar 1963).

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 but in Maharashtra, except Bendale et al. (1951), Raut (1962) and Atre (1960), nobody has tried to assess the boron status of soils developed under varying agro-climatic conditions and derived from different kinds of parent materials. Further, uptil now nobody has attempted to report the boron contents of well waters from any parts of Maharashtra State.

The present studies were, therefore, undertaken to assess the relative status of boron in different soil types of Maharashtra State and its concentration in well waters from different districts of Maharashtra. Such a study will throw light in locating the areas where probable deficiency of this element would be predicted and where the high concentrations of it in well waters may cause toxicity symptoms in plants. The study will also help us in an efficient use of waters of different quality. The knowledge about the boron status in soils from different agro-climatic zones of the State, can also help us in predicting the crop responses for boron, added through soil or spray. An account of the observations made with this objective is presented in the following pages.

II REVIEW OF LITERATURE :

Chapter II

REVIEW OF LITERATURE

The problem of boron supply in soils has received considerable attention in Western countries and field and laboratory studies having direct bearing to the problem covered several aspects of this important micronutrient element. Numerous workers have done intensive work on the various aspects of boron in soils and irrigation waters in abroad. The trace-element deficiency in Indian soils has been reported to be quite extensive. Unlike major nutrients, trace element study did not receive adequate attention in the country in the past and the information collected is, therefore, fragmentary. On the basis of the available information, an attempt has been made to assess the status of this minor element, both in respect of soil and water analysis and in respect of crop response to the application of micro-nutrients.

I: Geochemistry of boron in soils:

The total amount of boron present in the soil gives an indication of the reserves of the soil which could be changed by chemical or bacterial action into available form. Presence of boron bearing minerals like tourmaline in soils, the application of manures (Conner and Fergus, 1920) and irrigation with high boron waters (Eaton, 1935; Sastry and Viswanath, 1946; Mathur *et al.* 1964) leads to the accumulation of boron in soils.

High amounts of boron are usually found in soils of arid and semi-arid regions which are invariably saline and sodic in nature (Satyanarayana 1958; Kanwar 1961; Mathur et al. 1964; Moghe and Mathur, 1965), whereas acid soils of humid regions are usually deficient in it. (Askew et al. 1937).

Boron normally occurs in primary rocks in the form of borates and tends to be higher in acid and basic rocks than in igneous rocks. The more acid igneous rocks have slightly higher concentration of boron which is often due to the presence of highly resistant mineral tourmaline. Certain bauxite and kaolin sediments, along with carbonates are usually low in boron, whereas marine shales and glauconitic sandstones are commonly high in boron (Hodgson, 1963). Therefore, the contents of boron in different soils depend upon the nature of parent material from which it is derived as well as the characteristic of soil type. The geo-chemistry of boron is probably more affected by the process of sedimentation than any other element considered. Boron which remains relatively constant in igneous rocks in the range of 5-10 ppm varies from less than 3 ppm to over 300 ppm in sediments.

Boron has been reported to be present in varying amounts in almost all soil types of the world. The status of water soluble boron has been reported to be - Georgian soils 0.01-0.65 ppm; Illions soils 0.2 -0.22 ppm. (De Turk and Olson, 1941) and New-Zealand soils 0.15-2.20 ppm (Askew et al. 1937).

The amount of boron in the surface soils is observed to be more than the sub-surface layers in various soils (Ferguson and Wright,1940; Pilad *et al*. 1944; Coleman 1945) but sub-surface soils of Coachella Valley of California were found to contain more boron than the surface soils (Hass,1944). Total boron content in more than 300 soil samples collected from different parts of U.S.A. ranged from 10 to 133 ppm. in surface soil and from 0.2 to 51.0 ppm in sub-surface soil (Whetstone and Robinson,1942).

The factors like soils containing minerals bearing high boron, application of manures and fertilizers having more boron in them and irrigation with high boron waters are known to affect the boron status of soils (Conner, Fergus,1920; Eaton 1935, Sastry and Viswanath 1946 and Mathur *et al*. 1964). According to Sastry and Viswanath (1946) and Mathur *et al*. (1964), oil cakes, chilean nitrate, superphosphate, ammonium sulphate and sulphate of potash have been observed to be rich sources of boron and their continuous use would build up the boron content of soils. If the irrigation water itself is high in boron and if it is given to the soil, the accumulation of boron in the soil will occur. Quality of irrigation water is one of the causes in the accumulation of boron in soil profiles (Eaton and Singh 1935,1959). Even the long continuous use of irrigation waters containing boron within safe limit may result in the accumulation of boron in soils to a greater extent (Kanwar and Singh,1961).

II: Factors affecting Boron status in soils:

There are continuous losses of boron from the soils which make them deficient in it and tend to upset the additions of boron to the soil. Leaching and removal by the plants are the main losses of boron from the soil which affect the boron status of the soil.

(a) Leaching losses: -

One of the field investigation on boron movement was conducted in New-Zealand by Askew and Thomson (1937) and Askew *et al.* (1938), who found that boron applied to an apple orchard 2 years previously, had moved to a depth of 30 inches in this period. Woodbridge (1940), indicated that greatest movement was found in the lighter soils 2 years after application and the least movement in the heavier soils.

Krugel *et al.*(1937,1938) studied the effect of leaching the soil on the recovery of applied boron. They noted that approximately 78 percent of the applied boron was recovered in the leachate. The highest recovery of 94 percent was obtained in clay loams and the lowest 63 percent in heavy loam soils.

White Stevens (1941), has found that boron is readily leached out of acid Long Island soils by heavy rainfall and recommended heavier borax applications in wet years than in dry ones.

Reeve *et al.* (1944) applied water equivalent to one fourth of the average annual rainfall of New Jersey soils to which borax had been applied at the rate of 20 lb/acre. They found that about 85 percent of the boron leached from a sandy soil and 75 percent of the applied boron leached from loam and silt loam soils.

In study of Wisconsin soils, Kubota *et al.* (1948), found that the rate of boron movement was related primarily to the texture. Where the soil was uniformly light textured throughout the profile, much of the applied boron moved to a depth of 24 inches or deeper in 6 months. In the heavier soils, little percentage of the boron moved below the 12 inches layer. In the laboratory experiments, it was found that the bulk of applied boron moved downward in mass rather than in portions. The movement of boron was found to lag behind the movement of the water, and was also found to be independent of the movement of sodium in the borax.

Katalymov (1951), observed 64 to 76 percent loss of boron from a podzol soil after a few days leaching with water. There was a 30-52 percent loss from a few Chernozem soil. Winsor (1952), found that boron added in herbicidal amounts is lost from the surface 8 inches of a sandy loam within 6 months.

Scharrer and Hofner (1958), indicated that the presence of high pH and high clay content may seriously reduce the movement of boron in soil profiles.

Sinha (1969), studied the deficiencies of micronutrients in Bihar soils. From the results obtained, he reported that when boron is added to the soil through water, some quantity of it is removed by crops, some by drainage and the rest accumulates in the soil. The quantity accumulated was observed to be of the order of 6.04 kg/ha and the percentage accumulation found was 0.28 percent.

(b) Crop removal:

Because boron is found in such small quantities in plants, this is not often considered to be a serious loss. Reeve et al. (1944), however, have shown that in New Jersey, alfa-alfa contained boron equivalent to nearly 2 lb of borax per ton when grown on soils that were adequately supplied with the element. In most humid region soils,however, the boron removal from soils by alfa-alfa is much less than this.

(c) Calcium-Boron ratio:

Since Brenchly and Warington (1927), first indicated that there was an association between boron and calcium absorption by plants, numerous workers have studied boron calcium ratios in plants and the inter-relationships of various other element with boron.

Shive (1941), working with Corn, found that the metabolically effective calcium which is maintained in the soluble state in the active plant tissues is directly correlated with the supply of available boron in the tissues.

Later Reeve and Shive (1944), found that as the calcium content of the nutrient solution was increased, more boron was required to prevent boron deficiency in the plant and that more boron could be added to the solution without the development of symptoms of boron toxicity.

Jones and Scarseth (1944), working with a number of Indian farm crops, in green house experiments on limed and unlimed soils, found that plants would take up varying quantities of calcium and boron depending upon the availability of these elements in the soils. They found low tolerance for boron with low calcium in the plant and a high requirement for boron with high calcium.

Boron fixation in soils:

The mechanism of fixation of boron is an important factor in boron nutrition of plants. It is important because the plant obtains its boron from the soil solution and the equilibrium between the boron in solution and the fixed boron partly determines the instantaneous supply of boron to the plant (Bigger and Fireman, 1960).

Boron fixation is a rapid reversible chemical process. The oxidation of organic matter results in a significant release of boron in available form and causes a slight decrease in boron fixation (Olson and Berger, 1947).

Not all the soils have the same capacity to fix boron or to adsorb it from the soil solution. Boron probably forms surface compounds with the soluble aluminium, silica and iron. Also probable is an exchange adsorption of borate ions with hydroxyl ions of the soil surface, resulting in the fixation of boron to the aluminium, silicon and iron of the crystal lattice. It has been shown in the studies of the fixation of boron in the presence and absence of bentonite that, boron may be effectively precipitated in combination with several ions, particularly aluminium and silica. The presence of calcium ion, drying and high pH values all tended to increase the boron that was fixed. The formation of alumino-silicate prdducts or substitution of boron for aluminium in that formation of complexes is entirely possible. From the equilibrium, leaching and extracting experiments, much of the boron fixed by what is beleíved to be stable compound formation, appears not to be readily removed. It is quite possible that this boron would not be available to plants unless plant root growth decomposes the mineral on which boron is fixed (Bigger and Fireman, 1960).

The extent of boron fixation in soils is closely related to clay content and soil reaction. The cations of the bases have little influences on boron fixation but the alkali produced by them results in fixation. With carrington silt loam, $Ca(OH)_2$ is more effective in inducing boron fixation than NaOH; with Spencer silt loam, the bases are equally effective. Even at pH values of 9.5 or higher, not more than 40 percent of the added boron or the native available boron in the soil is fixed. In acid soils, there is no correlation between boron fixation and pH. Fixation of added boron due to change in pH is found to be proportional to the fixation of native boron due to a similar change. After removal of organic matter and free iron and aluminium oxides, the clay separate fixes the least amount of boron as calculated on the percentage weight basis of the separates (Olson and Berger, 1947).

Parks and Shaw (1941), beleived that boron fixation might be due to small amounts of boron entering in complexes of calcium with silica or alumina or in calcium-alumino silicate products of synthesis as a substitution product for aluminium ions. This and the calcium with saturated bentonite at pH 8.0 was insoluble in boiling distilled water. It seems highly probable that fixation of boron in this system might be due to occlusion. Boron fixed under acidic conditions can again be released by acidification of soil (Olson and Berger, 1946).

Harder (1961), observed in his experiment that equilibrium had not reached in 158 days after boron was added to the mineral which is due to the entry of boron in tetra hydral position of the clay substituting alumina and silica.

Hatcher, Bower and Clark (1967) reported that major soil constituents causing boron retention are $Al(OH)_3$ and similar materials; lime induced boron deficiency results from the additional absorption by $Al(OH)_3$ precipitating after lime.

The surface area over which the $Al(OH)_3$ is spread, is an important factor in boron adsorption.

Recent studies have indicated that boron adsorption by soils can be partially described by the Langmuir's adsorption equation. Hatcher and Bower (1958), compared adsorption equation.

Factors affecting the Boron fixation :

1) Liming -

The effect of lime on boron fixation in soils is in many cases very marked. Bobko et al.(1936) and Naftel (1938), originally interpreted this in terms of a stimulation of microbes in the soil, but Midgley and Dunklee (1939), found that microbial activity was not necessary to account for the effect of lime on boron and they argued in favour of reaction with mineral surfaces. The adsorption of boron by hydrated ferric oxide, Kaolin and other clays does increase with pH, although at least in one case it goes through a minimum at pH 5 (Barbier and Chabannes, 1953). Olson and Berger (1946), demonstrated that the Ca ions were not required to bring about fixation. NaOH was just as effective as the lime. Calcium most likely does have a specific physiological effect in reducing the boron uptake by plants (Parks,1944).

2) Alkalinity and change in pH:

Boron is fixed in alkaline soils, in the presence of free calcium, partially by organic matter and partially by the soil mineral. Midgley and Dunklee (1939, 1940) and Dunklee and Midgley (1943), found that very large amounts of boron were fixed by soil when the pH was changed considerably by acid leaching and then liming to neutrality.

3) Drying:

Drying has been shown by Parks (1944) and others to cause increased fixation of boron in the laboratory. Olson (1947), found that drying of soil after boron was added, increased the amount of boron fixed. The increase was greater in the case of limed soils than with the unlimed soils. Drying at 60°C increased fixation more than drying at 20°C. These findings confirm those of Parks who found that drying at 85°C almost doubled the amount of boron fixed when soil was dried at 26°C. Walker et al. (1944) observed that boron deficiencies were more severe in places in the fields where soil dried out excessively in dry years. Latimer (1941), showed that drought in June and July was the most important factor in the cause of internal cork in New Hampshire apple orchards.

Parks and Shaw (1941), in an experiment with pure chemical, precipitated boron in combination with silica and alumina. The presence of calcium ions, drying and high pH, all tended to increase the boron content of precipitates. They believed that the boron fixation might be due to small amounts of boron entering into complexes of calcium with silica or aluminium or in calcium alumino-silicate products of synthesis as a substitution product for aluminium ions. This and the calcium with saturated bentonite at pH 8.0 was insoluble in boiling water. It seems highly probable that the fixation of boron in this system might be due to occlusion.

Although a number of factors are reported to favour boron fixation as stated above, but in India, only the effect of soil texture has been studied. Finer textured soils fix more boron than the coarse textured soils. Mandal et al. (1956) and Jha (1964), found that boron fixation capacity of six soils from Bihar increased from 6.5 to 11.1 mg boron/kg soil as the soil texture varied from sandy loam to clay loam.

Singh and Kanwar (1963), reported that the adsorption capacity for boron of heavy soils is more as compared to the light textured soils, and desorption is of the opposite order, indicating that waters of equal boron content could be more toxic to plants in coarse textured than in the fine textured soils.

Gandhi and Mehta (1958) studied the mobility of applied boron in goradu soils of Gujarat both in the presence and absence of alfa-alfa under field conditions. The rate of application of boron varied from 10 to 44.83 kg borax/acre. The leaching of boron was confined to 48 inches. More boron leached down to deeper layer in the absence of crop than in the presence of crop.

Singh (1964) working with two soils of Punjab reported that Langmuir adsorption equation was found to be valid over ranges of limited boron concentrations of the solutions but when all the concentrations were taken into considerations, the relationship followed a quadratic curve which could finally be treated as B.E.T. formiadsorption isotherm.

III: <u>Boron in soils</u> :

The total boron content of soils generally ranges from 2 to 100 ppm with an average value of about 30 ppm. The high content of boron in clay sediments of marine origin (3-300 ppm) is due to the relatively high boron content of sea water. Boron is conserved during sedimentation and soil formation due the fact that the boron is largely present in soil parent materials as extremely resistant minerals, such as -tourmaline. Any soluble boron in the soil, such as that provided by the application of the fertilizer borates is very readily leached except, of course, where drainage is impeded or where rainfall is insufficient.

The total amount of boron in soils depends largely on the soil parent material (Anon,1967).

The total boron content of 118 soils showed an average value of 30 ppm. The total boron in soils ranged from 4 to 98 ppm and fine textured humid soils analysed showed a range of 30 to 60 ppm and sandy soils as low as 2 to 6 ppm. (Jackson, 1958).

According to Atre (1960), the water soluble boron in Vidarbha soils varies 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 range of water soluble boron in mineral soils of the humid regions is generally from 0.2 to 1.5 ppm and ranges upto 2 or more ppm in muck soils and down to 0.2 in fairly fertile sandy soil.

According to Richard _et al_.(1954), a concentration of water soluble boron in saturation extract of the soil below 0.7 ppm is safe for sensitive plants, 0.7 to 1.5 ppm is marginal and more than 1.5 ppm is unsafe.

According to Swaine (1955), the total boron content of most of the soils in the world is in the range of 2-100 ppm. Vinogradov (1938), gave 8 ppm as the average value for boron content of different soils. Robinson (1951), gave the range as 3 to 90 ppm.

Total boron in Indian soils has been found to vary from 7-630 ppm.(Ramamoorthi, 1946, Mandal 1956, Soni _et al_. 1961, Mathur _et al_. 1964). The range of available boron in Indian soils is from traces to 12.2 ppm (Kanwar and Randhawa, 1967).

Table 1

Total and available boron contents in Indian soils (ppm).

S.No.	Name of State.	Place	Parent material	Soil type	Forms of Boron in soil: Total Boron (ppm)	Available Boron(ppm)	Authors
1	2	3	4	5	6	7	8
1)	Maharashtra	..	Deccan trap	..	1.2 - 16.60	0.10 -0.60) 0.8 -3.0)	Bendale et al.(1951) Atre(1960),Raut(1962)
2)	Bengal	..	Alluvium	..	15 - 30.00	0.40 -2.00	Ghani and Haque(1945), Chanjee (1956)
3)	Bihar	..	Old alluvium Siwalik rocks.	..	18 -100.00	...	Mandal et.al(1956), Soni et al.(1961).
4)	Bihar	..	...	..	..	0.30 -2.20	Mandal et al.(1956)
5)	Bihar	North Bihar	Recent alluvium	..	7.50-57.50	0.40 -0.90	Sinha and Sinha(1966)
6)	Bihar	South Bihar	Old alluvium	..	15.00-40.00	0.45 - 1.40	-"-
7)	Bihar	Chota Nagpur	..	Sedentary soil.	7.5 - 38.90	0.20 -0.90 0.10 - 1.60	-"- Jha (1968)
8)	Bihar	Pusa	Old alluvium	..	3.75-32.50	..	Farooque(1964-69)
9)	Bombay	..	..	Black cotton soil.	24.5-29.6	..	Satyanarayana(1958 b).
10)	Delhi	..	Alluvium	..	..	0.6 - 4.6	Paliwal and Anjaneyulu (1967)

Table 1 contd:

1	2	3	4	5	6	7	8
11)	Gujarat	..	Deccan-trap and mixed.	normal soils	--	0.20 -1.50	Gandhi and Mehta (1958 a.b)
12)	Gujarat	Baroda and Saurashtra dists.	..	Saline soils.	--	3.00 -3.50	-"-
13)	Gujarat	Kaira and Baroda districts.	--	--	--	0.60 -1.70	Mehta (1968)
14)	Madhya Pradesh.	--	--	--	--	0.08 -0.20	Rai (1968)
15)	Erstwhile Punjab.	--	Upper and lower tertiary of sedimentary. river deposits.	--	16 -800	--	Sastry and Viswanath (1946)
16)	--	--	--	Normal soil.	--	0.10 -6.0	Hoon *et al.* (1941) Dhawan and Dhand (1950).
17)	--	--	--	Saline alkali soil.	--	3.00-11.80	Kanwar and Singh, (1961).
18)	--	--	--	Cotton growing areas.	14 -46	0.18 - 0.71	Bhumbla and Nair (1965).
19)	--	--	--	--	14 -43	0.75 - 5.75	Singh (1969)
20)	--	--	--	--	--	0.12 - 1.56	-"-
21)	--	--	--	Profiles	--	0.56 - 5.30	Grewel *et al*(1969)

Table 1 contd.

1	2	3	4	5	6	7	8
22)	..	Bhatinda	--	--	46.8-81.3	Tr. - 6.50	R.Singh and Randhawa (1969)
23)	Rajasthan	..	Desert (Sand)	..	..	Tr. -12.20	Satyanarayana, (1958).
24)	Rajasthan	Mewar	..	..	..	0.08 -0.42	Bager & Saxena (1967), Mathur et.al (1967).
25)	Rajasthan	Mewar	..	Irrigated soil.	..	2.10 -4.46	Nathani et al. (1968).
26)	Uttar Pradesh	..	Graneti-ferrous biotite, Schist, alluvium and Gneisis	Alluvial	49 -630	..	Agarwal(1963,1964)
27)	-"-	..	..	Bhabher	122-586	..	Agarwal(1963,1964).
28)	-"-	..	..	Bundel-khand	201-630	..	Agarwal(1963,1964).
29)	-"-	..	..	Vindhyan	58-467	..	-"-
30)	Uttar Pradesh	..	..	Normal soil.	---	0.10 - 15.5	Agarwal(1963,1964).
31)	Uttar Pradesh	..	..	Saline alkali soils.	...	0.82 - 1.55	Agarwal et al. (1964).
32)	Uttar Pradesh..	Vara-nasi	..	Normal soil.	9.4	0.37 Abs.Av. 0.69 Imme.Av.	Singh and Singh (1968)
33)	-"-	..	..	Alkali soil.	12.4	0.58 Abs.Av. 0.12 Imme.Av.	-"- -"-

Table 1 contd:

1	2	3	4	5	6	7	8
34)	All over India	..	..	Arid region	7 - 80	..	Ramamoorthy and Viswanath (1946)
		..	..	Semi-arid	36.- 0	..	-"-
		..	..	Humid	34.5	..	-"-
		..	..	Pre-humid	38.5	..	-"-
35)	World	..	..	..	2 - 100	..	Swine (1955)
		..	..	..	8	..	Vinogradov (1938)
		..	..	..	3 -90	..	Robinson (1951)

Depending upon the parent material from which the soils are derived, the total and available boron contents from different States of India reported by various workers are given in Table 1.

IV : Forms of Boron in soils:

Boron present in soils can be classified into three categories viz:

i) Total boron,

ii) Acid soluble boron

iii) Water soluble boron

According to Berger and Truog (1945), the fraction of boron soluble in hot water was found to be a most useful source for the plants.

The total boron can be determined by fusion method while acid soluble by acid extraction. But the figures derived by fusion method are higher than those derived from acid extraction. By hot water treatment, the water soluble boron can be determined.

Very few authors have used HCl digestion for total boron. Askew *et al.* (1937), working on New-Zealand soils gave figures for HCl soluble boron varying from 0.05 to 0.6 ppm; Tanda and Dean (1942) indicated 4-56 ppm of total boron in Havaiian soils, while Whetstone *et al.*(1942), reported total boron as 4-88 ppm and acid soluble boron as 0.4 to 64.8 ppm in American soils.

Most of the reported figures are for fusion method. According to Sastry and Viswanath (1944), the total boron(by fusion method) of Indian soils varied from 16-68 ppm.

A great number of factors are known to affect the boron availability and the total boron content of the soils. The trace element contents of a soil are dependent almost entirely on the process of geo-chemical as well as pedochemical weathering [Mukerjee (1957)]. Further, as pointed out by Goldschmidt (1945), the microelement contents of different minerals differ and even in the same mineral, the amount of any particular element present would depend upon its fractional crystallization from the magma.

The availability of soil boron to crops depend upon many factors. It is believed that soil boron in two forms can be utilized by plants. These forms are the available inorganic soil boron and the available organic soil boron. The available organic soil boron on decay through micro-organisms can be converted into inorganic form. It is thought by some workers that organic soil boron can also be directly absorbed by living plants. Both the inorganic and organic forms of available boron are in equilibrium with the total boron present in the soil (Agarwal, 1965).

Factors such as soil reaction, organic matter, texture, moisture content, calcium carbonate, quality of irrigation water, salt concentrations, fertilizer amendments, climate and other factors, relationship with total boron and calcium boron ratio are known to affect the availability of soil boron to plants. Only the relevant factors are discussed in greater details here.

V: Factors affecting the availability of boron in soils:

Soil reaction (pH):-

Kanwar and Singh (1961), reported that water soluble boron increased with increase in the soil pH. The correlation co-efficient of the pH of the saturation paste and the water soluble boron contents of saline-alkali soils were $r = 0.853$ and $r = 0.350$ respectively.

Singh and Kanwar (1963), again reported a significant correlation between SAR value of soil and its water soluble boron, the former was significant at 1 percent level and the latter at 5 percent. Mathur *et al.* (1964) also obtained a significant correlationship between available boron and pH of the irrigated soils. The range of pH was 7.8 to 8.2. In unirrigated soils, whose pH ranged between 7.4 to 9.2, no such relationship was observed.

The availability of boron in Vidarbha soils remained particularly uniform upto pH 7.2 and 8.0 and decreased with higher than 8.0 Atre(1960).

Bhattacharjee (1956), reported that availability of boron was comparatively more between pH 6.0 to 8.0 and it decreased below and above this range. However, the statistical analysis of the data showed a negative insignificant correlation between soil reaction and water soluble boron.

Paliwal and Anjineyulu (1967) working in Delhi soils and Singh (1969) and Grewal et al. (1969) in Punjab soils found a significant relationship between different forms of available boron and soil pH.

Mathur et al. (1964) and Baser and Saxena (1967) also found an increased available boron content in Rajasthan soils with increase in the soil pH.

Ghani and Haque (1945) and Gandhi and Mehta (1958 a,b) reported that pH had apparently no relationship with water soluble boron content of the Bengal and Gujarath soils respectively. This perhaps is due to the fact that other factors such as calcium carbonate, organic matter, soil texture, nature of irrigation water etc. were not constant.

Agarwal et al. (1964) reported that in the range of 1 to 8 E.S.P., the increase in E.S.P. is associated with an increase in water soluble boron and in soils of higher E.S.P., an available boron was statistically non-significant.

Organic matter :

Berger and Truog (1945), reported that availability of boron in acid soils is correlated and it increased with their organic matter content. They also found that in alkaline soils, available Ca and soil reaction seem to have more effect on availability than does the organic matter.

In arid soils of Rajasthan (Western) Satyanarayana (1958,b) got a significant positive correlation between available boron and organic matter content of these soils. However, the relationship in semi-arid soils of Central Rajasthan was statistically found to be non-significant.

Ghani and Haque (1945), Gandhi and Mehta (1958 a,b) and Grewel et al.(1969) found no relationship between available boron and organic matter content in Bengal, Gujarat and Punjab soils respectively.

Baser and Saxena (1967) noticed an increase in boron with increase in organic matter content. Singh and Singh (1967), found a significant negative correlation between available boron and organic matter content in soils.

Ghani and Haque (1945) although they did not observe any correlation between available boron and organic matter content of the Chittagong, Midnapur and Sundarban soils, they did observe a higher value of available boron on irrigation in these soils and attributed this increase to the boron percentage in organic combinations.

Gandhi and Mehta (1958 a and b) also reported a statistically non-significant relationship for Gujarath soils.

Texture :

Usually in the humid regions the lighter textured soil contain less available boron in the plow layer than do slight acid, silt and clay loams. Lehr (1940) has shown that clays, particularly those of marine origin, are high in boron and in sands they are low.

Kubota *et al.* (1948) also showed that sandy soil contain less available boron than do the soils with heavier textures.

Singh and Kanwar (1963), reported significant positive relationship between saturation percentage and water soluble boron. Since saturation percentage depends on the texture and increases with the clay content, therefore, such a relationship between boron and soil texture is expected.

However, Mathur *et al.* (1964), reported a significant negative relationship between finer fraction and available boron content of the irrigated and unirrigated Rajasthan soils.

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

Paliwal and Anjaneyulu (1967) and Singh (1969) observed that available boron and finer fraction of soils were significantly and positively correlated. Baser and Saxena (1967), also noted an increase in available boron in Mewar soils with increase in the content of finer fraction in soils.

Calcium carbonate :

It has been reported by workers from outside India that soils containing significant amount of lime are usually low in available boron. None of the workers in India (Bhattacharjee 1956, Gandhi and Mehta 1958, Mathur et al. 1964) got statistically significant relationship between $CaCO_3$ and water soluble boron content of the soil.

Bhattacharjee (1956), Gandhi and Mehta (1958 a,b), Mathur et al. (1964) and Grewal et al (1969) working with Bengal, Gujarat, Rajasthan and Punjab soils respectively did not find statistically significant relationship between $CaCO_3$ and water soluble boron content of soils.

Under Indian conditions, Ghani and Haque (1945) working with soils of East Bengal, Bhattacharjee (1956) working with Murshidabad soils, West Bengal, and Gandhi and Mehta (1958) working with Gujarat and Saurashtra Soils, found that soil pH and organic matter have no relationship with water soluble boron. Similarly no correlation exists between the calcareousness of soils and the amounts of water soluble boron in them.

According to Atre (1960), organic matter, total nitrogen and C/N ratio have no effect on the boron content of the Vidarbha soils.

In general, the amount of work done so far in India has not shown any positive correlation of the water soluble boron with factors that are known to influence boron availability in temperate countries (Agarwala, 1965).

VI : <u>Factors affecting the total boron in soils:</u>

Type and age of parent material, texture, calcium carbonate, cultivation, type of irrigation water are known to influence the total boron content in soils.

1) <u>Type and age of parent material:-</u>

Total boron content of soils varies according to regional surface geology and parent material. Ramamoorthy and Vishwanath (1946) after grouping the soils on the basis of regional geology into 5 groups, found the following ranges of total boron for each group.

		Range ppm	Mean ppm
a)	Ancient crystalline	8.5-34.0	21.8
b)	Delhi system	22.5-35.5	29.2
c)	Cuddapah system	27.5-50.0	39.2
d)	Trap	27.5-57.5	38.8
e)	Alluvium or recent deposits	7.0-80.0	42.3

They also analysed some Indian rocks for boron content and reported that granite, shales and limestones, augite-basalt and alluvium contained on an average 19.3, 39.2, 42.5 and 42.3 ppm boron, respectively.

Dakshinamurthy *et al.* (1955) for Delhi soils and Sinha and Singh (1966), for North and South Bihar soils found that, boron content was related to tourmaline content of soils.

2) Texture:

According to Soni et al.(1961) boron content of the sugarcane soils of Bihar bears no relationship with the clay content but is associated with the coarser fraction. They actually determined boron content of the sand fraction which agreed very well with the values calculated for the coarser fraction. They beleive that boron in the soil is entirely contained in the coarser fraction.

The results obtained by Mathur et al.(1964) for Rajasthan soils are at variance with those from Bihar. They observed a positive and statistically significant relationship between finer fraction (clay and silt) and total boron.

3) Calcium carbonate:

The calcareous soils have been known to fix larger amounts of boron and since these soils are formed under conditions where leaching losses by rainfall are not heavy, they are supposed to contain more boron.

Mathur et al.(1964) got a positive and statistically significant relationship ($r = 0.49$) between the calcium carbonate and total boron content of unirrigated soils.

Soni et al.(1961) showed that calcareous profiles from Bihar have considerably lower boron status than the non-calcareous profiles from the same State.

VII : Depthwise distribution of total boron:

Reports on nature of boron distribution in soil profiles are at variance.

Soni *et al.*(1961) observed that there was an indication of upward accumulation of boron in soil profiles of sugar belt of Bihar. However, they further noted that such differentiation was not apparent in heavy clay soil profiles. According to Agarwala (1963,1964), boron in Bhabhar and Bundelkhand soils generally increased with the depth, whereas in highly leached Vindhyan soils, it decreased with the depth.

Singh and Singh (1967) working with Uttar Pradesh soils found that content of total boron decreased inversely with the depth. Singh and Singh (1969) and Singh and Tomer (1969) reported an increase in HCl soluble boron content with the depth of soil profiles of erstwhile State of Punjab and cotton growing areas of Punjab and Hariyana. However, Singh and Randhawa (1969) did not find any definite distribution pattern in soil profiles from citrus orchards of Punjab.

Mathur *et al.*(1964) working with Rajasthan soils observed that in the irrigated soils, sub-surface accumulation prevails whereas in the unirrigated soils surface accumulation of boron was noticed. They also noted that irrigated soils had more total boron than the unirrigated soils.

Depthwise distribution of available boron:-

It has been observed that available boron increases with the depth in well drained soils, whereas in soils where drainage is a problem, it decreases with the depth.

Dhawan and Dhand (1950) and Satyanarayan (1958) observed that the available boron content in the Punjab and Rajasthan soils increased with the depth. Mathur et al.(1964) reported that available boron from Rajasthan soils decreased with the depth in unirrigated soils but after prolonged irrigation with well water, high in boron, water soluble boron increased with the depth. Singh and Singh (1967) also found that water soluble boron decreased inversely with the depth.

However, Singh (1969) and Grewel etal. (1969) observed a decrease in boron content with depth in erstwhile Punjab soil profiles. Gandhi and Mehta (1958 a,b) and Kanwar and Singh (1961) had noted a similar trend for boron distribution in saline-alkaline soils from Gujarat and Punjab respectively. In Vidarbha soils, there was an increase in boron content with the increase in depth, Atre (1960).

VIII: Boron in irrigation water :

The real problem is the decline in the productivity of several lacs of acres of land in the Maharashtra State, the yield from which has been reduced considerably because of the salt influence. In these days, the irrigation facilities are increasing in the State due to construction of head canals and implementation of cooperative lift irrigation schemes and thus we are having more facilities for irrigation. But we should make use of these facilities in a proper way. The lands from which the yields are reduced generally are present in arid irrigated areas and seem to have developed due to faulty irrigation practices and use of poor quality irrigation water under soil and climatic conditions condusive to salt accumulation. It is expected that the salt danger will further increase with the growing of high yielding varieties requiring more irrigation and due to the trend in irrigation agriculture in the direction of utilizing all the available water.

The maintenance of successful agriculture in the areas presently under irrigation needs a more efficient management of land and water. In the case of land, this involves a thorough knowledge of the soil, while efficient use of water requires a knowledge of the quality of water and the behaviour of soils and plants on its application.

The criteria used for deciding the quality of irrigation waters has been discussed at length by Agarwal and Gupta (1968). The quality of river water or canal waters in India has been found to be of very high order [Asghar and Dhawan 1947, Taylor *et al.* 1935, Agarwal and Mehrotra 1952, Venkataramian 1941, Mann and Tamhane 1910, Govind Iyer, 1957].

Well waters represent two sources of under ground water namely - tube wells from deep strata or shallow wells. These waters are usually of varying composition which usually depends upon the nature of strata tapped.

The major criteria used for deciding the quality of irrigation water are :

1) Salinity expressed as (E.C.) or total concentration in ppm.
2) S.A.R.
3) HCO_3^-
4) Boron
5) (Cl^-)
6) (li, Se etc.)
7) R.S.C.
8) S.S.P.
9) Salt index
10) Gypsum equivalent.

Besides the above criteria, the concentration and nature of salts present in irrigation water, determine its quality. The nature of salt in irrigation water, sometimes may be more important than the total amount of salts, e.g. if the proportion of sodium in irrigation water is high, the soil may become gradually unproductive. Even water of doubtful quality can be used without serious damage to soils and crops, if the necessary precautions are taken in irrigation and soil management (Thorne and Thorne,1951). The maximum permissible salt content of water depends also on the nature of the soil and sub-soil. Saline waters are better suited to be used on soils which are permeable and where the water table remains 1.8 - 3 m below the surface (Christiansen and Lyerly,1952).

It has been suggested by Fox and Albrecht (1955) that the boron problem in saline alkaline soils is of special importance when sodium is a dominant cation and enough calcium may not be present to check the boron toxicity. When boron is present at harmful level along with the soluble salts, the amount of water required to leach it down shall be very large.

Amongst the Indian workers, Asghar and Dhawan (1947), Agarwal *et al.*(1956) and Darra *et al.*(1964) have reported about the quality of irrigation and drainage waters.

Magistad and Christensen (1946), have suggested the limits of sodium and boron standards for irrigation waters.

Table 2

Sodium and boron standards for irrigation water.

Class	Conductance $K \times 10^5$ at 25°C.	Salt content Total ppm	Salt content Peracre foot tons.	Sodium content %	Boron content ppm.
I	.. 100	700	1	60	0.5
II	.. 100-300	700-2000	1-3	60-75	0.5 -2.0
III	.. 300	2000	3	75	2

Magistad and Christensen found 0.14 ppm of boron in the water of the lower Colorado river at Yuma, Arinzon and 0.71 ppm in water of well in the Coachella valley, California. They

They divided the irrigation waters of the South Western U.S.A. into three classes on the basis of their sodium and boron contents as shown in Table 2. Those of Class(I) category are suitable for most plants under moist conditions; waters of Class (II) category will harm the more sensitive crops; while waters which fall in Class III category on any basis will prove unsuitable for irrigation under most conditions.

Durand (1956), classified 40 waters of Algeria in relation to their salinity, boron toxicity and alkalinity. Waters of conductivity less than 250 micromhos/cm (C_1) were most suitable. Waters of 250-750 (C_2) were suitable for most plants. With waters of 750-2250 (C_3) good drainage was required. Alkalinity was measured by the S.A.R. Waters with ratio 0-10 (S_1) were most suitable, while those with 10-18 (S_2) were dangerous for fine textured and high exchangeable capacity soils. Waters with 18-26 (S_3) ratio proved to be dangerous on most soils and needed good drainage and addition of organic matter. Addition of gypsum was sometimes beneficial. Above 26 (S_4) most waters were unsuitable.

The well waters often contain more concentration of boron in them which is harmful to the plants if used for irrigation. In some areas of low rainfall, the boron content of well waters is so high that these cannot be used for irrigation purposes. Application of irrigation waters containing boron over long periods of time gradually builds up the boron content to a considerable extent.

Singh and Kanwar (1963) analysed well waters from Punjab with annual rainfall between 30" and 40" and found them to contain 0.2 to 0.5 ppm boron.

Singh and Kanwar (1963) analysed the well waters from Patti (Amritsar) and found them to contain boron within safe limit i.e. 0.33 ppm even for sensitive crops, but the boron concentration of the saturation extract of the soil irrigated with these waters varied from 1.42 to 2.90 ppm which was considered unsafe for sensitive crops.

Mathur et al.(1964) analysed well waters from Rajasthan (annual rainfall of 10") and found them to contain 2.8 to 4.1 ppm of boron. The data of Mathur et al. reveals that water containing more than 2 ppm boron can build up very high concentration of boron in soils which could be harmful to most crops.

Magistad and Christiansen (1944), analysed waters of South-Western U.S.A. and were of the opinion that water having more than 2 ppm boron may be considered as unsuitable for irrigation purposes.

The data of Kanwar and Singh (1961), further reveals that irrigation waters where boron is well within the safe limit, should be used with caution since their use over long periods of time can increase the boron content to the limit which could be harmful for most crops.

Harigopal and Rao (1969), analysed the well waters from

from a locality of Tirupati and arrived at the conclusion that the highest value of boron was 0.15 ppm obtained from well water from Virlapattidi area. The well water boron ranged from 0.06 to 0.1 ppm in Tummalagunta area, it was between 0.02 to 0.15 ppm in Vurlapattidi area and the range of boron in well water opposite to S.V.University was 0.02 to 0.09 ppm. Only one sample of irrigation water contained 2.1 ppm boron.

Agarwal, Mehrotra and Gangwar (1956), evaluated the quality of irrigation waters from U.P. The irrigation waters from canals have been found to be of safe quality and constitute the best source of irrigation water supply of the State. The quality of well waters has been found to vary with the nature of the soil formation and its ground water level. Immature and zonal soils contain well waters of doubtful quality and may present soil salinity problems. Well waters on mature soils are comparatively free from salinity problem.

Tripathi, Singh and Dixit (1969) studied the quality of irrigation water in semi-arid tract of U.P. 600 samples obtained from different districts were analysed to assess their suitability for irrigational use. The irrigation waters have been found to be free from appreciable sodium problems. Salinity problem is serious with the waters of all the districts which increases with aridity of the tract.

Balsundaram _et al_.(1969) analysed 14 water samples from the Agriculture College farm, Coimbatore and found them to contain 0.025 to 0.18 ppm of boron determined by turmeric method.

Rangaswamy _et al_. (1969) analysed the 13 water samples from open and bore well of Agriculture College farm, Coimbatore; all the waters studied have very low concentration of boron, being far from danger. The authors have also stated the ionic composition of waters for assessing the suitability of ground waters for irrigation.

Recently Krishnamurty (1970) critically examined the quality of waters from Kovilpatti taluka in Madras and reported the chemical composition of dissolved salts in a very good manner for judging the quality of waters from different aspects.

Govinda Iyer and Subramanian (1960), reported the quality of water from a locality of Madras. A quality appraisal of the irrigation waters from well, canal and river of Amaravathy Ayacut area has been made by using the recent water categorization schemes adopted in the U.S. The canal and river waters are of good quality while those of wells are of medium quality.

Sree Ramula and Thyagarajan (1967), opined that the well waters in the Periyane gamun area can be used successfully if proper management practices are adopted. The rest of water found in the area can be used for irrigation without any risk of sodium or salinity hazards.

Kanwar and Deo (1969) reported the Potassium and Magnesium in irrigation water and their effects on the physico-chemical soil properties.

Landey and Murty (1967), examined the quality of irrigation water from Mysore State and observed to be high to very high salinity in the water samples.

Darra and Mehta (1963) have given the inter-relationship between electrical conductivity and total solids of the under ground irrigation waters in Rajasthan.

Sharma _et al._ (1963), studied the underground waters in lower Luni Catchment and arrived at conclusion that nearly 50 percent of the waters are saline and 40 percent are both saline and alkaline on either side of the river.

Shankarnarayana _et al._ (1965), gave an appraisal of the quality of saline ground waters of arid tracts of Western Rajasthan for agricultural utilization.

Subramoney and Varma (1969), reported the analysis of water samples and its interpretation and different standards for judging the quality of irrigation water.

Nathani _et al._ (1966), found the range of boron in the ground waters of the Chambal commanded area from 0.1 to 3.0 ppm.

Boron increase with increase in electrical conductivity, pH, S.A.R. and residual sodium carbonate.

Darra, Mehta and Pareek (1964) reported the quality of irrigation waters in Rajasthan. Rajasthan waters are classified as saline and alkaline. Canal waters are of good quality, but well waters vary with soil types from moderately alkaline to highly alkaline.

Handa (1967) studied the agricultural quality of ground water in Kutch and stated that the ground waters vary from medium to highly saline and can be used for irrigating plants with moderate to high salt tolerance. Most of the waters with higher sodium concentration can be made suitable for irrigation by addition of $CaSo_4$ or some other cheap calcium salt.

Satyanarayana, Chibber and Verma (1967), gave the seasonal fluctuation in quality of some well waters. Two sets of well waters were collected - one before the monsoon, in the month of June and second after the cessation of monsoon rains in the month of October. After the rains, salt concentration in the well waters was generally reduced. Soil samples were also collected from areas irrigated by water of some of these wells and analysed to study the effect of continuous use of irrigation water on them. The continuous use of saline water did not show any apparent effect on well drained soils of the area, indicating that many waters apparently of questionable quality may actually be used with success, on light and well-drained soils.

Babreker et al.(1965) also reported the seasonal variation in the quality of irrigation waters in Dhulia

IX: Boron in Plants:

Role of Boron in crop nutrition -

The role of boron in crop production and nutrition was discussed by Lal and Srivastava (1948). Boron was not discovered in plants until (1857) when Wittstein and Apoiger obtained boric acid from the ash of the seeds of Maesa picta, an Abyasinian plant belonging to the order Myrsinaceae. In (1910) Agulhon published results showing increases in dry weight of wheat, oats and radish with the addition of boron to sand cultures. In (1915) Maze was the first to report that boron was essential for the growth of corn. Warington (1923) first showed that boron is not only a stimulant but that in its absence certain members of the order Leguminosae develope characteristic deficiency symptoms. Stiles (1946), Nokamurain (1903) had reported increased growth of Peas and Spinach as a result of adding boron to soil. From 1925-1930 further proof of the essential nature of boron for plant life was obtained.

Srivastava and Lal (1948), discussed the role of boron in crop production. According to Hoon et al.(1941), water soluble boron content in the range of 1.5 to 6.0 ppm in Punjab soils manifested a negative correlation with the yield of wheat. However, the same authors in their later studies (Hoon *et al.* 1946) did not observe such relationship between boron content of soil and the yield of rice.

Dhawan and Dhand (1950) reported a relationship between Ca/B ratio and growth and yield of crops in Punjab. The average value of Ca/B was more than 500 ppm for good soils and 100 ppm or less for poor soils.

Ramamoorthy and Desai (1946), reported that the availability of boron to tobacco was affected by an unfavourable Ca/K ratio in the soil.

Patnaik (1950), studied the effect of boron on catalase activity of rice plants. Catalase activity of leaves increased with 0.5 to 1.0 ppm of boron but decreased slightly when concentration was raised to 10 ppm. In roots, catalase activity was less than in the leaves, it increased with 0.5 ppm boron and dropped with 1.0 to 10 ppm of boron. However, with all the three concentrations used, the catalase activity was more than when boron was omitted.

Govindan (1952 a) using tomato as an indicator plant remarked that not only the formation and accumulation of different fractions of carbohydrate but also their utilization in the normal physiological metabolic process in the plant were affected by boron. All the carbohydrate fractions decrease with the increasing concentration of the elements.

Govindan (1952 c) observed that tomato plants in sand culture developed boron deficiency symptoms at different stages of its growth when the concentration of boron was 0.5, 1.0 and 2.0 ppm. With increasing concentration of boron, the yield of tomatoes continued to increase; however, with 8 ppm boron the plants developed toxicity symptoms.

Maize, barley, rice and sugarcane required 5.25, 2.60, 1.75 and 1.40 ppm boron, respectively for their growth in sand cultures. Patnaik (1955), reported 1.0 ppm concentration of boron in solution culture, as the optimum concentration for normal growth of rice but 10 ppm produced toxicity.

Gandhi and Mehta (1960), reported that tobacco had a high tolerance limit. The sufficiency levels under sand culture conditions for beans, bidi tobacco, guar and Pearl millet are 0.01, 0.01, 0.1 and 0.1 ppm, respectively.

According to Rao (1962), the absorption of boron by rice plants runs parallel with the dry matter production. There is a heavy demand for the element at flowering stage.

X: <u>Physiological role of Boron in plants</u>:

Warington (1923) first showed that meristematic activity was markedly affected in the broad bean and that both roots and stem tissues were abnormal in the absence of boron. Johnston and Dore (1929) found that plants grown in a boron deficient nutrient solution showed four distinct types of injury.

Haas and Klotz (1931) opined that boron is essential for cell division in the meristematic tissues and in the cambium. In the absence of sufficient boron, the cambium and portions of the phloem were observed to disintegrate and gum up.

Shive (1941) observed that boron is an important factor in the process of plant metabolism. Boron is very essential for cell division and is apparently a necessary component of the cell wall. It plays an important role in the synthesis of proteins, in its absence, nitrogen compounds and sugars accumulate while meristematic tissue die.

Boron is necessary for cell division and is a necessary component of cell wall. It is necessary for nitrogen and carbohydrate metabolism, in salt absorption and water relations in plants. It is a constituent of a membrane that regulates passage of sugars in plant bodies. Boron is regarded to be a buffer in plant tissues working as some kind of regulator of other substances.

Deficiency symptoms of boron in plants:

The boron can be readily washed out of soils and hence its deficiency is typically found on highly leached soils (Russell, 1961). Characteristic symptoms of boron deficiency are the death of growing points of shoots and roots and failure of flowering buds to develope.

The first visual symptom of boron deficiency is the death of growing point of the plant stem. As a result thereof, the buds below this point shoot out lateral stems which also ultimately die. As a result, the plant becomes multistemmed giving a rosette like appearance. Other symptoms are slight thickening and curling of the leaves. There may also be chlorosis. In legumes boron deficiency may lead to poor flower formation and lack of seed setting (Agarwal,1965).

Under conditions of boron deficiency, normal cell division does not proceed satisfactorily to complete separation of dividing cells and eventually the shoot and root apical meristems die or become extreamly moribund and after the loss of apical dominance, stunted side shoots develope from the auxillary meristem. The distortion of leaves, lack of elongation of internodes and the multiple auxillary branching are all related to the effect of boron on the separating cells in the meristem. The reduction in translocation may be primarily associated with the reduction in the utilization of sugar at the meristem (Anon,1967).

Excessive boron in saline soils and irrigation waters may also result in boron toxicity to plants. Although high boron concentrations beyond a certain limit are practically toxic to all plants, there are certain species of plant ~~skt~~ that can with-stand relatively high boron concentrations. Mandal et al.(1956), have recorded the toxicity ~~of~~ symptoms of boron in Peas, gram, barley, paddy, tobacco and onions.

Distribution of Boron in plants:

Moore (1937) found traces of boron in phloemexudate and parenchymasap of several plants and suggests that boron may be translocated in the phloem. Several workers have found that boron becomes concentrated in the leaves.

Robinson found boron content of turnip and potato leaves much higher than that of 'roots' and tubers respectively.

Bertrand and Silberstein have made also a detailed investigation of the distribution of boron throughout the organs of a single plant. Amongst vegetative organs the amount of thi$ element is lowest in the stem and highest in the leaves. Remarkable differences in boron content were shown to exist between floral organs. Thus the perianth contained a very small amount and the highest quantities were found in the anthers, ovaries and stigmas.

Comparable data have been provided in the case of maize by Bobko and Zerling, who found that, the boron content of vegetative organs tends to diminish when the plant blooms. Similar, though less complete, data were obtained by the same authors for tobacco lupin, red-clover, marrow and colchium autumnale.

Analyses by Miss Lohins have shown that little differences in boron content can be detected between young and old vegetative organs in lucern and tomato, or between that of haulms and immature ears in oats and wheat. In case of barley, the ears have a considerably higher boron content. Analysis of wheat flower parts showed boron to be concentrated in the pollen rather than in the legumes, stigmas were not investigated.

XI: Response of crops to Boron:

Different plants on the same soil or the same plant on different soils show a variable response to boron content of the soils because of their feeding habits and various soil conditions. The study of boron content of 30 species of plant growing on the same soil showed that boron content varied from 2.30 mg/kg in Barley to 94.7 mg/kg in Poppy (Bertrand and Dewall,1936).

Boron deficiency in plants may be present long before the visual symptoms occur and increased yield may be obtained if boron is applied. This was shown to be true with cotton in Malwa tract of Madhya Pradesh by Dastur and Singh (1953) and with wheat crop in Poona by Raychaudhari (1953).

De and Singh (1960) found in field trial for two years that in sugarcane 0.3%(percent) boric acid spray was better than

Table 8

Boron requirement of some common field and vegetable crops.

Probable available Boron content of soil in ppm required for optimum growth.		
Plants with high requirements (more than 0.5 ppm)	Plants with medium requirement(0.1-0.5 ppm)	Plants with lower requirements 0.1 ppm.
Apple	Tomato	Wheat
Alfa-alfa	Tobacco	Oats
Redclover	Lettuce	Rye
Crimsan clover	Peach	Barley
White clover	Cherry	Buckwheat
Sweet clover	Olive	Corn
Red beets	Pecon	Soyabeans
Sugarbeets	Cotton	Peas
Mangolds	Sweet potato	Green beans
Turnips	Peanut	Lima beans
Cabbage	Carrot	Navy beans
Broccoli	Walnut	Strawberry
Cauliflower	Filbert	Citrus
Asparagus	Onion	Rosbberry
Sunflower	Pear	White potato
Raddish	Groundnut.	Blue grass
Brussel sprouts		Bromegrass
Celery		Other grasses
Rutabaga		Flax
Burr clover		

Table 4

Boron concentration in the leaves of different plants grown in India.

Name of the plant	Boron content (ppm)	Authors
A: Fruit trees		
1. Guava, Custardapple, Ramphal, Fig, Pomegranate, Jambul, Almond, Mulberry, Banana, Papaya and Chiku.	15 - 225	Gandhi and Mehta (1958)
2. Different citrus and species, grape fruit, Italian lime, Kagzi lime, Mosambi, Narangi, Pummels etc.	127.0	
3. Ten Mango varieties	10 - 102 (mean)	
	10 - 225	Gandhi and Mehta (1960)
B: Vegetables		
1 Non-leafy vegetables	35 - 80 (mean)	Gandhi and Mehta (1958)
2 Leafy vegetables except - haron dodi	25 - 35	
haron dodi	215 -	
3 Spinach	30	Chebotina (1968)
	32 - 95	Idem (1958)
C: Condiments		
1 Ginger	40	Gandhi and Mehta (1960).
2 Turmeric	90	
3 Dill	62	
4 Sweetneem	110	
5 Garlic and Coriander	25	
D: Cereals.		
1 Paddy, wheat and maize	18 - 26	Gandhi and Mehta (1958)
2 Jowar, Bajara	50	
3 Oats	80	

Table 4 contd.

Name of the plant	Boron content(ppm)	Authors
E: Grasses	10 - 20	Gandhi and Mehta (1958)
	18 - 20*	Idem (1958)
Paddy straw	18 - 26	Gandhi and Meht (1960)
F : Legumes (nine types)	32 - 95	Gandhi and Mehta (1958)
Alfa alfa	35 - 60	Mandal, Ali, & Mukharjee (1956)
Soybean	...	
Barseem	...	
Fodder (non-legume)	06- 57	Collines.
G : Cash crops		
Tobacco	64 - 00	Gandhi and Mehta, (1958)
Sesame	50 - 00	
Sugarcane	44 - 00	
Castor	29 - 00	
Cotton	125 - 00	
Sugarcane leaves	44	Idem (1958).
H : Flower plants		
Alfalfa	35 - 60	Mandal et.al (1956)
Potato	30.0	
Pea	48.0	
Onion	100.0	
Kalai	82.0	
DICOTS		
Groundnut	64	
Castor	27	
Cabbage	74	

Table 4 contd:

Name of the plant	Boron content(ppm)	Authors
(DICOTS) :..		
Tomato	170	Harigopal and Rao, (1968)
Brinjal	62	
Bhendi	42	
Chilli	91	
Green-gram	57	
Clusterbean	41	
MONOCOTS		
Rice	7	Harigopal and Rao, (1968).
Sugarcane	18	
Maize	5	
Jowar	5	
Bajara	5	
Ragi	9	
Plantain	7	
Onion	20	

Table 5

Boron concentrations in tissues of different plants.

Micro nutrient	Plant species	Tissue concentration Deficient (ppm)	Normal (ppm)	References
BORON:	Wheat	6 - 9	52-84	
	Barley	3 - 14	27- 32 (126)	
	Paddy	8 - 22	38-72	
	Maize	6 - 20	34-63	
	Pearl millet	15	120	Gandhi and Mehta (1959)
	Guar	40	120	-"-
	Cauliflower	9 - 14	30- 35	
	Cabbage	13 - 16	31-40	
	Radish	9--21	42-45	
	Sugarbeet	15	45	
	Lettuce	10 - 22	30-44	
	Carrot	10	38	
	Onion	24	130 (190)	Gandhi and Mehta,(1959).
	Bean	15	18	
	Gram	16	34	Das and Motiramni(1949)
	Tobacco	39	66	Ramamoorthy and Desai (1946)
	Potato	30	..	Mandal *et al.* (1956)
	Cauliflower	22 - 31	..	Jha (1969)

soil treatment at 5 lb/acre. Foliar application of the element was found to be better utilized by the plants than soil applications. The maturity of cane was enhanced, juice quality is improved significantly and the sugar percent in juice increased by 2.5 units. There was better synthesis of sugar in leaves and increased growth.

Recently Zende (1970) reviewed micronutrient work done on sugarcane in different parts of the Country and responses obtained by it to various trace elements.

Rege and Divekar (1954) reported that combined effect of boron spray with soil application has shown considerable advantage in the sugar formation and recovery. Application of 50 and 100 ppm of boron in treatment showed increase in brix and sucrose.

Kodre (1955) observed that 200 ppm of spray has shown better results on light type of soil. No beneficial response on medium black soil was obtained. With increasing concentrations of boron spray, the quality of cane improved on medium black soil.

Leley and Desai (1954) found in sugarcane that application of phosphorus increases the availability of boron and boron was more concentrated in leaves than stem.

Mohan Rao et al.(1956) showed that tillering and juice quality improved as a result of boron sprays on sugarcane at Ankapalle (Andhra Pradesh).

Datta and Gurubasana (1958), observed an increase in yield of berseem from 89 - 976 md/acre and significant increase in number of nodules with application of 5 lb/acre of boron as Borax. Datta and Raj (1952,1955) found that berseem responded significantly to 5 lb borax/acre at Delhi. The number as well as weight of nodules increased with its application.

Norland and Starostka (1960) noted in their field trial with Alfa alfa grown on fine calcareous and find acid soils that, an increase in boron content and in some cases yield resulted when boron was applied to acid soils. Boron deficiency symptoms were pronounced when boron was not applied.

Brown and King (1939) found that application of 20 lb borax/acre reduced 'yellows' from 25 percent to 3 percent, increased plant height 15 percent, yields 16 percent and the boron content of alfa alfa leaves from 22 ppm to 62 ppm.

Rajkovic (1962) showed that fertilization of boron to single cross maize, boron as comparedd to control, increased absolute kernel weight, kernels/ear in mother plant (6.3 - 16.8 percent increase), Kernel weight/mother plant (12.9 to 23.9 percent increase. Sprinkling at the beginning of flowering was more effective than later treatment.

Boron increased the yield of hybrid maize by 30.2 percent (Ahuja and Gautam, 1961).

Wear, Scarsbrook and Langford (1968) grew cotton on boron deficient sandy soil to determine the effect of N rates on response to boron. Treatment included N rates of 60, 120 and 240 lb/acre each with and without boron added as side-dressing. Average increase for the added boron at the 3 N rates were 97, 168 and 219 lb of seed cotton respectively.

Miley *et al.*(1963) got increased yields of seed cotton on a loase loam from 420 to 1449 lb/acre by eight foliar sprays of 0.1 lb boron pre-emergence spray.

Bhake (1961) found in his field trial that micronutrients did not have any significant effect on cotton. The uptake of micronutrients by plants at various stages was almost the same in treated and untreated plots.

An increase in yield of seed cotton was obtained by Dastur and Kanwar Singh (1953) at Indore when boron was applied at 17 lb per acre.

Lancaster *et al.* (1962) in their field trials on cotton grown in 6 sites of Mississippi, observed that yield of seed cotton increased from an average of 1355 lb/acre with no boron to an average of approx. 1755/acre when boron was applied at 0.5 to 1.5 lb/acre by various methods.

Wasnik (1963) under pot culture and field experiment on cotton (A.K.277 V.) observed that application of molybdenum & boron in all combinations does not bring significant change in vegetative growth, number of leaves, buds, bolls, yield and fibre length. Increasing levels of molybdenum with constant boron levels, has adverse effect on dry matter content over normal molybdenum. Number of flowers per plot showed significant increase with different doses of molybdenum and constant doses of boron. More accumulation of boron and less of molybdenum was found at pross flowering stage.

Mehrotra, Saxena and Dube (1968) reported that 0.5 ppm boron in the nutrient medium gave best overall growth of *Abelmoschus esculentus*, the range suitable for normal growth being 0.125 - 1.5 ppm, 0.031 or below was in the deficient range and 2.0 ppm or above was toxic.

Boron deficiency in cauliflower and its effective cure by application of boron have been reported from Delhi by Dutt (1963).

Govindan (1950) found that with increasing doses of boron upto 3 ppm, the ascorbic acid content of tomatoes increased. The vitamin content is increased in the matured fruit.

Petijevic (1963) observed in 4 year trial of onions grown on a podzoli red soil (NPK and CaO were applied separately and together; with or without boron at 1.5 to 3 kg/ha) that, treatments with boron especially at a medium rate, increased yield upto 13 percent and improved quality ~~contents~~ by increasing the oil, protein and sugar contents of the bulbs and reducing their cellulose content.

Hua Hsiao (1961) reported that spray or a liquid culture with 0.1 percent H_3Bo_3 enhances tube formation, flowering, pollen viability and seed fertility in potatoes. Significant increases in soluble sugar (50.44 Vs. 34.37 mg) and starch (24.83 Vs 17.04) per gm of dry material are also observed in the boron treated leaves. Boron treatments are most effective before the formation of micro-spores.

Emilsson (1963) noted that boron deficiency reduces cooking quality and affect the skin of the tuber so that it is more susceptible to Scab. 10-20 kg/ha borax can be applied to clayey soils and clays, but not above 10 kg to sandy soils. Boron should be applied in boron containing fertilizers like N, P or K.

Shri-vastava (1965) found in his laboratory study on the variety of Basarai Banana that boron is required for the healthy growth and can be supplied in the form of foliar sprays.

Pandya _et al._ (1955) and Joshi (1956,b) in their field trial on bajara at college farm, Poona found no significant effect of any of the trace elements on bajara yields.

Kulkarni *et al.*(1970) under field trial on bajara, observed response to boron in Tharsa Research Centre,Nagpur.

Kulkarni *et al.*(1970) found response to boron by kharif jowar in their field trial at Akola.

Joshi (1955) reported the adverse effect of boron on jowar crop in field experiment. Boron when applied alone, the effect is more marked.

Joshi (1955) in pot culture experiment found 18 percent increase in the yield of wheat by application of boric acid and 78 percent increase when boric acid is applied with organic manures.

Shustove (1962) in water culture noted response to boron by Buckwheat.

Joshi(1956) got increased yields of wheat under field trial by boron application in Bombay. Mathur *et al.*(1959) also reported similar results.

Pawar (1961) under field trial on brinjal observed that boron when applied as foliar spray proved to be better than soil application which produce depressing yield.

Recently,Shrivastava (1970) noted a very good response to boron by Pineapple plants when applied through foliar spray. Boron helps in early flowering of the plants, early maturity of fruits. Sugar content of the fruits was improved significantly. The good effect of boron on the root system of the plant has been observed. The optimum dose of boron of 1 ppm was found effective in affecting all the characters.

Mandal (1956) obtained responses to boron on potato, maize, barley and gram.

Boron application to soil at various places have been reported to have no response or even to lower the yield of crops indicating presence of high amounts of boron in the soil. This was observed with paddy (Datta and Bains, 1961) at New Delhi, with Bajra at Poona (Pandya _et al._ 1955) and with Wheat at Monghyr (Mandal _et al._ 1956) and in Rajasthan (Mathur _et al._ 1959).

Eventhough boron applications recorded responses to field crops, great care is needed in its use as fertilizer since the limits of sufficiency and toxicity are very narrow. The soils in general appear to be well supplied with boron as found by chemical analysis but it is the available fraction that becomes important to crops than the absolute quantities present.

XII- Boron in manures and fertilizers:

One important aspect of the boron problem which has received a considerable attention in recent year is the relationship between the use of concentrated and purified fertilizers and the wide-spread appearance of boron deficiencies in soils.

It must be remembered, however, that the minor element content of the 'Natural' fertilizers is small and variable. Cutts (1937-38), found that the amount of boron in Chilean potassium nitrate was 0.08 percent.

It should perhaps be pointed out that the presence of minor elements in a fertilizer is not an unmixed blessing. Great interest was attached to published analysis for the boron content of modern commercial fertilizers. Studies of 27 representative 'complete' fertilizers in the U.S.A. showed their boron content to lie between 0.004 and 0.043 percent.

Rader (1940) and Hill (1940), found the boron content of a number of natural phosphates and phosphatic manures to range from less than 10 to 144 ppm and as might be expected, the boron content of apatite was on the whole high. According to Steenbjerg, normal application of commercial fertilizers supply the soil with only 100-150 gm of boron per hectare per annum.

Brown (1940) states that there is on the market in Canada a fertilizer advertised to contain particularly every known element from helium to Uranium. Brown tried this fertilizer on sugarbeet; on a soil where boron applications gave increased yields and found it to be inferior to a normal N.P.K. fertilizers.

Kainit (1940) found that with 35 gm boron/100 kg was quite inadequate and a 40 percent potash salt with 1 gm boron/100 kg was still more so. Superphosphate with 1 gm boron/100 kg gave no control and basic slag with 4 gm/100 kg was little better.

Dung with boron content of 5-6 gm/ton almost corrected the trouble; while there were indications that the boron content of Urine was more effective than in solid excrements. The ash of sea weeds gave nearly normal plant, but wood ash was rather less helpful. Odelin (1940), concluded that the boron content of synthetic nitrates of modern potash and phosphate fertilizers is of no practical importance in agriculture. Of the fertielizers used in Norway, only Farm Yard Manure is of value in this respect, though the boron content of chilean nitrate is also effective.

Steenbjerg found an average of 70 gm boron in 20 tons of Danish F.Y.M. and 90 gm boron content per 20 tons of liquid manure. Pure cow's urine had a boron content of the latter order. Salter and Schollenberger (1939-40) found F.Y.M. to contain approx. 0.005 percent boron and pointed out that since soil deficiencies of minor elements are reflected in the composition of crops, it is to be expected that the manure produced by animals fed on such crops will show similar deficiencies and will, therefore, be ineffective in correcting them.

In this connection, it is of interest to recall that so far there is no indication that boron is of value for animals and probably the bulk of the boron taken by them in vegetable matter is rapidly excreted. It has been suggested that in relation to the plant and animal Kingdom, boron and iodine form a pair of elements occupying a position similar to that of potassium and sodium.

Harigopal and Rao (1968), studied the boron content of fertilizers of a locality of Tirupati and reported the figures of analysis which have been reproduced in Table 6. From the table, it can be seen that the ammonium sulphate, superphosphate and amm. phosphatic fertilizers are quite high in their boron contents and which when applied to the soil can either increase the boron content or correct the boron deficiencies in the Soils.

Boron as a fertilizer:

Agricultural Borates and their application:

Several borate products (1967) which are listed below can be used as source of boron for plants both to prevent and cure boron deficiency. Of these products, the fertilizer borates and Solubor were developed with particular reference to agriculture. Sufficient boron materials are available to permit a choice to be made, not only on the basis of cost but also on the basis of the suitability of the material for the preferred methods of application or the compounding process.

Table 6

Boron content of manures and fertilizers.

S.No.	Manure	Boron content (ppm)	Authors
	Organic Manures:		
1	Animal tankage	45	Reeve et al. (1948)
2	Lucern hay	41	
3	Cocoa-tankage	37	
4	Moulded scrap plastic	29	
5	Chicken manure	20	
6	Cotton seed meal	10	
7	Wheat straw	7	
	Animal Manures:		
8	Eastern F.Y.M.	160	Mehring (1955)
9	Cattle	50	
10	Horse	50	
11	Sheep	50	
12	Swine	15	
13	Chicken	49	
	Miscellaneous:		
14	Sewage slug	1.0	
15	Night soil	7.0	
16	Peat	21.	
17	Sea-weeds	58	
	Fertilizers:		
18	Ammonium sulphate	11.6	Harigopal and Rao,(1968).
19	Superphosphate	2.7	
20	Urea	0.3	
21	Calcium amm.nitrate	1.9	
22	Ammonium phosphate	4.8	

Table 7

Boron contents of different borate products

	Material	Mesh	percent B_2O_3	percent Boron
1)	Fertilizer Borate 46 high grade	Mixed, fine or coarse.	46	14.3
2)	Fertilizer Borate-65 concentrated.	Coarse	65	20.2
3)	Fertilizer Borate-65 Granulated.	Granular	65	20.2
4)	Borax	Fine granular or powder	36.5	11.3
5)	Boric acid	Fine granular or powder	56.3	17.5
6)	Solubor	Fine powder	66.2	20.5

Fertilizer borate 46 is a crude Pentahydrate sodium tetra-borate (ore concentrate).

Fertilizer Borate 65 is a fused ore concentrate and is essentially a crude anhydrous sodium tetra borate. Borax is sodium tetra-borate, decohydrate, $Na_2B_4O_7$ 10 H_2O.

Solubor is a special spray dried and complex sodium borate product having an approx. composition. Na_2 B_8O 13.4 H_2O.

Methods of application:

As only small quantities of borates are normally required for the correction of boron deficiency, it is usually difficult to ensure uniform distribution when the borate is applied by itself. Unequal distribution may cause heavy local application which results in limited toxicity in a part of the field while leaving other part deficient.

There are two ways of facilitating an equal distribution. Firstly, the borate can be mixed or incorporated with other solid materials, applying the mix in a dry state. Secondly, ~~applying~~ the borate can be dissolved in water and either applied as a spray to the foliage (or to the soil) or incorporated in a liquid fertilizer for soil application.

(a) <u>Mixing and incorporation</u>:

Sand or other inert free flowing materials have also been used for mixing with borates in order to provide a suitable bulk for spreading, but this procedure is going out of practice and is not favoured on economic grounds. If the borate is to be applied by itself and particularly when inert material is not available for mixing, borax or possibly fertilizer borate 46 should be used; they have relatively low boron contents and so facilitate application by providing the maximum bulk.

(b) <u>Application of boron with other fertilizers</u>:

It is a more normal practice to mix or incorporate the chosen borate with other fertilizer materials and it is becoming a common practice for fertilizer manufacturers to produce boronated N.P.K. fertilizers; some of these are compounded materials in which the borate is incorporated in the granule itself.

The fertilizer borates or borax should either be mixed with superphosphate or the potassium salt before incorporating the ammonium salts, or they should be mixed with complete fertilizer. This procedure is advocated in order to minimise any chance of chemical reaction between a straight ammonium salt and alkaline borates which could result in a slight release of ammonia.

Boric acid is suitable for combination with straight ammonium fertilizers where as indicated, fertilizer borates or borax should not be used, mixtures of borax and boric acid can be used provided the pH is suitably controlled thereby.

(c) <u>Spray application:</u>

Solubor is designed primarily for spray application (normally 0.2 - 2.5% w/v concentration) but it can also be applied as dust. It is particularly useful where boron is to be applied separately from other fertilizer. It is readily soluble in water, is compatible with most insecticides and fungicides and makes an efficient boron additive for most liquid fertilizers.

Borax can be used for spray application but the slow rate of solution may cause difficulties.

Dose of Boron

The most common fertilizer (Agarwal, 1965) material used for supplying boron to the soil is Borax in our country. The common dose is 5 to 10 lb borax/acre of soil. This much amount of Borax supplies about ½ to 1 lb of elemental boron or 1 to 2 lb of boric acid/acre. Occassionally, potassium borate, boric acid and finally ground boro-silicates are used alone or mixed with other fertilizers.

Since boron is not retained in the soil, as an exchangeable ion, more frequent applications are necessary to produce satisfactory results. As large quantities of boron become toxic to plant, careful selection of dose for individual crop is necessary to safeguard against this toxicity hazards.

Little is said about the time of application, as this will vary from country to country. The agricultural borates should be considered in the same way as the soluble easily leached fertilizers, the best time to apply boron will depend upon the local rainfall pattern and the incorporation and retention of boron in the rooting Zone.

Fate of Boron applied to soils:

When boron is applied to a soil as a fertilizer, it may undergo the following change:-

1) It may be absorbed by the plants (Krugel *et al.* 1938)

2) It may become 'fixed' in the soils as a result of chemical reactions which are not yet fully understood. According to Lohins (1939), even tourmaline can act as a source of boron for plants.

3) It may be utilized by micro-organisms.

4) It may be leached out. About 75 percent of the added boron may be removed in this way. It must be remembered, however, that conditions in the field may be very different from those in the laboratory and it seems highly desirable to obtain series of Lysimeter observations on this subject under field conditions with growing crops.

The rates of application of boron to different crops have been given in Table 8 below.

Table 8

Rates of Boron application to different crops

(All rates lb/acre or kg/hectare) (Annos.(1967) Boron deficiency-its prevention and cure).

Crop	Boron	Borax	Boric acid.	Fertili-zer Borate 46	Fertilizer Borate-65	Solubor	Remarks
1	2	3	4	5	6	7	8
Cotton	Drill 1/5-1/2 broad cart ½ -1	2 - 4 4 - 9	1 - 3	1 - 3	1 - 2	2 - 3	Spray Solubor 4-6 times at 0.5 lb SOLUBOR/acre each time (upto 0.5 percent w/v).
Groundnut	1/2 - 1/2	3 - 4	2 - 3	2 - 3	1 - 2	1 - 2	Apply at planting.
Maize	1/2 - 1	4 - 9	3 - 6	3 - 7	2 - 5	2 - 5)	) Preferably apply in fertilizer at planting.
Tobacco	1/2 - 1	3 - 9	2 - 6	2 - 7	1 - 5	1 - 5)	
Apple	1/2 - 2	4 - 18	3 - 11	3 - 14	2 - 10	2 - 10	One soil application sufficient for 3 years. SOLUBOR spray 2-3 lb. in 100 gallons sapply in early spring.
Banana	2 - 4 lb/acre	18-- 35 lb/acre	11-23 lb/acre	14-28 lb/acre	10-20 lb/acre	10/20 lb/acre	For experimental use only.
Citrus (orange, grape-furit)	½ - 1	3 - 9	2 - 6	2 - 7	1- 5	1 - 5	
Lemon-lime	½ - ½	3 - 4	2 - 3	2 - 3	1 - 2	1 - 2	Spray with SOLUBOR 2-3 lb/100 gallon before blooming, effective for 4 years(soil application)

Table 8
contd.

1	2	3	4	5	6	7	8
Grape	2½ - 7 lb/acre	22 - 60 lb/acre	14 - 40 lb/acre	17 - 50 lb/acre	12 - 35 lb/acre	12 - 35 lb/acre	
Pineapple	1 - 3	9 - 26	6 - 17	7 - 21	5 - 15	5 - 15	
Cabbage	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	For all vegetables, it is preferable to apply the boren mixed with the regular fertilizer or in a boronated fertilizers. Otherwise, apply SOLUBOR (0.25 - 0.5 percent w/v) if symptoms appear.
Cauliflower	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	
Watermelon	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	
Carrot	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	
Eggplant	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	
Onion	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	
Radish	1 - 2	9 - 18	6 - 11	7 - 14	5 - 10	5 - 10	
Potato	½ - 1	4 - 9	3 - 6	3 - 7	2 - 5	2 - 5	
Sweet potato	½ - 1	4 - 9	3 - 6	3 - 7	2 - 5	2 - 5	
Tomato	1 - 1½	9 - 13	6 - 9	7 - 10	5 - 7	5 - 7	

III MATERIAL AND METHODS :

Chapter III

MATERIAL AND METHODS

Procedure followed in collection of soil samples:

The soil samples from the different agro-climatic zones into which the Maharashtra State has been broadly divided (Sahasrabuddhe,1967) were collected mostly from Government farms located in these Zones and in some cases from the cultivators' field in the vicinity of such farms. A representative field was selected and arbitrarily divided into four quadrants, from each of which the sample was drawn to a depth of 9". The four individual samples were pooled and a bulk composite sample was drawn by the method of quartering. The bulk sample was pounded in a wooden mortar with wooden pastle and passed through appropriate sieves as per requirements. The samples were collected from the following places located under different Zones.

I-B : Zone of very high rainfall with Non-Lateritic Soils :

(Zone No.1) : Places.

1 Igatpuri 2 Khopoli 3 Panvel 4 Dahanu

5 Palghar 6 Shriwardhan.

I-A : Zone of very high rainfall with Lateritic Soils :

(Zone No.2) :

7 Ratnagiri 8 Radhanagari 9 Dapoli 10 Ajara

II : Transition Zone :

(Zone No.3) :

11 Medha 12 Paud 13 Vadgaon

III : Scarcity Tract:

(zone No.4) :

14 Poona 15 Dhond 16 Dhulia 17 Jeur

18 Chas 19 Indapur.

IV-B :Zone of assured rainfall with kharif and rabi cropping:

(Zone No.5) :

20 Chopda 21 Bhir 22 Sholapur 23 Jalgaon

24 Badnapur

IV-A :Zone of assured rainfall with kharif cropping:

(Zone No.6):

25 Washim 26 Parbhani 27 Akola

28 Hingoli 29 Latur.

V-B: Zone of moderately high rainfall with trap soils:

(Zone No.7):

30 Nagpur 31 Yeotmal 32 Nanded 33 Wardha.

V-A : Zone of moderately high rainfall with soils from mixed rocks:

(Zone No.8):

34 Chanda 35 Bhandara

VI : Zone of high rainfall with soils from mixed rocks:

36 Gondia 37 Gadchiroli 38 Amgaon

39 Sindewahi 40 Vihad.

Table 9

The general description of soils collected from different agro-climatic Zones of Maharashtra State (Tanwade, M.Sc. Thesis, May, 1969)

Location	Taluka	District	Mean annual rainfall of the place from where the sample was collected (in mm) *	Parent material
1	2	3	4	5
I B: Zone of heavy rainfall with non-lateritic soils:				
Igatpuri	Igatpuri	Nasik	3341.60	Basalt
Khopoli	Karjat	Kolaba	3278.50	Basalt
Panwel	Panwel	Kolaba	2741.20	Basalt
Dahanu	Dahanu	Thana	1759.00	Basalt
Palghar	Palghar	Thana	2534.60	Basalt
Shriwardhan	Shriwardhan	Kolaba	2527.30	Basalt
		Average:	2697.03	
I A : Zone of heavy rainfall with lateritic soils:				
Ratnagiri	Ratnagiri	Ratnagiri	2667.00	Laterite
Radhanagari	Radhanagari	Kolhapur	3817.60	Laterite
Dapoli	Dapoli	Ratnagiri	3365.50	Laterite
Ajara	Ajara	Kolhapur	2676.40	Laterite
		Average:	3131.62	
II : Tr[illegible]sition Zone:				
Medha	Javali	Satara	1723.40	Basalt
Paud	Paud	Poona	1519.20	Basalt
Vad[illegible]on	Maval	Poona	1147.00	Basalt
		Average:	1463.20	

contd.

Table 9 contd:

1	2	3	4	5
III: Arid to semi-arid zone:				
Poona	Haveli	Poona	675.00	Basalt
Dhond	Dhond	Poona	460.75	Basalt
Dhulia	Dhulia	Dhulia	609.60	Basalt
Jeur	Karmala	Sholapur	609.60	Basalt
Chas	Ahmed-nagar	Ahmednagar	521.50	Basalt
Indapur	Indapur	Poona	503.00	Basalt
		Average:	579.64	
IV B: Zone of assured rainfall with kharif-cum-rabi cropping:				
Chopada	Chopada	Jalgaon	736.60	Basalt
Bhir	Bhir	Bhir	685.80	Basalt
Sholapur	Sholapur	Sholapur	685.80	Basalt
Jalgaon	Jalgaon	Jalgaon	775.00	Basalt
Badnapur	Jalna	Aurangabad	785.80	Basalt
		Average:	713.80	
IV A: Zone of assured rainfall with kharif cropping:				
Washim	Washim	Akola	914.00	Basalt
Parbhani	Parbhani	Parbhani	863.70	Basalt
Akola	Akola	Akola	812.80	Basalt
Hingoli	Hingoli	Parbhani	812.80	Basalt
Latur	Latur	Osmanabad	809.90	Basalt
		Average:	842.92	

..contd.

Table 9 contd:

1	2	3	4	5
V B: Zone of moderately high rainfall with soils derived from Deccan Trap:				
Nagpur	Nagpur	Nagpur	1242.00	Basalt
Yeotmal	Yeotmal	Yeotmal	1092.20	Basalt
Nanded	Nanded	Nanded	939.80	Basalt
Wardha	Wardha	Wardha	1081.00	Basalt
		Average:	1086.75	
V A: Zone of moderately high rainfall and soil derived from mixed parent material:				
Chanda	Chanda	Chanda	1324.00	Granite and Gneisses.
Bhandara	Bhandara	Bhandara	1422.40	Granite and Gneisses.
		Average:	1373.20	
VI : Zone of high rainfall:				
Gondia	Gondia	Bhandara	1597.00	Granite and Gneisses.
Gadchiroli	Gadchiroli	Chanda	1534.16	Granite and Gneisses.
Amgaon	Gondia	Bhandara	1388.20	Granite and Gneisses.
Shinde-wahi	Bramhapuri	Chanda	1549.40	Granite and Gneisses.
Vihad	Gadchiroli	Chanda	1270.00	Granite and Gneisses.

(*) Anon (1958) : Maharashtra Krishi Jeevan Sankhikiya Darshan, Gokhale Institute, Poona.

Procedure followed in collection of water samples :

The well water samples from Poona and adjoining areas were collected in the beginning. While collecting the sample, the bottle was rinsed thoroughly at least three times with the water to be collected and nearly one litre of was taken in a clean, colourless glass bottle, stoppered tightly and brought to the laboratory for analytical purposes. When water was collected from a pipe or tap, the water was allowed to run waste for a couple of minutes before the sample was drawn. The water samples were first filtered and then used for further analysis.

An opportunity was also taken to analyse well waters collected from bore wells from different districts of Maharashtra, by the Chief Ground Water Survey Officer, Department of Agriculture and sent to the laboratory of the Agricultural Chemist for analytical purposes.

Methods of Analysis :

The methods used for soil and water analysis are the ones described by Wright (1934), A.O.A.C.(1950), Hatcher and Wilcox (1950), Piper (1950), Jackson (1958) and Chapman and Pratt (1961) with required modifications wherever found to be necessary. The results are expressed on oven dry basis.

: SOILS :

Moisture:

This was determined by dehydrating the soil at 100-105°C in an electric oven (A.O.A.C.1951).

Loss on ignition:

The soil was ignited in a muffle furnace until the organic matter was fully dehydrated. It was then cooled, moistened with a drop of ammonium carbonate to correct for the carbonates and weighed after oven drying.

Moisture equivalent:

The method followed consisted of centrifuging the soil at 2000 r.p.m. for 30 minutes using Briggs and MaClean (1910) moisture equivalent centrifuge fitted with a special drum head. The details were the same as described by Piper (1950).

Calcium Carbonate:

This was determined by using Collins' Calcimeter using a 70 mesh soil sample (Wright,1934).

Organic Carbon:

Organic carbon was determined by the modified method of Walkley and Black (1947) as described by Piper (1950).

Mechanical analysis:

This was carried out by using soda dispersion and pipette technique (Piper,1950).

Exchangeable Calcium :

This was estimated by the method described by Chang and Bray (1950), using 23 percent $NaNo_3$ as the extracting solution.

Five gm of the soil sample was shaken with 10 ml of the extracting solution for one minute and filtered.

The filtrate was diluted to about 50 ml by distilled water and 2 ml of 10 percent NaOH (pH of 12) was added. Then about 0.3 gm of mureoxide indicator was added and then titrated with 0.02 N of versanate solution (EDTA). The colour change is from red to orange red, violet or violet red.

Soil pH :

pH was measured in 1:2.5 soil water suspension by means of a glass electrode (Piper,1950).

: Water soluble boron in soil :

For all boron determinations, the boron free glass was used. The chemicals and acids used were also of high purity (ANALAR Grade).

The water soluble boron in soil was determined colorimetrically by the Carmine method as described by Hatcher and Wilcox (1950).

Procedure:

Twenty gm of air dried and sieved soil sample was placed in a 250 ml conical flask, 40 ml of distilled water were added and a reflux condenser was attached. The suspension was boiled for 5 minutes and allowed to cool and then the condenser was disconnected. The suspension was filtered through a funnel using Whatman 42 filter paper and the filtrate was made to a suitable volume of 50 ml with washings of distilled water.

A blank was determined by taking 40 ml of water in the extraction flask in a similar manner as described under soil extraction. This solution was carried through all steps in subsequent stages.

For the determination of boron by Carmine method, a 20 ml aliquot of the clear supernatent solution was transferred by means of a pipette to a platinum evaporating dish and 5 drops of 40 percent K_2Co_3 solution were added and the entire solution was evaporated to dryness on a water bath.

The residue was ignited gently to destroy nitrates and all organic matter on a burner for about 1½ to 2 hours. It was then cooled and 5 ml of approx. 0.36 N sulphuric acid (10 ml of concentrated sulphuric acid in one litre of distilled water) were added and triturated thoroughly with a rubber policeman to dissolve all the soluble matter. The solution was filtered through a filter paper (Whatman No.1) on a micro funnel. 2 ml aliquot of the clear filtrate was taken for further determination.

Two ml aliquot from above filtrate was taken in a 100 ml conical flask, 2 drops of concentrated hydrochloric acid and 10 ml of concentrated sulphuric acid were added, mixed and then cooled. 10 ml of carmine solution (0.92 gm of Carmine powder dissolved in one litre of concentrated sulphuric acid were added, mixed and allowed to stand for an hour for colour development. Then the readings were taken on a Klett Summersion Colorimeter using 600 (red) filter against a reference solution of 2 ml of distilled water carried through the entire procedure.

Acid soluble boron in soil

Preparation of hydrochloric acid extract (Piper,1958):

Ten gm of the soil passed through a 2 mm sieve was digested for an hour with 100 ml concentrated hydrochloric acid of constant boiling point; using a reflux condenser. The soil was allowed to settle overnight and the supernatent liquid was decanted. The next day, the residue was lixivated a number of times with small quantities of boiling water and the washings were filtered through a Whatman (No.42) filter paper. The washings were made upto 250 c.c. and analiquot of this stock solution was used for the determination of the acid soluble boron, by the method suggested by Naftel (1939), Haas (1944).

Procedure:

The method was originally suggested by Naftel (1939) and was subsequently used by Haas (1944), for the examination of the available boron status of the Californian Citrus soils.

After a number of trials, the following procedure was found to give satisfactory results. An aliquit of the hydrochloric acid extract (50 ml) was evaporated to dryness in a silica basin on a water-bath. It was then taken up with a small quantity of water and treated with a solution of Na_2Co_3 (25 percent) in order to make it distinctly alkaline. It was then dried and baked at 120 ^{o}C on a sand bath for half an hour. The baked material was then extracted with hot water till free of alkalinity. The filtrate and washings were evaporated to a small volume and then dried completely. 20 ml of the (1:10) sulphuric acid were added and the residue was triturated thoroughly to dissolve the soluble matter. Then the solution was filtered through ordinary filter on a small funnel and a clear filtrate was obtained in a glass test tube. 2 ml of aliquot of the clear filtrate was taken in a 100 ml conical flask and proceeded for the Carmine method as described previously under 'water soluble boron'.

WELL WATER

Representative samples of underground waters collected from different agro-climatic regions were analysed for the anions namely - Carbonates (CO_3^{--}), bicarbonates (HCO_3^{-}), Chlorides (Cl^-) by usual volumetric methods (Piper, 1950). Calcium and magnesium were determined by versanate (E.D.T.A.) titration and sodium (Na^+) and Potassium (K^+) were determined by the flamephotometer, Chapman & Pratt (1961). The contents of cations were expressed in milli-equivalent /litre.

pH:

pH was measured by means of a glass electrode on Beckman's pH meter (Piper, 1950).

T.S.S.

The T.S.S. of the original water sample was measured by solubridge (Jackson, 1958).

Determination of boron in well water

No pre-treatment is required for estimation of boron from well water samples. Directly 2 ml of the filtered sample was taken in an erlenmeyer flask, two drops of concentrated hydrochloric acid and 10 ml of concentrated sulphuric acid were added and mixed thoroughly without any bubble formation in the flask and then it was cooled. 10 ml of Carmine solution (prepared by dissolving 0.32 gm of Carmine powder in 1 litre of concentrated sulphuric acid) were added and mixed well and the solution was allowed to stand for an hour for the colour development. Then the readings were taken on Colorimeter (Klet-Summerson) using 600 (red) filter against a reference solution of 2 ml of distilled water carried through the entire procedure.

Field Studies

The field trial on hybrid bajara was conducted with a view to determine the boron requirements of the crop receiving varying doses of N,P and K. along with micro-nutrient applications such as - Mn, Zn, Cu, B and Mo. The details of the trial are given below:-

1)	Total area of the plot	.. 11.01 m x 10.07 m
2)	Area of the sub-block	.. 0.45 m x 0.30 m
3)	Block	.. 1.48 m x 0.30 m
4)	Net plot size	.. 0.12 m x 0.075 m
5)	Gross plot size	.. 0.15 m x 0.15 m
6)	Place	.. West side of Soil Laboratory of Chemistry Section, Agril.College, Poona 5.
7)	Design	.. Randomised split plot design.
8)	No.of main treatments	.. 3 (A, B, C)
9)	No.of sub-treatments	.. 6 (a,b,c,d,e,f)
10)	No.of replications	.. Three
11)	Total number of sub.plots	.. 3 x 6 x 3 = 54
12)	Main plot treatments	.. 3, namely doses of N,P,K.

Treatment A: -- N_1 P_1 K_1 - 30, 15, 15 kg/acre

Treatment B: -- N_2 P_2 K_2 - 60, 30, 30 kg/acre

Treatment C: -- N_3 P_3 K_3 - 90, 45, 45 kg/acre

13) Sub plot treatments- 6, namely: soil application of trace-elements:

a) Mn-25 ppm, b) Zn-10 ppm
c) Cu-10 ppm d) Boron-2.5 ppm
e) Mo-0.5 ppm f) Control

14.	Date of sowing	11th July,1969
15.	Method of sowing	Dibbling
16.	Distance between rows	15"
17.	Distance between plants	6"
18.	No.of seeds per hill	Eight
19.	No.of seedlings per hill	Four
20.	Date of application of major nutrients.	18th July,1969
21.	Date of application of micro nutrients.	19th July,1969
22.	Date of harvest	7th October,1969.

Sowing was done on 11th July,1969, complete germination took place within a week period. In the third week after sowing, the thinning was done keeping four seedlings per hill. Whenever necessary frequent weedings were given and the plot was kept always clean. At different stages of the crop i.e. tillering, flowering and harvesting, the plant samples were taken for uptake studies.

Sampling at tillering stage

The samples were taken at tillering stage to determine boron uptake by the plants. The sampling was done on 18th August 1969. From each sub-plot, four plants were taken, they were washed free of adhering soil, wiped, dried by means of filter paper and then dried in the oven, the dry matter was weighed and recorded.

Table 10A

Details of treatments

Treatments	Main plot treatments *			Sub plot treatments *					Control
	Nitrogen	Phosphorus	Potash	$MnSo_4$	$ZnSo_4$	$CuSo_4$	Borax	Sodium Molybdate	
A	30	15	15	91.97	9.06	35.60	2.26	0.45	-
B	60	30	30	91.97	9.06	35.60	2.26	0.45	-
C	90	45	45	91.97	9.06	35.60	2.26	0.45	-

*Quantities in kg/acre.

Table 10B

Quantities of fertilizers applied to mainplot and sub-plot treatments.

Treatments	Main plot treatments **			Sub plot treatments **					Control.
	Ammonium sulphate.	Super phosphate	Potassium sulphate.	$MnSo_4$	$ZnSo_4$	$Cuso_4$	Borax	Sodium molybdate	
A	492	323	103.5	52.7	22.9	20.43	7.4	0.56	-
B	984	646	207.0	52.7	22.9	20.43	7.4	0.56	--
C	1476	969	310.5	52.7	22.9	20.43	7.4	0.56	--

**Quantities in gm/plot.

Sampling at flowering stage

The sampling was done on 12th September,1969. From each sub-plot, one plant along with earhead was taken, it was cut close to the ground, immediately the fresh weight was taken, then it was dried in shade and then in oven and dry matter was recorded and it was kept in paper bags with proper labelling and pinning. After grinding, the samples were used for further analysis.

Sampling at harvesting stage

The harvesting was done on 7th October,1969. From each sub-plot, the four plants along with the earheads were taken and immediately their fresh weight was recorded. Then the ears were separated from the stalks and length of stem, diameter, and length of earhead and diameter were recorded for individual plants and earheads. Then stems and earheads were dried first under shade, packed in paper bags and again they were dried in oven at low temperature and the grain yield and straw (dry matter production) were recorded after accurate weighing. After grinding, the samples were used for further analysis. Total boron contents of plants at three different stages were estimated by the method described by Hatcher and Wilcox (1950). At harvesting stage total boron from straw and grains was estimated separately.

Plant Analysis

Total boron in plant

Preparation of the sample:

All the foreign matter from the green plant material was removed avoiding excessive washings and the plant material was dried at 70 °C, ground, dried again to constant weight, stored in a paper bags with proper labelling. The finely ground homogenous plant sample was used for further analysis and the results were expressed on oven dry basis.

Procedure for boron determination:

Five gm of the dry sample was taken and mixed with 0.5 gm of calcium oxide thoroughly on a paper. Then the material was transferred in a platinum dish and ignited as completely as possible on a burner at 500 to 550 °C for about 2-3 hours. It was cooled, moistened with distilled water and covered with a watch-glass, 15 ml of 6 N hydrochloric acid were introduced in a dish which made the solution strongly acidic, then it was heated on a waterbath for half an hour, cooled, filtered through Whatman No.1 on a small funnel, washed the residue with hot distilled water till free of acid and the final volume was made to 100 ml, 2 ml of an aliquot of the above filtrate was pipetted accurately in a 100 ml conical flask and followed the procedure as given under soil and water determinations, but two drops of distilled water were added in place of concentrated hydrochloric acid, since these solutions were already strongly acidic.

IV RESULTS AND DISCUSSION

Chapter IV

RESULTS AND DISCUSSION

The present study was undertaken with a specific objective of determining the boron status of soils of different agro-climatic regions of the Maharashtra State and to assess the factors affecting its availability in soils. The boron contents of ground well waters collected from different districts of Maharashtra was also assessed and is discussed in the present report. For this purpose, 260 well water samples sent to the laboratory of the Agricultural Chemist by Chief Ground Water Survey Officer were used. The 40 soil samples from various agro-climatic zones, analysed previously by Tanwade (1969) and Khonde (1969) were utilized for determining their boron status. The results obtained by the above workers for physical and chemical properties for 40 soil samples are utilized in the present investigation. The results of these studies have been presented and discussed under appropriate headings.

Section I-A

Physico-chemical properties of soils used in the investigation:

Organic carbon contents of soils:

The results relating to the various mechanical constituents along with the organic carbon and free $CaCO_3$ contents of soils are given in table 11. A glance at the data indicates that the average organic carbon contents of soils of different agro-climatic zones vary from as low as 0.62 percent in zone V-B to as high as 1.48 percent in zone I-A. The soils from zones I-B, V-A and VI contain fairly higher proportion of organic carbon than the soils from zones II, III, IV-B, IV-A and V-B.

Free $CaCO_3$:

The soils of high rainfall and moderately high rainfall zones, (zones I-B, I:A, V-A and VI) are characterised by very little or no free $CaCO_3$ in them. Soils from zone III show the highest level of free $CaCO_3$ i.e. 4.77 percent while those from zones IV-A, IV-B and V-B are intermediate in this respect.

Clay percent:

The data reported in table 11 indicates that the average clay content in soils from different zones varies from as low as 32.05 percent in zone VI to as high as 48.7 percent in zone IV-A. The texture of the soils under study varies from sandy clay loam to clayey. The soils of arid to semi arid zones (zones IV-A, IV-B, V-A and V-B) developed on basalts are clayey in texture.

Soil pH:

It is seen that the soils from zones I-A, V-A and VI have an acidic reaction. In rest of the soils, the average pH values vary from 6.7 to 8.2. It is also observed that in respect of soils derived from basalt, they show a slight relationship between pH and the mean annual rainfall.

Table 11

Physico-chemical characteristics of soils of different agroclimatic zones of Maharashtra State (Tanawade, 1969)

Location	Soil pH	Organic carbon percent	Free $CaCO_3$ percent	Clay percent	Textural class.
1	2	3	4	5	6
Zone I-B					
Igatpuri	6.2	0.81	Nil	33.19	Sandy clay loam
Khopoli	6.9	0.94	Nil	38.39	Clay loam
Panvel	7.5	0.66	Nil	22.70	Sandy clay loam
Dahanu	7.3	0.75	0.15	35.78	Clay loam
Palghar	6.9	0.92	0.90	40.64	Clayey
Shriwardhan	5.7	0.95	Nil	36.00	Clayey
	6.7	0.84	0.170	33.62	
Zone I-A					
Ratnagiri	5.4	1.70	Nil	36.53	Clay loam
Radhanagari	6.2	1.41	Nil	37.75	Clay loam
Dapoli	5.1	1.80	Nil	36.60	Clay loam
Ajara	5.8	0.81	Nil	50.62	Clayey
	5.6	1.43	Nil	40.32	
Zone II					
Medha	6.6	0.63	0.10	38.39	Clay loam
Paud	7.0	0.68	0.21	38.23	Clay loam
Vadgaon	7.6	0.75	1.37	37.35	Clay loam
	7.0	0.68	0.56	37.92	
Zone III					
Poona	7.8	0.57	4.10	38.60	Clay loam
Dhond	7.8	0.70	4.80	45.85	Clayey
Dhulia	8.0	0.54	4.16	45.00	Clayey
Jeur	8.1	0.75	4.23	44.60	Clayey
Chas	8.2	0.58	6.19	46.26	Clayay
Indapur	8.2	0.63	5.24	38.54	Clayey
	8.0	0.65	4.77	43.14	

contd

Table 11 contd.

1	2	3	4	5	6
Zone IV-B					
Chopda	7.9	0.68	3.89	41.35	Clayey
Bhir	8.1	0.63	4.56	44.59	Clayey
Sholapur	8.1	0.54	3.68	44.75	Clayey
Jalgaon	8.0	0.63	3.46	42.60	Clayey
Badnapur	7.8	0.74	3.42	45.20	Clayey
	8.0	0.63	3.80	43.78	
Zone IV-A					
Washim	7.8	0.63	3.63	47.20	Clayey
Parbhani	7.7	0.66	4.48	46.80	Clayey
Akola	8.1	0.69	5.10	49.80	Clayey
Hingoli	7.8	0.71	5.60	51.20	Clayey
Latur	7.7	0.66	1.62	48.62	Clayey
	7.8	0.67	4.12	48.72	
Zone V-B					
Nagpur	7.6	0.66	1.58	48.40	Clayey
Yeotmal	7.7	0.59	1.26	45.74	Clayey
Nanded	7.9	0.69	2.80	49.50	Clayey
Wardha	7.8	0.54	3.10	42.02	Clayey
	7.7	0.62	2.18	46.41	
Zone V-A					
Chanda	5.8	0.81	Nil	32.85	Sandy clay loam.
Bhandara	5.4	0.84	Nil	33.51	Sandy clay loam.
	5.6	0.83	Nil	33.18	
Zone VI					
Gondia	5.7	0.85	Traces	31.60	Sandy clay loam.
Gadchiroli	5.5	0.81	Traces	35.15	Clay loam
Amgaon	5.3	0.92	Nil	38.58	Clay loam
Sindewahi	5.4	0.78	Nil	23.43	Sandy clay loam.
Vihad	7.4	0.39	0.22	31.50	Clay loam
	5.9	0.75	0.04	32.05	

SECTION I - B

Boron status of soils from different agro-climatic Zones of Maharashtra State.

In the present study, forty soil samples collected from six different agro-climatic zone of Maharashtra State were analysed for their different fractions of boron.

The values for different fractions of boron in individual soil as well as average values for each zone are reported in tables 12 and 13 and graphically presented in Fig.1, while the variation in the average and range values for each fraction and their relative proportion to the total boron are presented in tables 14-A and 14-B respectively. Similarly, the relative distribution of different samples falling under different range values are reported in tables 15-A and 15-B and graphically presented in Fig.2.

Total boron:

The data reported in table 12 indicate that the total boron contents of soils of Maharashtra vary from as low as 2.75 ppm in Shriwardhan soil in zone I-B to as high as 20.90 ppm in Sholapur soil in zone IV-B (which is derived from basalt). The average value observed for the whole State, based on 40 soil samples is 9.41 ppm. On agro-climatic zone basis, zones IV-B, II, V-B, VI and I-A showed higher status for ~~their~~ this fraction, while zones II-A, III, I-B and IV-A showed lower values. As seen from the data reported in tables 15 A and 15 B, 40 percent of the total soil samples fall in the range of 5-10 ppm,

Table 12

Boron status of soils of Maharashtra State

S.No. 1	Location 2	Average annual rainfall (mm) 3	Soil pH. 4	Total boron (ppm) 5	Water soluble boron. (ppm) 6
	Zone I-B				
1	Igatpuri	3341.00	6.2	10.31	0.55
2	Khopoli	3276.50	6.9	4.12	0.48
3	Panvel	2941.20	7.5	20.00	0.70
4	Dahanu	1759.00	7.3	7.15	0.20
5	Palghar	2534.60	6.9	5.50	0.68
6	Shriwardhan	2527.50	6.7	2.75	0.10
	Average:	2697.03	6.7	8.30	0.45
	Zone I-A				
7	Ratnagiri	2687.00	5.4	4.12	0.13
8	Radhanagari	3317.60	6.2	15.00	0.69
9	Dapoli	3365.00	5.1	12.10	0.17
10	Ajara	2876.62	5.6	6.05	0.14
	Average:	3131.62	5.6	9.32	0.28
	Zone-II				
11	Medha	1723.40	6.3	17.05	0.32
12	Paud	1519.20	7.0	5.50	0.35
13	Vadgaon	1147.00	7.6	8.80	0.35
14-	Average	1463.20	7.0	10.45	0.34
	Zone III				
14	Poona	673.00	7.8	7.85	0.20
15	Dhond	460.75	7.6	11.00	0.17
16	Dhulia	609.60	8.0	3.85	0.14
17	Jeur	609.60	8.1	13.20	0.19
18	Chas	621.90	8.2	4.95	0.10
19	Indapur	505.00	8.00	5.50	0.10
	Average	570.64	8.00	7.72	0.15
	Zone IV-B				
20	Chopda	736.60	7.9	11.55	0.24
21	Bhir	685.80	8.1	10.40	0.68
22	Sholapur	685.80	8.1	20.90	0.93
23	Jalgaon	775.00	8.0	8.25	0.14

Table 12 contd.

1	2	3	4	5	6
24	Badnapur	685.80	7.8	12.50	0.36
	Average	713.80	8.0	12.72	0.47
	Zone IV-A				
25	Washim	914.40	7.8	7.70	0.52
26	Parbhani	863.70	7.7	10.40	0.27
27	Akola	812.80	8.1	12.62	0.45
28	Hingoli	812.80	7.8	8.54	0.25
29	Latur	809.90	7.7	5.50	0.33
	Average	842.92	7.8	8.95	0.36
	Zone V-B				
30	Nagpur	1242.00	7.6	11.00	0.48
31	Yeotmal	1092.20	7.7	14.85	0.27
32	Nanded	939.80	7.9	4.95	0.24
33	Wardha	1001.00	7.8	10.55	0.32
	Average:	1068.75	7.7	10.34	0.33
	Zone V-A				
34	Chanda	1324.00	5.8	7.70	0.10
35	Bhandara	1422.40	5.4	5.78	0.14
	Average:	1373.20	5.6	6.74	0.12
	Zone VI				
36	Gondia	1597.00	5.7	8.55	0.15
37	Gadchiroli	1534.10	5.5	8.25	0.10
38	Amgaon	1388.20	5.3	12.55	0.17
39	Sindewahi	1549.40	5.4	10.35	00.15
40	Vihad	1270.00	7.4	8.80	0.20
	Average:	1470.00	5.8	9.70	0.15

37.5 percent of the soil samples fall under the range of 10-15 ppm, and 15 percent of the samples show a status less than 5 ppm; only 7.5 percent of the total samples show the range higher than 15 ppm. The values for total boron recorded in different agro-climatic zones of the Maharashtra State as well as the average values for the State (based on 40 samples) are in agreement with the values reported by Bendale et al.(1951) for Bombay State soils. The values reported in present study for this fraction are in accordance with the values reported by various workers in the country. But the values under study are much less as compared to values reported by Agarwal (1963,1964) for Uttar Pradesh soils.

A glance at the data reported for total boron in table 12, suggests that the total boron content of soils of Maharashtra is adequate and well within the safe limit.

Water soluble boron:

A very small portion of the total boron present in the soils is in a water soluble form constituting about 3.38 percent of the total boron as seen from the table 14B. From the data presented in table 12, the lowest values for this fraction of boron on individual basis is 0.10 ppm and is seen in case of soils at Chas, Indapur, Chanda and Gadchiroli from zone I-A, V-A and VI respectively. While the highest level of this fraction 0.93 ppm is seen in case of soils of at Sholapur (from zone IV-B). The average value observed for whole State

Table 13

Total and water soluble boron in soils from different agro-climatic Zones of Maharashtra State.

S.No.	Agro-climatic Zone	No.of samples analysed	Total boron (ppm)			Water soluble boron (ppm)		
			Minimum	Maximum	Average	Minimum	Maximum	Average
1	I-B	6	2.75	20.00	8.20	0.10	0.70	0.45
2	I-A	4	4.12	15.00	9.32	0.13	0.69	0.28
3	II	3	5.50	17.05	10.45	0.32	0.35	0.34
4	III	6	3.85	13.20	7.72	0.10	0.20	0.15
5	IV-B	5	8.25	20.90	12.72	0.14	0.93	0.47
6	IV-A	5	5.50	12.62	8.95	0.27	0.52	0.36
7	V-B	4	4.95	14.85	10.34	0.24	0.48	0.33
8	V-A	2	5.78	7.70	6.74	0.10	0.13	0.12
9	VI	5	8.25	12.55	9.70	0.10	0.20	0.15
	Average:				9.36			0.29

FIG-1

BORON STATUS OF SOILS FROM DIFFERENT AGROCLIMATIC ZONES OF MAHARASHTRA STATE

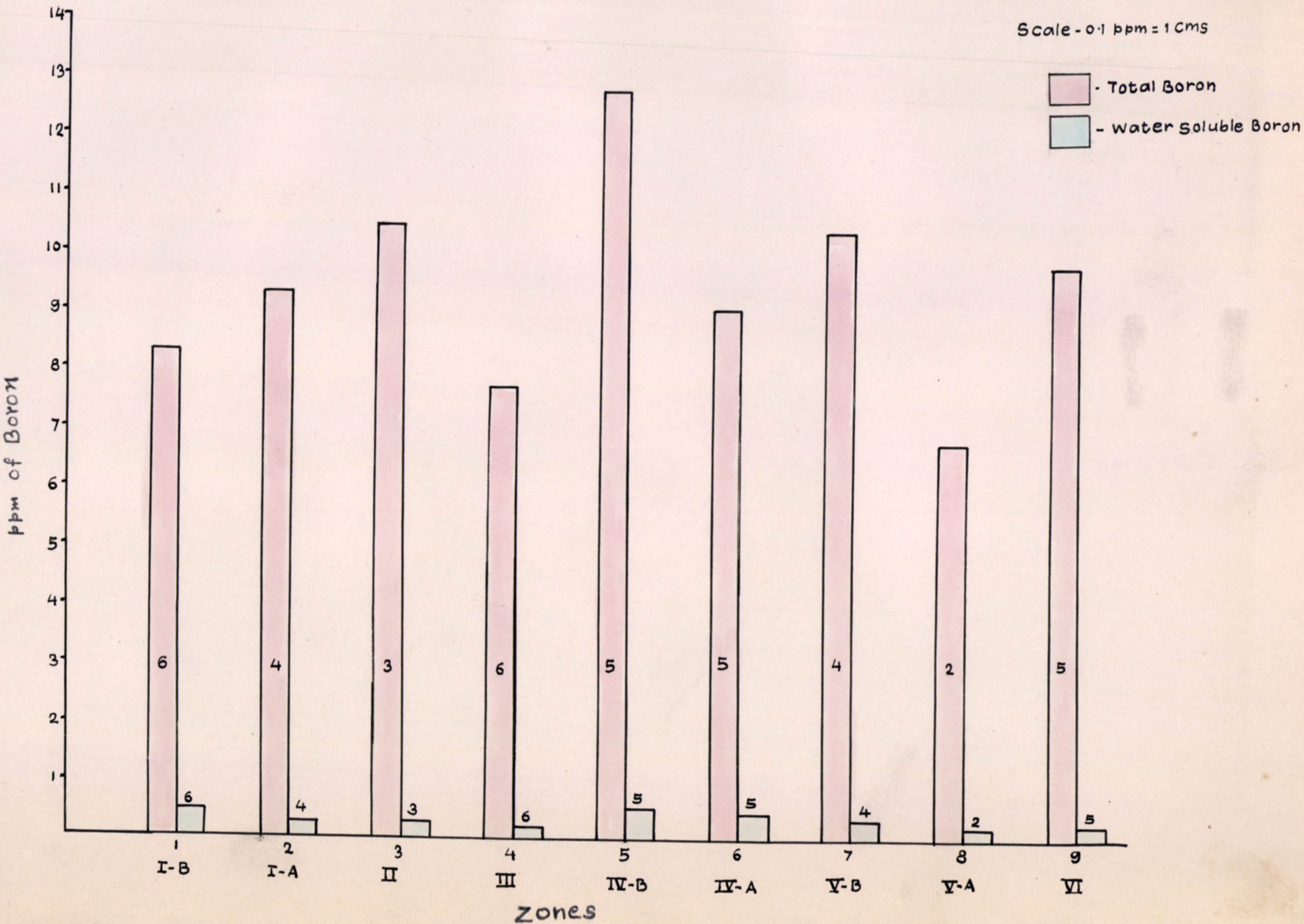


Table 14 A

Average values for physico-chemical properties of soils of Maharashtra S t a t e :

Attribute	Minimum value	Maximum value	Average value (40 samples)
1) Soil pH	5.1	8.2	7.08
2) % organic carbon	0.39	1.80	0.75
3) % clay	22.70	51.50	44.21
4) % Free $CaCO_3$	Nil	6.19	1.74
5) Total boron (ppm)	2.75	20.9	9.41
6) Water soluble boron (ppm)	0.1030	0.9280	0.3065

is 0.31 ppm. Between the different zones, zones I-B, IV-B and IV-A show higher level of available boron as compared to others. The figures reported in tables 15A and 15B indicate that 81 percent of the total soils studied in the present investigation fall in the range of 0.0 to 0.1 ppm, 11 percent of the samples show a status more than 0.1 ppm, 16 percent more than 0.2 ppm and 1.0 percent above 0.3 ppm. The average as well as individual figures reported in the present study agree well with the standard figures suggested by Richard et al. (1954). In general, it can be seen that the water soluble boron in soils of Maharashtra is well within the safe limit suggested by the above authors. The data in the present study on water soluble boron hold good with the data reported by Bendale et al.(1951) for the soils of Bombay State. However, the values for water soluble boron for the Maharashtra State are less than those reported by Kanwar and Singh (1961),Singh (1969) and Bhumbla and Nair (1965) for Punjab soils.

Inspite of wide range of values for each fraction in different soils and in different zones, the soils from zones IV-B, V-B and II are richer in both the fractions of boron studied in the present investigation; while those from zones IV-A and VI are lower in the average values for each of the two fractions. There is no direct effect of the parent material on the different levels of boron. However, based on the

Table 14-B

Relationship between water soluble and total boron in soils.

S.No.	Locality	Water soluble boron x 100 / Total boron	Average value %
	Zone I-B		
1	Igatpuri	5.33	
2	Khopoli	11.66	
3	Panvel	3.50	6.56 percent
4	Daharu	2.97	
5	Palghar	12.36	
6	Shriwardhan	3.74	
	Zone I-A		
7	Ratnagiri	3.93	
8	Radhanagiri	4.58	3.05 percent
9	Dapoli	1.42	
10	Ajara	2.27	
	Zone II		
11	Madha	1.94	4.09 percent
12	Paud	6.36	
13	Vadgaon	3.98	
	Zone III		
14	Poona	2.55	
15	Dhond	1.58	
16	Dhulia	1.25	1.80 percent
17	Jeur	1.45	
18	Chas	2.08	
19	Indapur	1.87	

contd./

Table 14-B contd:

S.No.	Locality	Water soluble boron x100 / Total boron	Average value %
	Zone IV-B		
20	Chopada	2.09	
21	Bhir	6.61	
22	Sholapur	4.44	3.54 percent
23	Jalgaon	1.66	
24	Badnapur	2.88	
	Zone IV-A		
25	Washim	6.70	
26	Parbhani	2.61	
27	Akola	3.53	4.34 percent
28	Hingoli	2.93	
29	Latur	5.92	
	Zone V-B		
30	Nagpur	4.37	
31	Yeotmal	1.85	3.54 percent
32	Nanded	4.87	
33	Wardha	3.08	
	Zone V-A		
34	Chanda	1.34	1.86 percent
35	Bhandara	2.38	
	Zone VI		
36	Gondia	1.75	
37	Gadchiroli	1.25	
38	Amgaon	1.37	1.62 percent
39	Sindewahi	1.47	
40	Vihad	2.27	

Overall Average : 3.38 percent.

Table 15A

Rating of soil samples in different categories of total boron.

(Total number of soil samples 40)

Fraction of boron	1 - 5 (ppm)		5 - 10 (ppm)		10 - 15 (ppm)		15 - 20 (ppm)	
	No. of samples	%	No. of samples	%	No. of samples	%	No. of samples	%
Total boron	6	15	16	40	15	37.5	3	7.5

Table 15B

Rating of soil samples in different categories of water soluble b o r o n

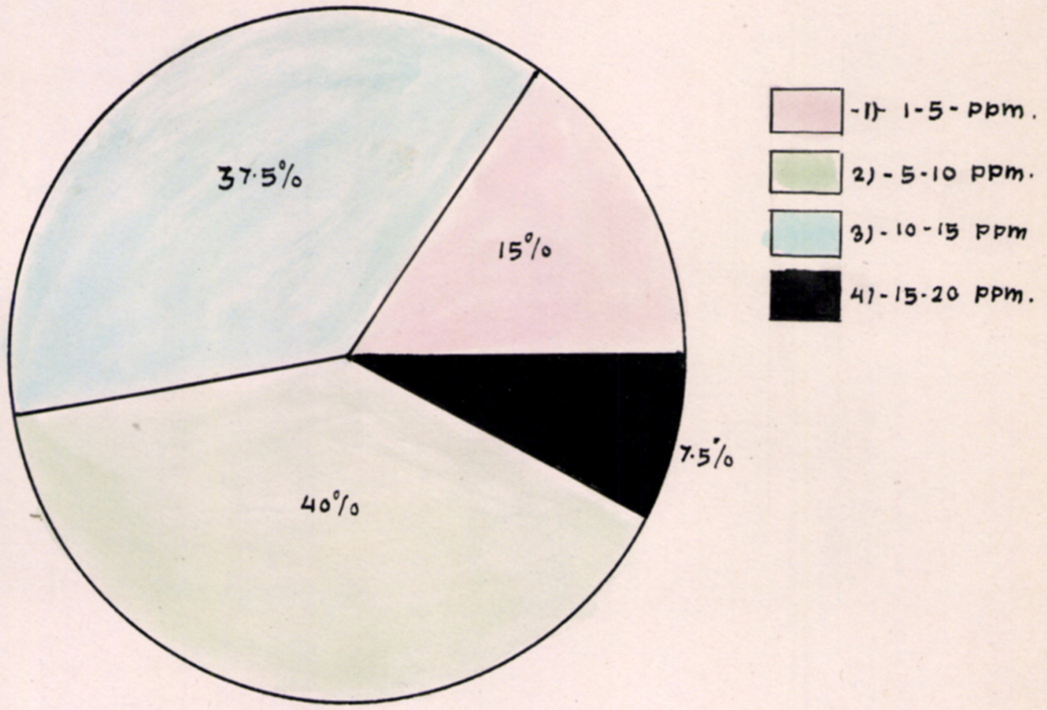
(Total number of soil samples 40)

Fraction of boron	0.1 -0.3 (ppm)		0.3 - 0.6 (ppm)		0.6 -0.10 (ppm)	
	No. of samples	%	No. of samples	%	No. of samples	%
Water soluble boron	24	60	11	27.5	5	12.5

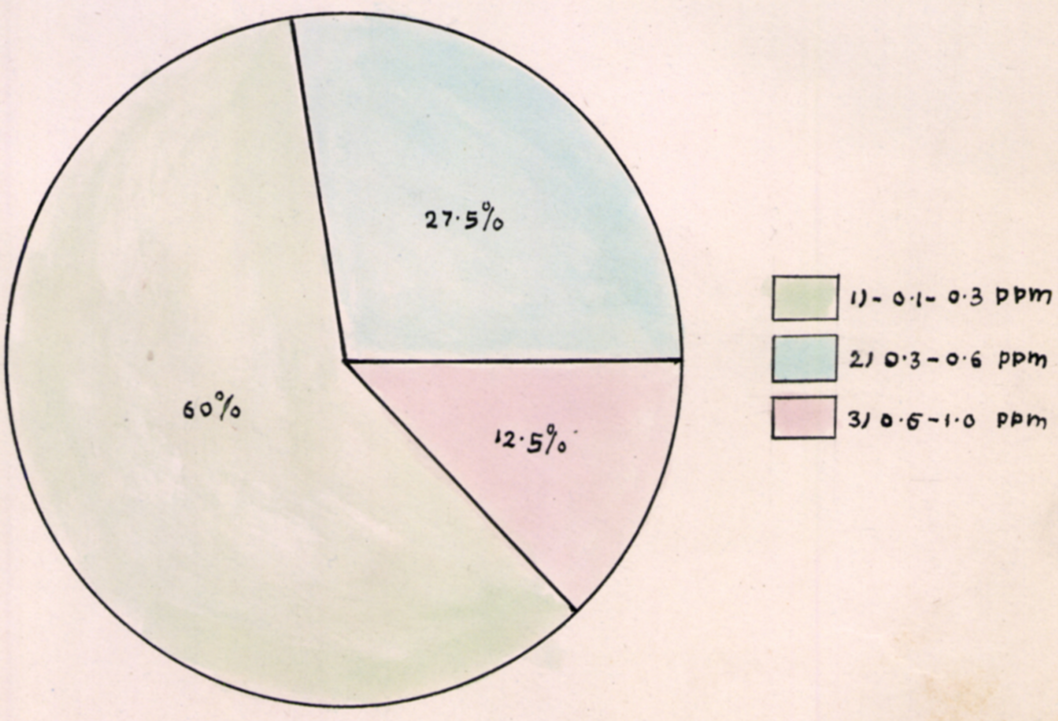
FIG-2

RATING OF SOILS SAMPLE IN DIFFERENT CATEGORIES OF VARIOUS FRACTIONS OF BORON

Total Boron



Water soluble Boron



present observations in table(16-A), it can be said that the soils derived from basalt are richer in both the fractions of boron, while the soils derived from mixed parent material show a poor trend for both the fractions. The soils from lateritic origin show an intermediate trend.

SECTION I-C
Total and water soluble boron in different districts of Maharashtra State

The scrutiny of the data reported in table 16 and graphically presented in fig.3 indicates that the total boron in different districts of Maharashtra State ranges from as low as 2.75 ppm in Kolaba district to as high as 20.90 ppm in Sholapur district. The soils from districts like Sholapur, Satara, Aurangabad, Yeotmal and Nagpur contain a fairly high proportion of total boron than the soils from Ahmednagar, Thana, Nanded, Poona and Dhulia. The average total boron content in different districts of Maharashtra is 9.21 ppm. The figures reported above are in accordance with those of Bendale et al.(1951).

A glance at the data presented in table 16 and graphically presented in Fig.4 indicates that the average value for the water soluble boron in different districts of Maharashtra State is 0.33 ppm which is below safe limit of 0.7 ppm suggested by Richard et al.(1954). The range value

Table 16

Total and water soluble boron in soils from different districts of Maharashtra State

S.No.	Locality	No. of samples analysed	Total boron (ppm)			Water soluble boron (ppm)		
			Minimum	Maximum	Average	Minimum	Maximum	Average
1	Thana	2	5.50	7.15	6.32	0.20	0.69	0.44
2	Kolaba	3	2.75	20.00	8.96	0.10	0.70	0.43
3	Ratnagiri	2	4.12	12.10	8.11	0.23	0.17	0.15
4	Kolhapur	2	6.05	15.00	10.5	0.14	0.69	0.41
5	Dhulia	1	..	3.85	3.85	..	0.14	0.14
6	Nasik	1	..	10.31	10.31	..	0.55	0.55
7	Ahmednagar	1	..	4.95	4.95	..	0.10	0.10
8	Poona	5	5.50	11.00	7.33	0.10	0.35	0.23
9	Satara	1	..	17.05	17.05	..	0.32	0.32
10	Jalgaon	2	8.25	11.55	9.90	0.14	0.24	0.19
11	Aurangabad	1	..	12.50	12.50	..	0.36	0.36
12	Bhir	1	..	10.40	10.40	..	0.69	0.69
13	Sholapur	2	13.20	20.90	17.05	0.19	0.92	0.58
14	Akola	2	7.70	12.62	10.16	0.45	0.51	0.48
15	Parbhani	2	8.54	10.40	9.47	0.25	0.27	0.26
16	Osmanabad	1	..	5.50	5.50	...	0.32	0.32
17	Nagpur	1	..	11.00	11.00	...	0.48	0.48
18	Wardha	1	..	10.55	10.55	...	0.32	0.32
19	Yeotmal	1	..	14.85	14.85	...	0.27	0.27
20	Nanded	1	..	4.95	4.95	...	0.24	0.24
21	Chanda	4	7.70	10.35	8.77	0.10	0.20	0.14
22	Bhandara	3	8.55	12.55	8.96	0.14	0.17	0.15
	Average:	--	--	--	9.21	..	..	0.33

FIG.3

TOTAL BORON IN SOILS FROM DIFFERENT DISTRICTS OF MAHARASHTRA STATE

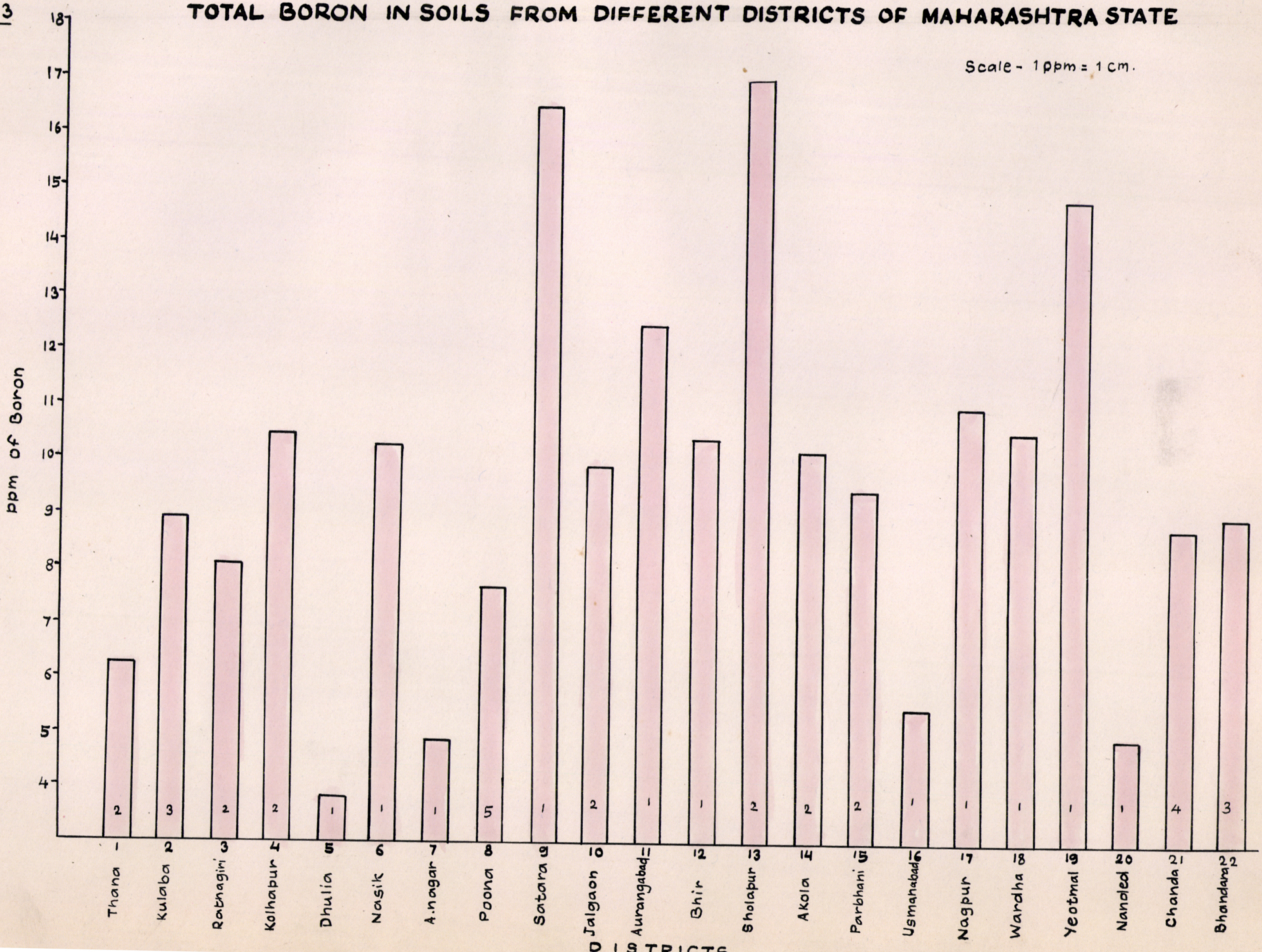


FIG. 4 WATER SOLUBLE BORON IN SOILS FROM DIFFERENT DISTRICTS OF MAHARASHTRA STATE

Scale - 0·1 ppm = 1 cm.

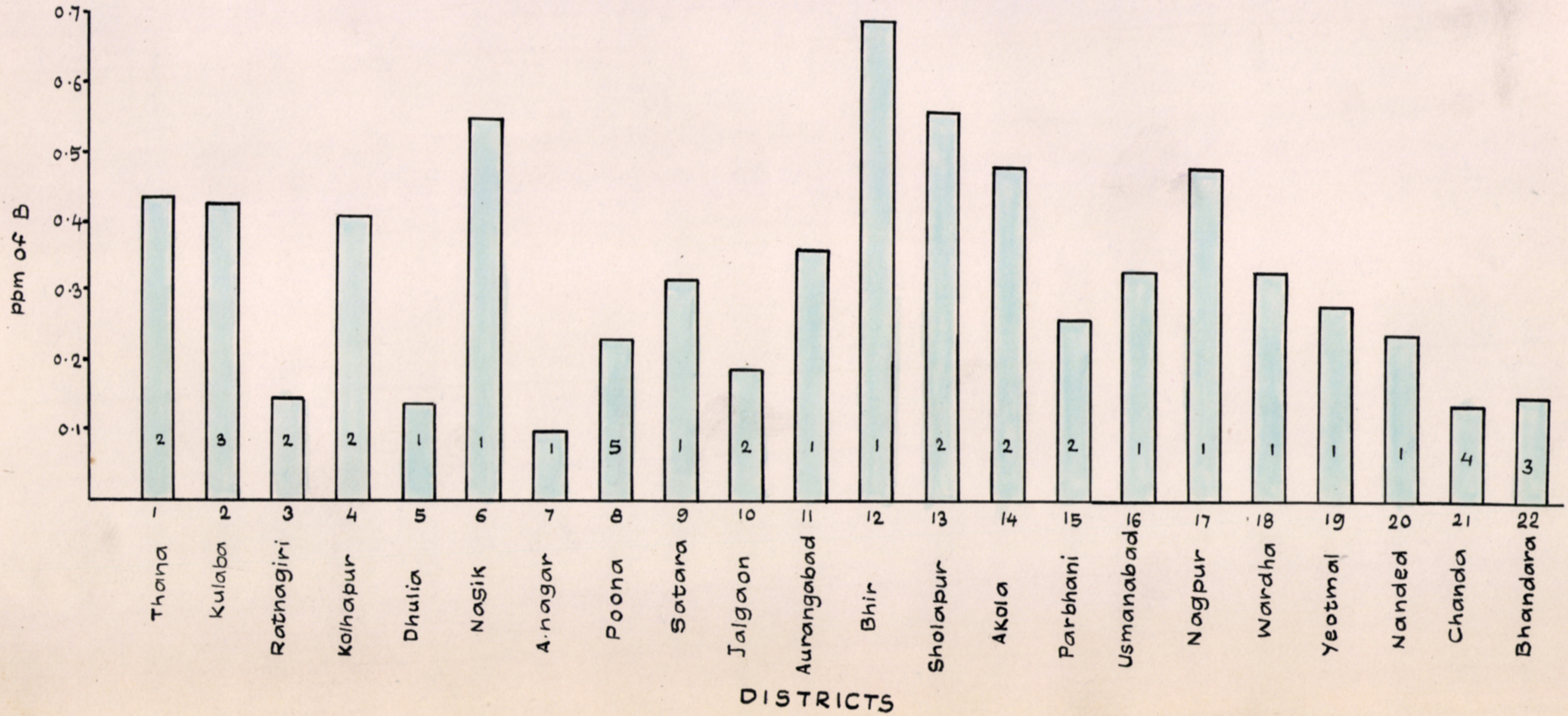


Table 15-A

Boron status of soils derived from different parent materials.

S.No.	Physico chemical character -istics	Basaltic (29) Zones I-B, II, III, IV-B, IV-A V-B.	Granitic Gneises (7) Zone V-A, VI.	Lateritic (4) Zone I-A.
1	pH	7.6	5.8	5.6
2	Organic carbon %	0.66	0.77	1.48
3	Free lime %	2.75	Traces	Nil
4	Clay %	42.15	32.37	40.32
5	Total boron (ppm)	9.75	8.23	9.32
6	Water soluble boron (ppm)	0.35	0.13	0.28

Total boron Basaltic soil > Lateritic > Mixed parent

Water solubb Basaltic soil > Lateritic > Mixed parent

----

of this fraction is from traces to 0.92 ppm. The lowest value observed 0.10 ppm is in soils of Ahmednagar district while highest value 0.69 ppm in soils of Bhir district. The soils from districts like Thana, Kolaba, Kolhapur, Nasik, Sholapur, Bhir, Akola and Nagpur found to be rich in this fraction than the soils from other districts. The values, individual and average, observed are well within the safe limit. Thus it can be said that, both the fractions of boron are in adequate quantities in different districts of Maharashtra State.

The values for both fractions of boron obtained in the present investigation are somewhat lower than those reported by Atre (1960) for Vidharbha soils, while the values are higher than those obtained by Raut (1962) for typical soil profiles of Nagpur Division.

Relationship between different fractions of Boron and the soil attributes like organic carbon, clay content, pH and free lime in the soils:

After assessing the status of each fraction of boron in soils from various agro-climatic zones of Maharashtra State and their probable relationship with the factors like parent material, it was felt necessary to see whether the individual fractions of boron show any direct relationship with any of the important soil attributes like organic carbon, pH, free lime contents and percent clay. The data reported in table 11 was recasted and is presented in table 17 to show the relationship, if any, between organic carbon, pH, free lime and clay percent

Table 17

Correlation co-efficient for showing the relationship between total and water soluble boron and the various soil attributes.

Factors under study		r values
1)	Water soluble boron and pH	0.1379
2)	Water soluble boron and organic carbon (%)	0.0683
3)	Water soluble boron and clay (percent)	0.0447
4)	Total boron and pH	0.5380
5)	Total boron and organic carbon	0.0066
6)	Total boron and clay percent	0.07698

and the different fractions of boron.

The glance at the value reported in table 17 indicates that there is no apparent relationship between different fractions of boron and the soil attributes stated above. Under Indian conditions, Ghani and Haque (1945) working with soils of East Bengal, Bhattacharjee (1956) working with Murshidabad soils (West Bengal); and Gandhi and Mehta (1958) working with Gujarath and Saurashtra soils found no relationship with soil pH, organic carbon and $CaCO_3$ with the water soluble boron in the soils. The results in the present investigation tally very well with the above workers. Howeever, the results are in conflict with those reported by Paliwal and Anjineyulu (1967) in Delhi soils, Singh (1969) and Grewel *et al.* (1969) in Punjab soils and Mathur (1964), Baser and Saxena (1967) in Rajasthan soils.

General Conclusions

Based on the data reported in tables 12,13, 14A, 14B, 15A, 15B, 16A, 16 and 17, the following bread conclusions can be drawn:

1) In respect of total boron, it ranges from 2.75 ppm to 20.9 ppm with an average value of 9.41 ppm.

2) Forty percent of the soils studied in the present work fall in the range of 5-10 ppm and 37 percent of the total soils studied fall in the range of 10 - 15 ppm.

3) The basaltic soils are little bit higher in their contents of total boron (9.75 ppm) as against 9.32 ppm in lateritic soils and 8.23 ppm in soils derived from mixed parent material.

4) The water soluble boron in different soils varies from 0.10 ppm to 0.93 ppm with an average value of 0.31 ppm.

5) The water soluble boron constitutes on an average 3.38 percent of the total boron.

6) Sixty percent of the total soils fall in the range of 0.1 - 0.3 ppm.

7) The basaltic soils contain more amount of water soluble boron while lateritic less and the soils derived from

mixed parent material are least in their boron contents.

8) There is no specific trend of soils falling in different ranges of water soluble boron.

9) In respect of all the fractions of boron, the soil derived from mixed parent material show a lowest value.

10) Based on the values reported by other workers, soils of Maharashtra State are adequately supplied with boron.

11) No relationship is found between soil attributes like organic carbon, free lime, clay, soil reaction of the soils and the levels of boron in the present work. The results agree well with some workers while they are in conflict with others.

SECTION II

Boron in irrigation water :

The ground well water samples collected from different districts of Maharashtra State were analysed for their pH, total soluble salts and chemical composition of dissolved salts. The results pertaining to the above analysis are presented in table 20. The boron content of well waters is reported in table 18 and graphically presented in fig.5.

The data reveals that the average boron contents of well waters from different districts of Maharashtra State vary from as low as 0.085 ppm in Akola district to as high as 0.31 ppm in Dhulia district. The well waters from

Table 18

Average pH and boron contents of well waters from different districts of Maharashtra State.

S.No.	Locality	Av. pH.	No. of samples	Boron in well waters(ppm) Minimum	Maximum	Average
1	Dhulia	8.3	23	Traces	2.1	0.31
2	Poona	7.6	25	Traces	0.27	0.11
3	Sangli	7.9	5	0.055	0.27	0.10
4	Jalgaon	7.4	29	Traces	2.31	0.27
5	Sholapur	8.3	24	Traces	1.21	0.26
6	Akola	8.8	24	Traces	0.27	0.085
7	Buldhana	8.6	29	Traces	0.44	0.12
8	Amraoti	8.7	33	Traces	0.77	0.17
	Average:	8.2	..	..	..	0.18

Dhulia, Jalgaon, Sholapur districts contain a fairly high proportion of boron, however, it is well within the safe limit. (Magistad and Christensen, 1944). While the waters from districts like Poona, Akola, Sangli, Buldhana and Amraoti show a lower proportion of boron in them. The over-all average for boron in well waters based on 192 samples is 0.18 ppm. The figures recorded in the present investigation agree very well with the figures quoted by Magistad and Christensen (1944). The standards prescribed for boron in irrigation waters by the above workers are; the waters containing 0.1 to 0.5 ppm of boron in them are suitable for

FIG. 5

BORON IN WELL WATERS FROM DIFFERENT DISTRICTS OF MAHARASHTRA STATE

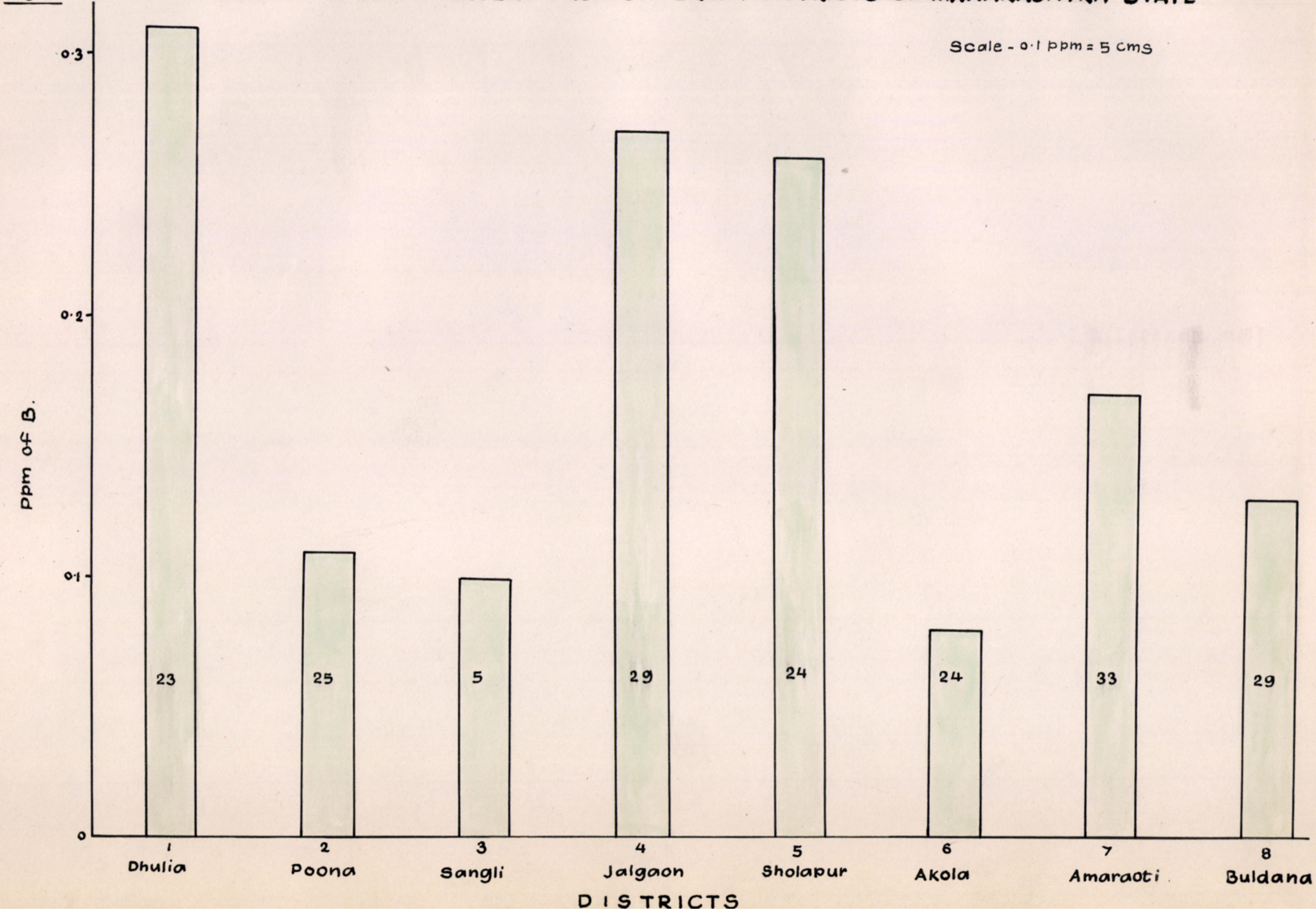


Table 19

Rating of well water samples in different categories of boron

Category		No. of samples falling under category	Percent
I	0.0 - 0.5	274	93.84
II	0.5 - 1.0	13	4.45
III	1.0 - 1.5	1	0.34
IV	1.5 - 2.0	1	0.34
V	2.0 - 2.5	3	1.03
5		292	100.00

Category I : (No. of samples 274)

0.0 - 0.1		0.1 - 0.2		0.2 - 0.3		0.3 - 0.4	
No. of samples	Percent	No. of samples	Percent	No. of samples	Percent	No. of samples	Per-cent
222	81.02	30	10.92	16	5.85	1.[illegible]	0.35

0.4 - 0.5	
Sample	Percent
5	1.83

Category II: (No. of samples 13)

0.5-0.6		0.6-0.7		0.7-0.8		0.8-0.9		0.9- 1.0	
No. of samples	*	No. of samples	*	No. of samples	*	No. of samples	*	No. of samples	*
3	23.08	2	15.38	5	38.46	..	..	3	23.08

* = percent.

most plant under most conditions and are of excellent quality. Those containing 0.5 to 2.0 ppm are good to injurious and probably harmful to most crops. The waters having more than 2.0 ppm boron are injurious and not suitable for irrigation purposes. Mathur (1964), also found the same observations. From the standards suggested by the above workers, it can be seen that the well waters from all the districts under study are well within the safe limit.

The values given in table 19 indicate that 81 percent of the total water samples fall in the range of traces to 0.1 ppm, 11 percent in the range of 0.1 to 0.2 ppm and 6 percent of the total water samples show a status more than 0.2 ppm. Very few samples fall above 0.3 to 0.5 ppm range.

The scrutiny of the data presented in table 20 shows that the average pH of well waters from different districts of Maharashtra vary from 7.6 in Poona district to 8.9 in Akola district indicating that they are alkaline to moderately alkaline in reaction. The overall average for pH based on 292 samples is 8.2. The well waters from districts like Akola, Amraoti, Buldhana and Dhulia show a higher level of pH than the others. The values for pH as observed in the present work are in accordance with those reported by Babrekar _et al._ (1965) for well water samples collected from College Farm, Dhulia.

The data also reveals that the average carbonate contents of ground well waters vary from traces to 1.23 meq/litre.

The overall average being 0.845 meq/ litre. The well waters from districts like Akola, Amraoti and Buldhana show a higher level for their carbonate contents than the others. The average bicarbonates in well waters from different districts of the State vary from 5.72 meq/ litre in Poona district to 9.89 meq/ litre in Akola district. The overall average being 7.28 meq/ leitre. The average chlorides in well waters fall in the range of 4.19 meq/ litre in Buldhana district to 57.46 meq/ litre in Sholapur district with an average value of 18.27 meq/ litre. The range of total soluble salts is from 481 ppm to 2088 ppm, with an average value being 892 ppm. Most of the samples show higher values than that is prescribed for the safe limit U.S.D.A. (1947). The lowest and highest values for different attributes for well waters from each district are given in appendix-A.

In the present investigation, the waters have been classified according to U.S.D.A. classification (1947). In this classification electrical conductivity and S.A.R. values are taken into consideration and the standards prescribed for those values are as under:-

Electrical conductivity millimhos/ cm at 25°C.	Class	Interpretation
Less than 0.25	C 1	Excellent
0.25 to 0.75	C 2	Good
0.75 to 2.25	C 3	Doubtful
2.25 and above	C 4	Unsuitable
S.A.R. values:		
0 to 10	S 1	Low
10 to 18	S 2	Medium
18 to 26	S 3	High
26 and above	S 4	Very high

Various workers have tried to modify the criteria for classification of irrigation waters. Kelley (1963), considered important aspects such as osmotic pressure, effect of replaceable cations of the soil and the effect on the ratio of cations in the soil solution in relation to plant growth. According to Richard (1954), the most important characteristics of an irrigation waters are :

i) the total concentration of salts,

ii) relative proportion of Na /other cations,

iii) concentration of specific elements like boron and under certain conditions,

iv) the bicarbonates as related to concentration of calcium and magnesium.

Categorisation of water was done in various ways. Puri (1949), classified waters on the basis of salt indices. Asghar and Dhawan (1947) correlated the salt index with total soluble salts; Ca/Na ratio and pH values. Eaton (1950) categorised them according to the residual alkalinity. A comprehensive classification as suggested by Wilcox (1948) taking into account the specific conductance and exchangeable sodium percentage for judging the quality. Thorne and Patterson (1954), have suggested an improvement upon this by classifying waters into salinity grades in terms of S.A.R. Darra _et al._ (1963), Shankarnarayan _et al._ (1965) and Landey and Murty (1967) have tried to modify the classification for the quality of underground waters under Indian conditions. However, in the present work the classification has been done based on U.S.D.A. classification (1947).

While judging these water samples in the light of their sodium adsorption ratio (S.A.R.), residual sodium carbonate (R.S.C.) and soluble sodium percentage (S.S.P.), it is found that all the water samples studied fall within the safe limit of S.A.R. 0.10 (S_1) as suggested by Durand (1956). In respect of residual sodium carbonate (R.S.C.) excepting water samples from districts like Poona, Sangli, Jalgaon and Sholapur, the rest of them fall above the safe limit of 2.5 meq/litre as suggested by Wilcox (1955). Likewise, the ratio between Na to (Ca + Mg) exceeds the safe limit of 1.0 (Kelley,1963) in most of the cases. Soluble sodium percentage (S.S.P.) in all the cases is more or less the same except in Poona and Sangli districts which show a lowest level of S.S.P. than the other districts. In majority of the cases, the S.S.P. is less than 60 percent which is below the critical limit suggested by Sharma (1963). The range of S.S.P. is between 21.21 to 68.50 percent with an average value of 49.89 percent.

The striking feature of the analytical data presented in table 20 is that the concentration of magnesium as compared to calcium is high in all cases excepting water samples from Poona district. Likewise, the values for Na in relation to Ca exceeds the safe limit in all the cases excepting in Poona and Sangli districts as propounded by Kelley (1963). The ratio of Na to (Ca + Mg +K) Eaton (1950) exceeds the safe limit of unity in majority of the samples excepting in Dhulia, Poona and Sangli districts; while the ratio of Na to (Ca+Mg) (Kelleys' Na ratio,1940) is also found to be beyond unity in most of the samples. The ratio of Na to (Ca+Mg+K) ranges from 0.22 to 2.18 with an average value of 1.22, while the ratio of Na to (Ca+Mg) varies from 0.22 to 2.57 with an average value of 1.29.

The electrical conductivity of the water samples from different districts of Maharashtra State fall within the range of 0.76 millimhos/cm in Buldhana and Poona district with an average value of 1.27 millimhos/cm. In all the cases, water samples fall under the category C_3 as suggested by U.S.D.A. classification (1947).

When boron is considered in judging the quality of water samples, all the water samples fall within the safe limit of 0.1 - 0.5 ppm as reported by Magistad and Christensen (1944) and Mathur et al.(1964). The water samples from all the districts therefore fall under the Category-I.

The data reported in table 20 reveals that there is no apparent relationship between the pH and boron contents of the water samples. With the higher values of S.A.R. there is subsequently higher level of boron concentration in the water samples. It is also observed that at higher level of R.S.C., the boron content seems to be more. There is no relationship between the S.S.P. values and boron contents of well water samples. No apparent relationship was found between total soluble salts and the boron content of the well waters.

In the present report, the most of the water samples analysed, show the quality as C_3S_1; U.S.D.A. salinity Laboratory (1947). The boron concentration seems to be below the safe limit prescribed by above authority and all the waters are of good quality in respect of boron content.

The underground water samples from different districts of Maharashtra are not so harmful as compared to the under ground waters from Rajasthan (Darra,1963) or well waters from Punjab (Dhawan et al. 1957), U.P.(Agarwal et al. 1956). In relation to salinity hazards (S.A.R.), the waters are of good quality (S_1) while the most waters fall under the category C_3 in respect of E.C. values. With little care and proper management these waters can safely be used for irrigation purposes.

General Conclusions :

Based on the data reported in tables 18, 19 and 20 the following bread conclusions can be drawn:

1) The boron in well waters from different districts of the Maharashtra State varies from 0.085 ppm to 0.31 ppm with an average value of 0.18 ppm.

2) Eightyone percent of the well waters studied in the present investigation fall in the range of traces to 0.1 ppm, 11 percent

in the range of 0.1 -0.2 ppm, 6 percent in 0.2 to 0.3 ppm and very few samples show a range more than 0.3 to 0.5 ppm.

3) The well waters from districts like Dhulia, Jalgaon and Sholapur are higher in their contents of boron as compared to other districts.

4) Amongst the districts studied, the well waters from Sangli and Poona, show the lowest value for their boron contents while waters from Dhulia are highest.

5) The pH of the waters under study varies from 7.4 to 8.8 with an average value of 8.2.

6) The waters from districts like Akola, Amraoti, Buldhana and Sholapur show higher pH than the rest of the districts.

7) The total soluble salts of the waters studied, range from 481 ppm to 2033 ppm with an average value of 892 ppm.

8) The waters from districts like Sholapur, Jalgaon, Sangli and Amraoti are higher in their T.S.S. as compared to other districts.

9) The carbonates in different well waters vary from traces to 1.23 meq/litre with an average value of 0.84 meq/litre.

10) The amount of bicarbonate in different well waters ranged from 5.72 meq/litre to 9.89 meq/litre with an average value of 7.28 meq/litre.

11) The range of chlorides in different waters is from 4.9 meq/litre to 57.46 meq/litre with an average value of 18.27 meq/litre.

12) The values for magnesium in waters in relation to calcium are higher in most cases.

13) The ratio between Na to (Ca +Mg) - Kelleys' Na ratio exceeds the safe limit of unity in majority of samples.

14) All the water samples fall below the safe limit of S.A.R. values 0-10 (Durand 1956).

15) Fifty percent of the water samples fall below the safe limit of 2.5 meq/litre of residual sodium carbonate while 50 percent show more R.S.C. than the safe limit (Wilcox,1955).

16) The soluble sodium percentage in all the cases is more or less the same excepting few and in most cases well within the safe limit of 60 percent (Sharma,1963).

17) All the water samples under study show the quality as C_3S_1, U.S.D.A. classification (1947).

18) No relationship between boron and pH, S.S.P. and T.S.S. is observed while there is an apparent relationship between R.S.C. and S.A.R. in some cases. With the increase in these values, there is subsequent increase in the boron concentration.

19) The water samples in all cases are alkaline to moderately alkaline in reaction.

20) In respect of total solids, majority of the samples exceed the safe limit of 600 ppm, (U.S.D.A.,1947).

SECTION III

Uptake studies on hybrid bajra grown under field conditions

The field trial was conducted on a medium black calcareous soils with hybrid bajra as a test crop with a view to determine its boron requirements. The crop received ~~higher~~ varying doses of N,P, K and usual doses of micro-nutrients. At flowering stage, one plant from each sub plot was cut close to the ground, dried in the shade, then in the oven at low temperature and after grinding to a fine powder, it was used for the analysis. At harvest, four plants from each sub-plot were cut close to the ground, immediately weighed, dried in the shade and then in the oven, again weighed and after grinding, the samples were used for determining boron in them. The boron was estimated separately from straw and grain at harvesting stage.

Dry matter production and grain yield

The variation in the range values of dry matter produced by hybrid bajara plant at flowering and harvesting stages and their average values have been presented in tables 21, 22 and 23.

It is observed from table 21 that the minimum dry matter produced by the bajra plant at flowering is 6.9 gm

Table 21

Boron uptake and dry matter produced by hybrid bajra crop at flowering stage.

S.No.	Replica -tions	Dry matter produced in (gm)	Boron uptake in plants (ppm)
1	2	3	4
	RI		
1	Aa	12.4	3.3
2	Ab	12.5	3.3
3	Ac	13.8	1.1
4	Ad	11.0	5.5
5	Ae	10.2	3.3
6	Af	11.9	Tr.
	Average:	11.97	2.76
7	Ba	7.4	1.1
8	Bb	11.6	2.2
9	Bc	17.6	2.5
10	Bd	14.6	5.5
11	Be	7.8	1.2
12	Bf	12.1	Tr.
	Average:	11.75	2.12
13	Ca	11.3	1.5
14	Cb	13.5	3.3
15	Cc	10.0	2.2
16	Cd	8.0	6.0
17	Ce	9.7	1.5
18	Cf	8.5	Tr.
	Average:	10.17	2.42
	RII		
19	Aa	10.2	1.5
20	Ab	15.6	2.0
21	Ac	11.7	2.2
22	Ad	13.8	3.8
23	Ae	15.9	1.2
24	Af	10.7	0.5
	Average:	12.98	1.87

contd.

Table 21 contd:

1	2	3	4
RII			
25	Ba	6.9	1.0
26	Bb	13.5	1.1
27	Bc	10.8	3.3
28	Bd	15.1	4.0
29	Be	7.1	2.5
30	Bf	17.0	1.0
	Average:	11.73	2.15
31	Ca	8.8	2.0
32	Cb	9.5	1.1
33	Cc	12.8	2.2
34	Cd	13.0	4.4
35	Ce	11.8	2.3
36	Cf	12.5	1.0
	Average:	11.40	2.17
RIII			
37	Aa	17.5	2.0
38	Ab	14.7	2.2
39	Ac	10.5	2.5
40	Ad	11.5	5.0
41	Ae	11.0	1.2
42	Af	10.7	Tr.
	Average:	12.65	2.15
43	Ba	17.9	1.5
44	Bb	10.8	2.5
45	Bc	12.2	2.0
46	Bd	15.5	4.8
47	Be	11.9	3.0
48	Bf	13.0	1.0
	Average:	13.55	2.47
49	Ca	15.5	3.0
50	Cb	13.2	3.3
51	Cc	19.6	2.7
52	Cd	14.3	6.0
53	Ce	16.5	3.5
54	Cf	7.6	1.0
	Average:	14.45	3.25

while the maximum value is 19.6 gm with an average value of 12.29 gm. At harvest, the range of dry matter produced was 32.0 gm to 95.50 gm with an average of 60.80 gm.

The grain yield ranges from 19 gm to 48 gm with an average value of 29.62 gm. From the figures reported, it can be said that the dry matter production at harvest is about five times more than that at flowering stage of bajara crop. The dry matter at harvest is twice the grain yield. Thus the straw to grain ratio seems to be 2:1.

From the tables 21, 22 and 23, it is clearly seen that neither the application of N.P.K. nor the application of boron affected the production of dry matter or grain yield. A similar observation has been recorded by Pandya et al.(1955). Kulkarni et al.(1970) did not get any response to boron by bajara in their field trials at various Research Stations. The results obtained in the present study are in accordance with those of above authors. Kulkarni et al.(1970) observed response to kharif jowar grown at Akola and the present investigation is, however, in conflict with the Kulkarni et als' observations. Joshi (1955), found that, there was an adverse effect of boron on the jowar yield and the findings in the present investigation are in agreement with those of Joshi.

It is seen from the data reported in tables 23 (i),(ii), (iii), (iv) and (v) that the average uptake of boron at flowering stage by bajara plants is 2.37 ppm with a range of traces

Table 22

Boron uptake and dry matter and grain yield produced by hybrid bajra crop

S.No.	Replications	Dry matter (gm)	Uptake of boron in dry matter (ppm)	Grain yield (gm)	Uptake of boron in grains (ppm)
1	2	3	4	5	6
	RI :				
1	Aa	35.50	1.1	29.5	3.3
2	Ab	35.50	1.1	28.0	2.1
3	Ac	50.00	1.1	30.0	3.3
4	Ad	60.00	3.3	19.0	5.5
5	Ae	63.50	Tr.	32.0	2.0
6	Af	37.00	Tr.	24.0	1.0
	Average:	55.25		27.83	2.87
7	Ba	49.50	1.1	27.50	2.5
8	Bb	73.50	3.3	28.0	3.3
9	Bc	62.50	1.1	19.5	3.3
10	Bd	62.50	5.5	22.5	8.8
11	Be	55.5	3.3	23.5	2.2
12	Bf	55.0	0.2	41.5	1.1
	Average:	59.75		27.83	3.53
13	Ca	55.00	3.3	29.5	2.2
14	Cb	74.00	1.5	35.0	2.7
15	Cc	93.00	1.1	29.0	3.3
16	Cd	64.00	4.4	23.0	10.1
17	Ce	76.50	1.1	21.0	3.3
18	Cf	51.50	Tr	23.0	Tr.
	Average:	69.00		26.75	3.60
R II: 19	Aa	48.50	Tr	35.5	2.7
20	Ab	74.00	Tr	26.0	3.3
21	Ac	51.50	Tr	31.5	2.5
22	Ad	70.00	3.3	23.5	8.8
23	Ae	65.00	1.1	27.0	3.3
24	Af	32.50	Tr.	30.5	1.0
	Average:	56.92		29.00	3.6

Table 22 contd:

1	2	3	4	5	6
25	Ba	70.0	Tr.	48.0	1.10
26	Bb	35.0	Tr.	22.5	3.3
27	Bc	47.5	Tr.	38.0	2.2
28	Bd	79.0	3.3	33.0	11.1
29	Be	78.5	Tr.	40.0	5.5
30	Bf	68.5	Tr.	42.5	Tr.
Average:		63.08		37.33	3.7
31	Ca	85.0	Tr.	42.5	2.2
32	Cb	42.5	Tr.	19.0	3.3
33	Cc	72.0	Tr.	21.0	2.7
34	Cd	58.0	3.3.	27.0	6.6
35	Ce	65.5	Tr.	33.0	3.3
36	Cf	39.0	Tr.	35.5	1.0
Average:		60.33		29.66	3.18
R I II					
37	Aa	89.0		34.0	2.7
38	Ab	52.5		21.0	2.9
39	Ac	65.0		20.5	3.3
40	Ad	72.5	3.3	27.0	8.8
41	Ae	58.5		24.0	4.4
42	Af	32.0		31.0	0.5
Average:		61.58	..	26.25	3.76
43	Ba	61.0		34.0	1.1
44	Bb	49.0		31.5	1.1
45	Bc	51.0		31.5	3.3
46	Bd	44.0	3.3	26.5	9.9
47	Be	76.0		28.5	4.4
48	Bf	37.5		28.5	0.5
Average:		53.08	..	30.08	3.38
49	Ca	76.5		36.0	2.7
50	Cb	65.0		32.5	3.3
51	Cc	45.5		43.5	3.3
52	Cd	49.0	3.3	29.0	6.6
53	Ce	48.0		42.0	5.5
54	Cf	95.5		28.0	1.0
Average:		63.25	..	31.83	3.73

Table 23

(I) .. Average and range of dry matter produced by hybrid bajra crop at flowering stage.

Crop taken	Average dry matter (gm)	Minimum dry matter (gm)	Maximum dry matter (gm)
Hybrid bajra	12.29	6.90	19.6

(II) .. Average and range of dry matter produced by hybrid bajra at harvesting stage.

Crop taken	Average dry matter (gm)	Minimum dry matter (gm)	Maximum dry matter (gm)
Hybrid bajra	60.80	32.0	95.5

(III) .. Average and range of grain yield produced by hybrid bajra.

Crop taken	Average	Minimum	Maximum
Hybrid bajra	29.62	19.0	48.0

(IV) .. Average and range uptake of boron in straw by hybrid bajra at flowering stage.

Crop	Average uptake (ppm)	Minimum uptake (ppm)	Maximum uptake (ppm)
Hybrid bajra.	2.87	Traces	5.5

(V) .. Average and range uptake in grains by hybrid bajra at harvesting stage.

Crop	Average (ppm)	Minimum (ppm)	Maximum (ppm)
Hybrid bajra	3.48	Trace	11.1

to 5.5 ppm. While at harvest, the uptake by grains ranges from traces to 11.0 ppm with an average value of 3.48 ppm.

Thus, it can be concluded that the uptake of boron in in grain is more than the uptake by dry matter, at harvesting stage the uptake by dry matter being very less. More uptake is found in the boron treated plot than the untreated ones.

It is seen that, at harvest in grain and at flowering in straw, there is more uptake of boron. Eventhough boron is taken up, it has not affected neither increase in yield nor dry matter production. Thus it is clearly seen that plants might have taken boron for their luxury consumption.

A glance at the data in table 24 indicates that the effect of main plot treatments viz. A, B and C-subsequently varying doses of N.P.K. on the yield of hybrid bajra is non-significant, indicating that there is no differential behaviour of the treatments. However, the mean grain yield obtained by the meain treatments was 27.74, 31.50 and 30.44 gm per plot respectively.

From the mean grain yield data of sub-plot treatments, it is revealed that Manganese gave significantly higher yield i.e.(35.17 gm/plot) over boron and Zinc giving 25.61 and 26.89 gm/ plot respectively. While the copper, molybdenum and control behaved similarly to Manganese giving 29.38, 30.11 and 35.17 gm per plot respectively. Boron and zinc had a similar effect on the yield of bajara.

Table 24

Mean yield of grains/plot in gm of hybrid bajara as affected by various treatments.

Sub plot treatments	Main plot treatments A	B	C	Mean	S.E.D.	C.D. at 5 percent ±
a (Mn)	33.00	36.50	36.00	35.17	2.98	6.08
b (Zn)	25.00	27.33	28.83	26.89		
c (Cu)	27.33	29.66	31.16	29.38		
d (B)	23.16	27.33	26.33	25.61		
e (Mo)	27.66	30.66	32.00	30.11		
f (Control)	28.50	37.50	28.83	31.44		
Mean :	27.44	31.50	30.44			

S.E.D.	3.07
C.D. at 5 percent ±	N.S.

	N	P_2O_5	K_2O
A ..	30	15	15
B ..	60	30	30
C. ..	90	45	45

a	b	c	d	e	f
Mn	Zn	Cu	B	Mo	Control

Table 25

Mean yield of straw in gm of hybrid bajra at harvesting stage as affected by various treatments.

Sub plot treatments	Main plot treatments A	B	C	Mean	S.E.D.	C.D. at 5 per-cent ±
					11.8	N.S.
a (Manganese)	57.66	60.16	72.16	63.33		
b (Zinc)	70.66	52.83	60.50	61.33		
c (Copper)	55.50	53.33	70.16	59.66		
d((Boron)	67.50	61.83	57.00	62.11		
e (Molybdenum)	63.33	70.00	62.33	65.22		
f (Control)	33.83	53.66	62.00	49.33		
M e a n:	57.91	58.63	64.19	...		

S.E.D. .. 4.21 C.D. at 5 percent ± N.S.

Table 26

Mean yield of straw in gm of hybrid bajara at flowering stage as affected by various treatments.

Sub plot treatments	Main plot treatments A	B	C	Mean	S.E.D.	C.D. at 5 percent ±
					4.37	N.S.
a (Mn)	13.33	10.73	11.86	11.97		
b (Zn)	14.26	11.96	12.06	12.76		
c (Cu)	12.00	13.33	14.13	13.15		
d (B)	12.10	15.06	11.76	12.97		
e (Mo)	13.33	8.93	12.66	11.31		
f (Control)	11.10	14.03	9.53	11.55		
Mean:	12.52	12.34	12.00			

S.E.D. = 2.79 C.D. at 5 percent ± N.S.

The effect of various sub-treatments at the same level of all the main treatments was found to be non-significant.

Similarly the effect of main treatments at the same level of sub treatments was found to be non-significant.

Pandya _et al_.(1955) and Joshi (1956) could not get increase in the yield of bajara (_Pennisetum typhoides_) by the application of B, Cu and Mo. They believe that the micro-nutrient requirements of bajara are low as compared with other cereals. Kulkarni _et al_.(1970) in field trials observed the similar results.

From the data presented in table 25, it is observed that the mean yield of fodder at harvest was not significantly affected by either the main plot treatments or by the sub-plot treatments.

The data reported in table 26, reveals that the mean yield of fodder at flowering was not significantly affected by either the main or by the sub-plot treatments.

The data given in table 27, indicated that the uptake of boron was not affected by the main plot treatments. The uptake for main plot treatments viz. A, B and C was 2.25, 2.24 and 2.60 ppm respectively.

Uptake of boron was significantly more in sub-plot treatments viz. Mn, Mo, Cu, Zn and B, the uptake being 1.87, 2.19, 2.29, 2.33 and 5.01 ppm respectively over the control. The uptake of boron was significantly more in boron treated plots over all the other sub plot treatments. In sub-plot

Table 27

Mean uptake of boron in ppm in plants (hybrid bajara) at flowering stage as affected by various treatments.

Sub plot treatments	Main plot treatments A	B	C	Mean	S.E.D.	C.D. at 5 per cent ±
					0.35	0.71
a (Mn)	2.26	1.20	2.16	1.87		
b (Zn)	2.50	1.93	2.56	2.33		
c (Cu)	1.93	2.60	2.33	2.29		
d (B)	4.73	4.83	5.46	5.01		
e (Mo)	1.90	2.23	2.43	2.19		
f (control)	0.16	0.66	0.66	0.49		
Mean:	2.25	2.24	2.60			

S.E.D. 0.33 ¦ C.D. at 5 percent ± N.S.

Table 28

Mean uptake of boron in grains (ppm) by hybrid bajara at harvest as affected by various treatments.

Sub plot treatments	Main plot treatments A	B	C	Mean	S.E.D.	C.D. at 5 per cent ±
					0.49	0.99
a (Mn)	2.90	1.56	2.36	2.27		
b (Zn)	2.76	2.56	3.10	2.81		
c (Cu)	3.03	2.93	3.10	3.02		
d (B)	7.70	9.60	7.76	8.35		
e (Mo)	3.23	4.03	4.03	3.76		
f (control)	0.83	0.53	0.66	0.67		
Mean:	3.41	3.53	3.50			

S.E.D. 0.32 ¦ C.D. at 5 percent ± N.S.

treatments viz. Mn, Mo, Cu and Zn, the boron uptake was ranging from 1.87 to 2.38 ppm and was at par.

Uptake of boron was not significantly influenced by the interaction of main x sub-plot treatments at flowering stage.

The data in table 28, revealed that, the main plot treatments viz. A,B and C did not help in increasing the uptake of boron in grains, the uptake being 3.41, 3.53 and 3.50 ppm respectively.

From the data on mean uptake of boron by grains, it can be seen that the uptake of boron was significantly more in boron treated plots. Sub plot treatments viz. Zn, Cu,Mo behaved similarly in uptake of boron giving 2.81, 3.02 and 3.71 ppm of boron respectively. Mo was significantly superior to Mn in inducing higher uptake of boron in grains; the uptake of boron in Mo treatment being 3.76 and that in Mn treatment being 2.27 ppm.

The application of Mn, Zn and Cu did not affect the boron uptake in grains but they are at par. The uptake ranged from 2.27 to 3.02 ppm. The uptake of boron in control was the lowest, being 0.67 ppm.

The interaction between uptake of boron in grains, NPK x micronutrients under study was found to be non-significant.

General conclusions

Based on the results obtained in tables 21, 22, 23, 24, 25, 26, 27 and 28 in field trial on hybrid bajara, the following broad conclusions can be derived:-

1. The range of dry matter produced at flowering stage varies from 6.90 to 19.6 gm, with an average value of 12.29 gm.

2. The grain yield varies from 19 to 48 gm with an average value of 29.62 gm.

3. The dry matter produced at harvest, ranges from 32 to 95.5 gm with an average value of 60.80 gm.

4. The uptake of boron at flowering, in straw ranges from traces to 5.5 ppm with an average value of 2.87 ppm. Uptake was significantly more in subplot treatments viz. Mn, Mo, Cu, Zn and B over control. The uptake was not significantly influenced by the interaction of main x subplot treatments at flowering stage.

5. The range of uptake in grains at harvest, is from traces to 11.1 ppm, average value being 3.48 ppm.

6. The main plot treatments viz. A,B and C did not help in increasing the uptake of boron in grains and the uptake being significantly more in boron treated plots.

7. No interaction between uptake of boron in grains NPK and micronutrients under study was observed.

8. The average dry matter produced at harvest is approximately five times more than that at flowering. The uptake in

straw at harvest is very less. The dry matter at harvest is double than the grain yield produced at harvest.

9. The mean yield of fodder at harvest was not significantly affected by either the main treatments or by the sub-treatments.

10. Similarly there is no significant effect on the mean yield of fodder at flowering by either the main treatments or sub-treatments.

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V GENERAL DISCUSSION :

Chapter V

GENERAL DISCUSSION

In view of its importance in many biochemical and physiological processesess, boron is considered to be an important plant nutrients amongst the micronutrients. It is of universal occurrence in living organisms and flowering plants cannot attain their full development in the absence of traces of this element. (Anon. 1967). It plays a multiple role in plant and animal production. Amongst the trace elements, boron has received a considerable attention in recent years owing to its role as a nutrient and due to its importance in deciding the quality of irrigation waters.

Boron exists in soil in variety of forms like water soluble or available boron, total boron and acid soluble boron. Available boron can be utilized by the plants in the form of available inorganic soil boron and available organic soil boron. The fraction of boron, soluble in hot water was found to be the most useful source for the plants (Berger and Truog, 1945).

These forms can vary in their proportion in different soils depending upon the nature of parent material from which the soils are derived (Mukerjee, 1957). The conversion of boron in an available form depends upon the rate of transformation of each form into lower form and the relative equilibrium between the process of microbial and adsorption in the the soils (Agarwal, 1964). A great number of factors are known to affect the boron availability in the soil, the most important soil factors being soil reaction, organic carbon, clay content and free lime status of the soil.

Numerous workers have done an intensive work on the various aspects of boron in soils and irrigation waters in abroad. In general, the work carried out in India is limited. In Maharashtra, except Bendale et al. (1951) Atre (1960) and Raut (1962), nobody has tried to assess the boron status of soils of Maharashtra State. Unlike the major nutrients, trace elements study did not receive adequate attention in the country in the past and the information collected is,therefore, fragmentory. Further, uptil now no body has tried to estimate the boron concentration in well waters from any part of Maharashtra State.

The values for two forms of boron i.e. total boron and water soluble boron indicated the average level of 9.41 ppm and 0.81 ppm respectively.

Based on the figures reported by Bendale et al (1951), it appears that soils of Maharashtra State are well supplied with this element and can supply enough quantity of boron in an available form. When compared with the Punjab soils, the soils from Maharashtra show a comparatively lower status in respect of both the fractions of boron.

The nature of parent material has got a positive effect on the level of different fractions of boron. This relationship is well illustrated in the values for boron in basaltic soils as compared to those derived from lateritic and mixed parent material. It is, further observed that, the contents of organic carbon and rainfall do not show any effect in increasing or decreasing the boron status of soils.

The relationship between the pH, organic matter, $CaCO_3$ and forms of boron as observed in the present work appears to be in well agreement with the results obtained by Ghani and Haque (1945) for East Bengal soil, Bhattacharjee (1956) for Murshidabad soils (West Bengal) and Gandhi and Mehta (1958) for Gujarath and Saurashtra soils. However, the results in the present investigation are in conflict with those reported by Paliwal and Anjineyulu (1967) in Delhi soils, Singh (1969) and Grewel et al. (1969) in Punjab soils and Mathur (1964), Baser and Saxena (1967) in Rajasthan soils.

From the standards suggested by various workers for the content of boron in soils, it appears that the soils from the Maharashtra State are well within the safe limit in respect of this element and are adequately supplied with it. [Richard et al. (1954); U.S.D.A. (1947)].

The values for boron obtained in the present study are somewhat lower than those reported by Atre (1960) for Vidarbha soils; while the values are higher than those obtained by Raut (1962) in typical soil profiles of Nagpur division. Soils from Maharashtra show a lower status for both the fractions of boron than the soils from Gujarat, Bengal, Rajasthan and Uttar Pradesh.

The ground well water samples analysed from different districts of Maharashtra State show the concentration of boron from 0.085 ppm to 0.31 ppm with an average content of 0.18 ppm in them. The values obtained in the present report are within the safe limit suggested by Magistad and Christensen (1944) and U.S.D.A.(1947).

The values obtained for pH in the present investigation are in accordance with those reported by Babreker, et al.(1965) for well water samples collected from College Farm, Dhulia. The ratio of Na/other cations mostly exceeds the safe limit of unity (Kelley 1940). The electrical conductivity of the ground well waters found to be varying from 0.76 millimhos/cm to 2.33 millimhos/cm, average being 1.27 millimhos/cm. In respect of total soluble salts, most waters cross the safe limit of 600 ppm, U.S.D.A.(1947).

No apparent relationship was found between pH and boron content of the water samples. These findings are in conflict with those reported by Singh and Kanwar (1963) for well waters from Patti (Amritsar). Similarly, there is no relationship between soluble sodium percentage, total soluble salts and the boron. However, with the higher values of S.A.R. and Residual Sodium Carbonate, subsequently higher concentrations of boron was found in the water samples.

Most of the well waters from different districts of Maharashtra fall under the category C_3S_1, U.S.D.A.(1947). Based on the values reported and quality predicted by various workers like Darra and Mehta (1963), Mathur et al.(1964) and

Nathani et al.(1966) for Rajasthan ground waters, it appears that ground well waters from Maharashtra are not so harmful than those of Rajasthan and can be used for irrigation purposes with little care and proper management.

The uptake of boron by different crops is governed by their boron requirements and boron supplying capacity of the soil, in a water soluble form. In the present investigation hybrid bajara (Pennisetum typhoides) was grown as a test crop under field condition with the application of varying doses of N.P.K. and usual doses of boron to determine its boron requirements. It appears from the findings that boron requirements of hybrid bajara is low and neither the application of varying doses of N.P. and K nor micronutrients affected the dry matter and grain yield. There is also, no effect of N.P.K. on uptake of boron. The uptake being more in grains than in the straw, but it has not been utilized to improve any of the characteristics of the crop and hence, it can be said that, the crop might have taken boron for its luxury consumption. A similar negative effect has been observed by Pandya et al.(1955) and Kulkarni et al.(1970) in their field trial at various Research Centres. The observations in the present report are in accordance with those reported by Joshi (1955) on jowar grown under field conditions.

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VI SUMMARY A N D CONCLUSIONS :

Chapter VI

SUMMARY AND CONCLUSIONS

Laboratory and field studies were undertaken to assess the boron status of soils and ground well waters of Maharashtra State and to find out the boron requirements of hybrid bajara (*Pennisetum typhoides*) grown as a test crop on a medium black calcareous soil.

For this purpose 40 soil samples representing six major Zones (9 sub-zones) and 292 ground well water samples collected from eight different districts of Maharashtra State were analysed for different fractions of boron in soils and concentrations of it in ground well waters.

To determine the boron requirements of *hybrid bajara*, it was grown under field condition as a test crop and the production of dry matter and boron uptake at various stages viz. tillering, flowering and harvesting was determined. The uptake at harvest was determined separately in straw and grains. The observations recorded in these studies are summarised below:-

1) The level of total boron in Maharashtra soils varies from 2.75 to 20.90 ppm with an average value of 9.41 ppm.

2) The water soluble boron constitutes a very small proportion (3.38 percent) of total boron and varies from 0.10 to 0.93 ppm with an average value of 0.31 ppm.

3) Forty percent of the total soil samples fall in the range of 5-10 ppm of total boron, 37 percent-10 to 15 ppm,

15 percent show a status less than 5 ppm and only 8 percent of the total samples show a range higher than 15 ppm.

4) Eighty-two percent of the total samples contain between 0.0 to 0.1 ppm of water soluble boron, 11 percent more than 0.1 ppm, 16 percent more than 0.2 ppm and only one percent of the samples were found to contain 0.3 ppm.

5) Based on the average values for different fractions of boron, soils from Maharashtra State appear to be well supplied with this element and are within the safe limit.

6) Soil derived from basalt show comparatively higher proportion of both the fractions of boron as compared to the soils derived from mixed parent material. Soils of lateritic origin show an intermediate trend.

7) The soil attributes like pH, free $CaCO_3$, organic carbon, clay content showed no relationship with the two fractions of boron.

8) The boron in well waters from different districts of the State varies from 0.085 ppm to 0.31 ppm with an average value of 0.18 ppm.

9) Eighty percent of the well waters studied in the present investigation fall in the range of traces to 0.1 ppm, 11 percent in the range of 0.1 to 0.2 ppm, 6 percent in 0.2 to 0.3 ppm and very few samples show a range more than 0.3 to 0.5 ppm.

10) The well waters from districts like Dhulia, Jalgaon and Sholapur are higher in their contents of boron as compared to other districts.

11) Amongst the districts studied, the well waters from Sangli and Poona districts show the lowest value for their boron contents while waters from Dhulia are highest.

12) The waters from Akola, Amraoti, Buldhana and Sholapur districts show higher pH than the rest of the districts. The water samples in all cases are alkaline to moderately alkaline in reaction.

13) Total soluble salts content of the water under study, ranges from 481 ppm to 2033 ppm with an average value of 892 ppm. The waters from districts like Sholapur, Jalgaon, Sangli and Amraoti are higher in their T.S.S. as compared to other districts.

14) The carbonates in different well waters vary from traces to 1.23 meq/litre with an average value of 0.845 meq/litre. The amount of bicarbonates in different waters ranged from 5.72 meq/litre to 9.89 meq/litre with an average value of 7.28 meq/litre. The range of chlorides in different waters is from 4.19 meq/litre to 57.46 meq/litre with an average value of 18.27 meq/litre.

15) The values for magnesium in the waters in relation to calcium are higher in most cases.

16) The ratio between Na to (Ca +Mg)-Kelley's Na ratio - exceeds the safe limit of unity in majority of samples.

17) Fifty percent of the water samples fall below the safe limit of 2.5 meq/litre of R.S.C. while 50 percent show higher R.S.C. than the safe limit.

18) All the water samples fall below the safe limit of S.A.R. values namely - 0-10.

19) The soluble sodium percentage in all the cases is more or less the same excepting few and in most cases well within the safe limit of 60 percent.

20) No relationship between boron and pH, S.S.P., T.S.S. is observed, while there is an apparent relationship between R.S.C. and S.A.R. in some cases. With the increase in these values, there is subsequent increase in the boron concentration.

21) All the well waters under study exhibit the quality of water as C_3S_1.

22) The uptake of boron at flowering stage in bajra straw ranges from traces to 5.5 ppm with an average value of 2.37 ppm. Uptake was significantly more in sub-plot treatments viz. Mn, Mo, Cu, Zn and B over control. It was not significantly influenced by the interaction of main x sub-plot treatment at flowering stage.

23) The fertilizer application of nitrogen, phosphorus and potash did not help in increasing the uptake of boron in grains, however, the uptake was significantly more in boron treated ~~soils~~ plots.

24) There appears to be no interaction between the uptake of boron by bajara plants and the application of N,P and K and the micronutrients.

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Chapter Opener Page

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