MICRONUTRIENT STATUS OF PRINCIPAL SOIL TYPES OF UTTAR PRADESH

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ABSTRACT

Study has been made of the total and available micronutrients—iron, manganese, copper, zinc, molybdenum and boron—in six representative profiles drawn from each of the principal soil types of Uttar Pradesh—Tarai, Bhabhar, Vindhyan, Bundelkhand (types IB-Rakar and IIA-Parwa) and Alluvial (arid and semi-desert). The total content of these micronutrients, as also the fraction of the total that can be extracted in chemical extractants indicating plant availability, have been found to show marked differences in the different soil types. Alluvial soils are found to be very low in total as well as available molybdenum. Available boron in semi-desert Alluvial soils and available copper in most Alluvial and Tarai soils are also very low. Values of available molybdenum and available copper in many Alluvial soils are markedly lower than the corresponding values reported for other world soils. Information presented suggest that low availability of molybdenum in Alluvial and Rakar type of Bundelkhand soils and that of zinc in Tarai and Bhabhar soils may be an outcome of the low soil reserve of these elements. But reduced availability of iron and boron in most Alluvial soils is a function of factors other than their total soil reserve.

INTRODUCTION

Adequate supply of essential plant nutrients in soils is an essential prerequisite for efficient crop production. In order to ensure this and to make a proper appraisal of the long term fertilizer needs of plants, it is necessary to obtain information not only on the available plant nutrients but also on their total content in soils. This information is particularly useful in the case of micronutrients for, if the total quantity of particular micronutrients in a soil is high and their availability low, their addition to soil may show immediate crop improvement but may subsequently create toxicity problems. In such a situation it might be more desirable to raise the available quantity of the micronutrient by judicious soil management or by growing crop varieties resistant to particular micronutrient deficiencies.

In spite of the great importance for the study of total and available micronutrients in the important soil types of India, such information is very scanty (KANWAR & RANDHAWA, 1974). This paper describes the depth-wise distribution of total and available micronutrients in the six major soil types of Uttar Pradesh.

MATERIAL AND METHODS

Representative profile samples (0 to 90 cm deep) were collected from the six major soil types of Uttar Pradesh mentioned below:

(i) *Tarai soils* (district Nainital); 6 profiles—R1 to R6.
(ii) *Bhabhar soils* (district Nainital); 6 profiles—H1 to H6.
(iii) *Vindhyan soils* (districts Varanasi and Mirzapur): 6 profiles—M1 to M6.
(iv) (*a*) *Bundelkhand type IB-Rakar soils* (district Jhansi): 3 profiles—J1 to J3.

(iv) (*b*) *Bundelkhand type* IIA-*Parwa soils* (district Jhansi): 3 profiles—J4 to J6.
(v) *Arid Alluvial soils* (district Lucknow): 6 profiles—L1 to L6.
(vi) *Semi desert Alluvial soils* (districts Agra and Mathura): 5 profiles—A1 to A5.

Samples for estimation of total and available micronutrients were prepared by drying the soils on a polythene sheet, grinding them in an electrically driven agate pestle and mortar, and screening through muslin cloth. Total quantities of iron, manganese, copper, and zinc were extracted with hydrofluoric acid (JACKSON, 1958). Total boron was brought into solution by fusing the soil with sodium carbonate and dissolving the melt in HCl (JACKSON, 1958). Total molybdenum was estimated according to the procedure described by CHATTERJEE AND AGARWALA (1971). Available micronutrients were extracted as under:

Iron: Normal ammonium acetate pH 3.0 (JACKSON, 1958).
Manganese: Exchangeable-normal ammonium acetate pH 7.0 (JACKSON, 1958).
Copper and Zinc: 0.1 N hydrochloric acid (WEAR AND SOMMER, 1948).
Molybdenum: Bioassay using *Aspergillus niger* M. strain (NICHOLAS & FIELDING, 1951).
Boron: Hot water extraction (BERGER & TRUOG, 1944).

Iron was estimated as ferrous-o-phenanthroline complex (HUMPHRIES, 1956), Zinc as zinc dithizonate (COWLING & MILLER, 1941), and boron as its carmine complex (HATCHER & WILCOX, 1950). Copper was estimated as copper carbamate by the PIPERS' (1942) modification of the method given by SYLVESTER AND LAMPITT (1940). Manganese and molybdenum were estimated by two alternative methods. When in low concentrations manganese was estimated by the tetrabase method (NICHOLAS & FISHER, 1950), and molybdenum by the bioassay method using *Aspergillus niger* M. strain (HEWITT & HALLAS ,1951). When present in the sufficiency range, manganese was estimated by the periodate method (COLEMAN & GILBERT, 1939) and molybdenum as its dithiol complex (PIPER & BECKWITH, 1948).

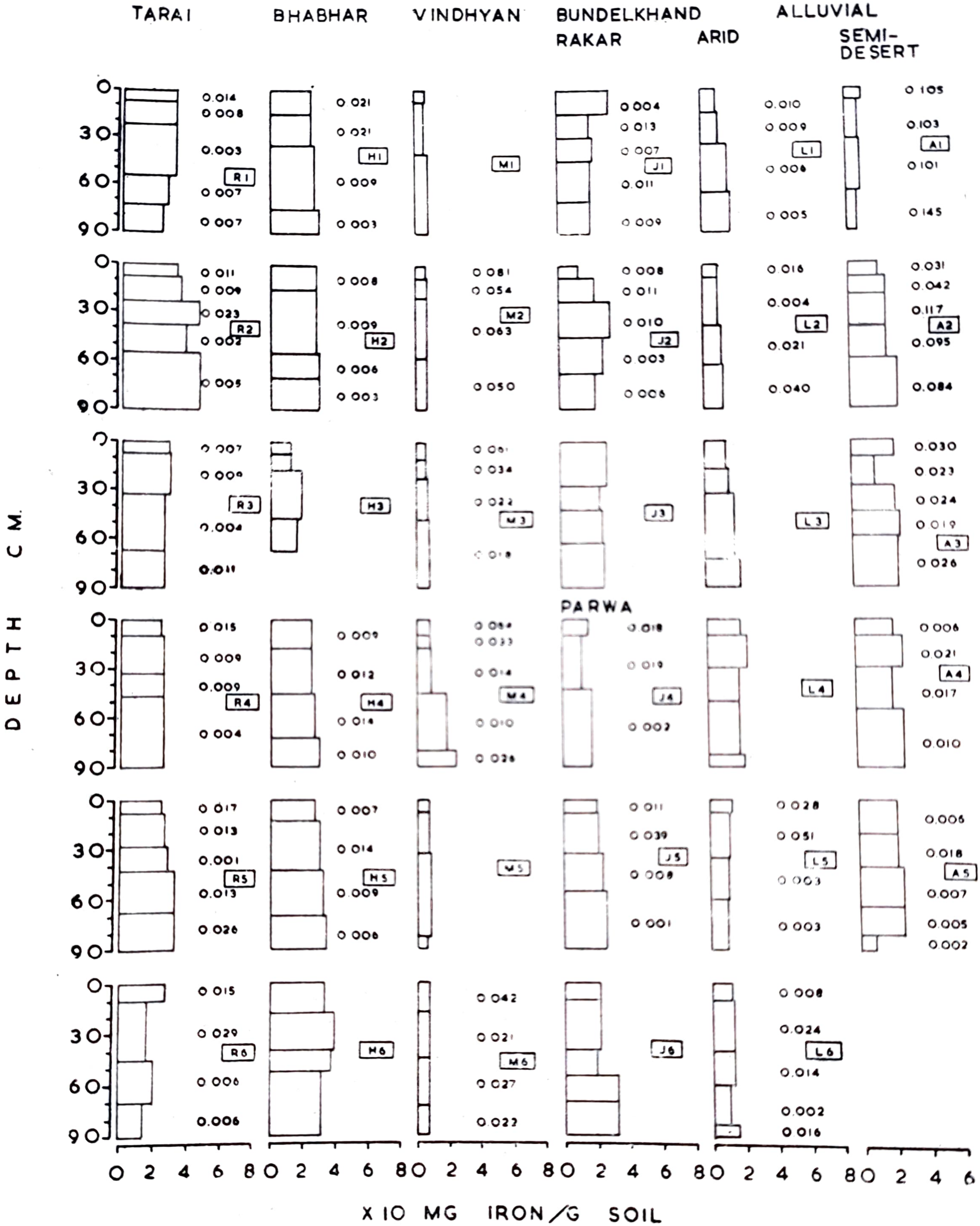
RESULTS AND DISCUSSION

IRON

The total iron content of the six U. P. soil types examined here ranged from 5.6 to 45.6 mg/g and resembled the order of the magnitude of total iron reported for other soils of U. P. (GANGWAR, MANN & SHARMA, 1971; KANWAR & RANDHAWA, 1974; MISRA & PANDE, 1975) and other states of India (KANWAR & RANDHAWA, 1974). Compared to Vindhyan and arid Alluvial soils, the total iron content was higher in Tarai (14.8 to 45.6 mg/g), Bhabhar (12.0 to 38.9 mg/g) and Bundelkhand (12.0 to 32.3 mg/g) soils. The Vindhyan soils were comparatively low in total iron (5.6 to 24.4 mg/g). In general, total iron did not show any definite trend in depthwise distribution (Text-fig. 1).

Available iron did not bear any relation to the total iron content of soils. Nor was it related to the soil parent material. While the parent material of Rakar and Parwa types of the Bundelkhand soils was essentially similar, their available iron content showed a marked difference. The same was true of the arid and semi-desert Alluvial soils. In Vindhyan soils which were relatively low in total iron appreciably high (0.010 to 0.082 per cent) proportion of the total iron formed the available fraction (Text-fig. 1).

The available iron content of the different soil types examined here ranged from 0.25 to 25.75 ppm, an order of magnitude not much different from that reported by other workers for most soils of U. P. (GANGWAR, MANN & SHARMA, 1971; KANWAR & RANDHAWA,



Text-fig. 1 Distribution of total and available iron in the profiles of major soil types of Uttar Pradesh. Boxed numbers indicate the profile number and the figures against different horizons in a soil profile indicate available iron as percentage of the total.

1974; MISRA & PANDE, 1975) and other states of India (KANWAR & RANDHAWA, 1974). Compared to the other soils, the available iron content of Bundelkhand type IB Rakar soils and most of the arid Alluvial soils was low. Taking 6.0 ppm as critical limit of available iron (BRYAN, 1958), 6 out of the 7 profiles from the former and 16 out of the 17 samples drawn from the latter indicated deficiency of iron. In Bundelkhand, Alluvial and Bhabhar soils available iron did not show any definite trend in depth-wise distribution, but in most profiles of Tarai and Vindhyan soils, available iron showed a decrease with increase in the depth of the profiles. GANGWAR, MANN AND SHARMA (1971) also made similar observations for the Tarai soils of Nainital district.

MANGANESE

The total manganese content of the different soil types examined showed a wide variation (Text-fig. 2). Most of the Bhabhar soil profiles developed on colluvial deposits of Himalayan origin were high (340 to 1600 ppm) in total manganese. In the other soils, total manganese ranged between 107 and 709 ppm. Except in some arid Alluvial and Rakar type of Bundelkhand soils, total manganese did not show any definite trend in depth-wise distribution. In the Vindhyan soil profiles and in certain other profiles of arid and semi-desert Alluvial soils, total manganese was fairly uniformly distributed throughout the profile (Text-fig. 2). Similar observations have earlier been made for total manganese in some desert and old Alluvial soils (LAL & BISWAS, 1974).

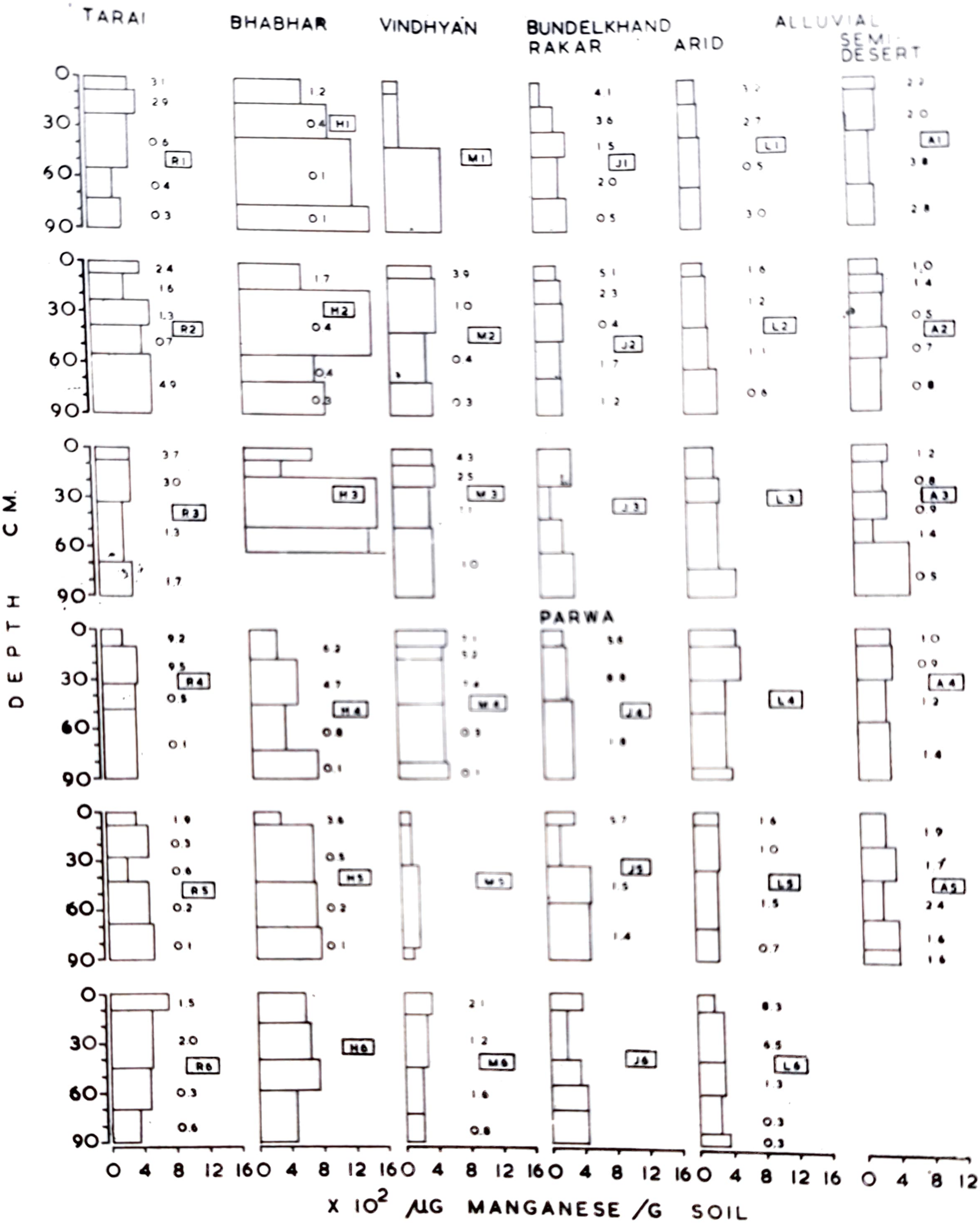
As has been observed in case of Gujarat (MEHTA & PATEL, 1967) and most other soils of India (KANWAR & RANDHAWA, 1974) in the soils examined here also, the available (exchangeable) manganese was not related to the total manganese content of the soils. In most instances, soils with higher total manganese showed a lower availability of manganese than soils low in total manganese (Text-fig. 2).

The available manganese content of the soils under study varied from 0.4 to 119 ppm. These values are, in general, lower than those reported by others (KANWAR & RANDHAWA, 1974). TEWARI, MISRA, OJHA AND MISRA (1969) observed that Alluvial soils of Ballia district in U. P. contained upto 450 ppm exchangeable manganese, whereas in the present investigations the exchangeable manganese in arid Alluvial soils ranged between 1.24 and 7.1 ppm and that in semi-desert Alluvial soils between 2.0 and 10.5 ppm. In fact, amongst the soils examined, the Alluvial soils were the lowest in exchangeable manganese. If 3 to 5 ppm exchangeable manganese is taken as the critical limit for manganese deficiency, as has been suggested by HEINTZE (1946) and TOTH (1951), a large number of soil horizons in the profiles of Alluvial soils would indicate deficient or marginal availability of manganese.

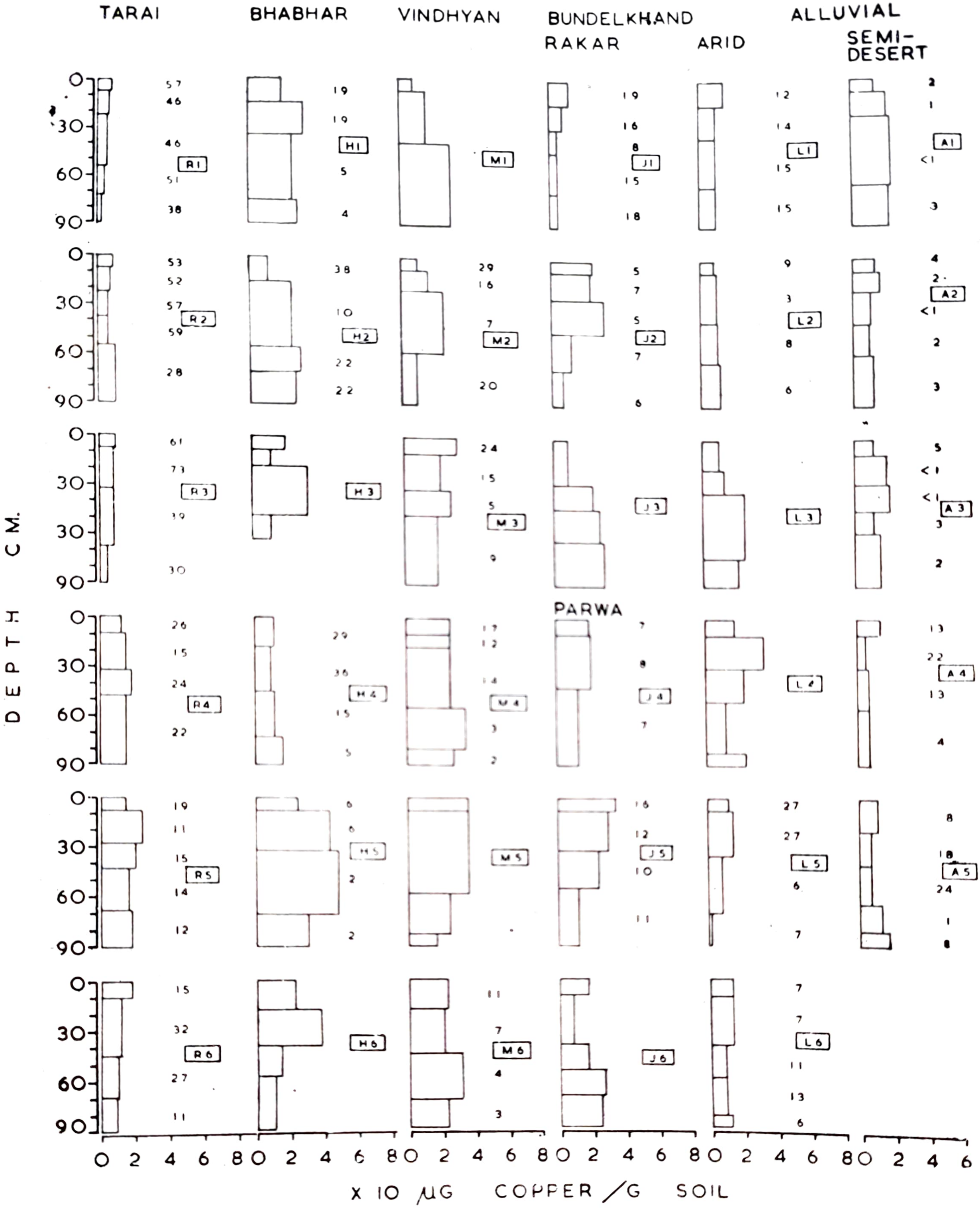
In general, except in the semi-desert Alluvial soils, available manganese decreased with increase in the depth of the profile. This observation is in accord with many others (MEHTA & PATEL, 1967; MISRA & TRIPATHY, 1972; KANWAR & RANDHAWA, 1974; LAL & BISWAS, 1974). The higher accumulation of manganese in surface horizons could well be attributed to relatively higher organic matter associated with these horizons.

COPPER

The total copper content in the profiles drawn from the six major soil types of U. P. ranged from 1.8 to 49.3 ppm (Text-fig. 3). Compared to the Bhabhar, Vindhyan and Parwa type of Bundelkhand soils, copper content of which ranged between 8 and 50 ppm, the total copper content of the Tarai, semi-desert Alluvial and arid Alluvial soils was low (1.8 to 35 ppm). The total copper values in some of the horizons of these soil profiles con-



Text-fig. 2—Distribution of total and available manganese in the profiles of major soil types of Uttar Pradesh. Boxed numbers indicate the profile number and the figures against different horizons in a soil profile indicate available manganese as percentage of the total.



Text-fig. 3—Distribution of total and available copper in the profiles of major soil types of Uttar Pradesh. Boxed numbers indicate the profile number and the figures against individual horizons in different soil profiles indicate available copper as percentage of the total.

tained such low values of total copper as have not been reported earlier for any soil of U. P. (MISHRA, TRIPATHY & DAYAL, 1969; SINGH & SINGH, 1967a), other states of India (KANWAR & RANDHAWA, 1974) or generally in any of the typical world soils (WIKLANDER, 1958; MITCHELL, 1964).

As has been observed by MISHRA, TRIPATHY AND DAYAL (1969) for some soils of U. P. and by KANWAR & RANDHAWA (1974) for other Indian soils, most soil profiles examined here did not show any definite trend in depth-wise distribution of total copper.

Available copper ranged from 0.088 to 1.787 ppm in semi-desert Alluvial soils to about five times more, 0.62 to 7.72 ppm, in the Vindhyan soils. Thus, the upper limit of available copper in any of the U. P. soils under study was much lower than the upper limit of available copper (16.8 ppm) reported for other Indian soils (KANWAR & RANDHAWA, 1974). If 1.6 ppm 0.1N HCl extractable copper is taken as the critical limit for deficiency, 80 to 90 per cent samples of arid and semi-desert Alluvial soils would indicate deficiency of copper for normal plant growth.

In the Vindhyan soil profiles, the fraction of the total copper that constituted the available copper decreased with increase in the depth of the profile. In the other five soil types, available copper did not show any definite trend in depth-wise distribution.

ZINC

The total zinc content in the profiles of the major soil types of U. P. ranged between 13 and 382 ppm. Generally, there were large differences in the total zinc content of the different soil types examined (Text-fig. 4), and on the basis of their total zinc content, these soils could be arranged in the decreasing order: Bundelkhand type IIA—Parwa (65 to 384 ppm), Bundelkhand type IB—Rakar (36 to 348 ppm), Vindhyan (30 to 124 ppm), arid Alluvial (31 to 109 ppm), semi-desert Alluvial (34 to 94 ppm), Bhabhar (13 to 95 ppm), and Tarai (13 to 96 ppm). Thus, of the six major soil types, the Tarai and Bhabhar soils were relatively low in total zinc. TRIPATHI, MISHRA AND DAYAL (1969) and VITTAL AND GANGAWAR (1974) also reported Tarai soils of U. P. to be low in total zinc.

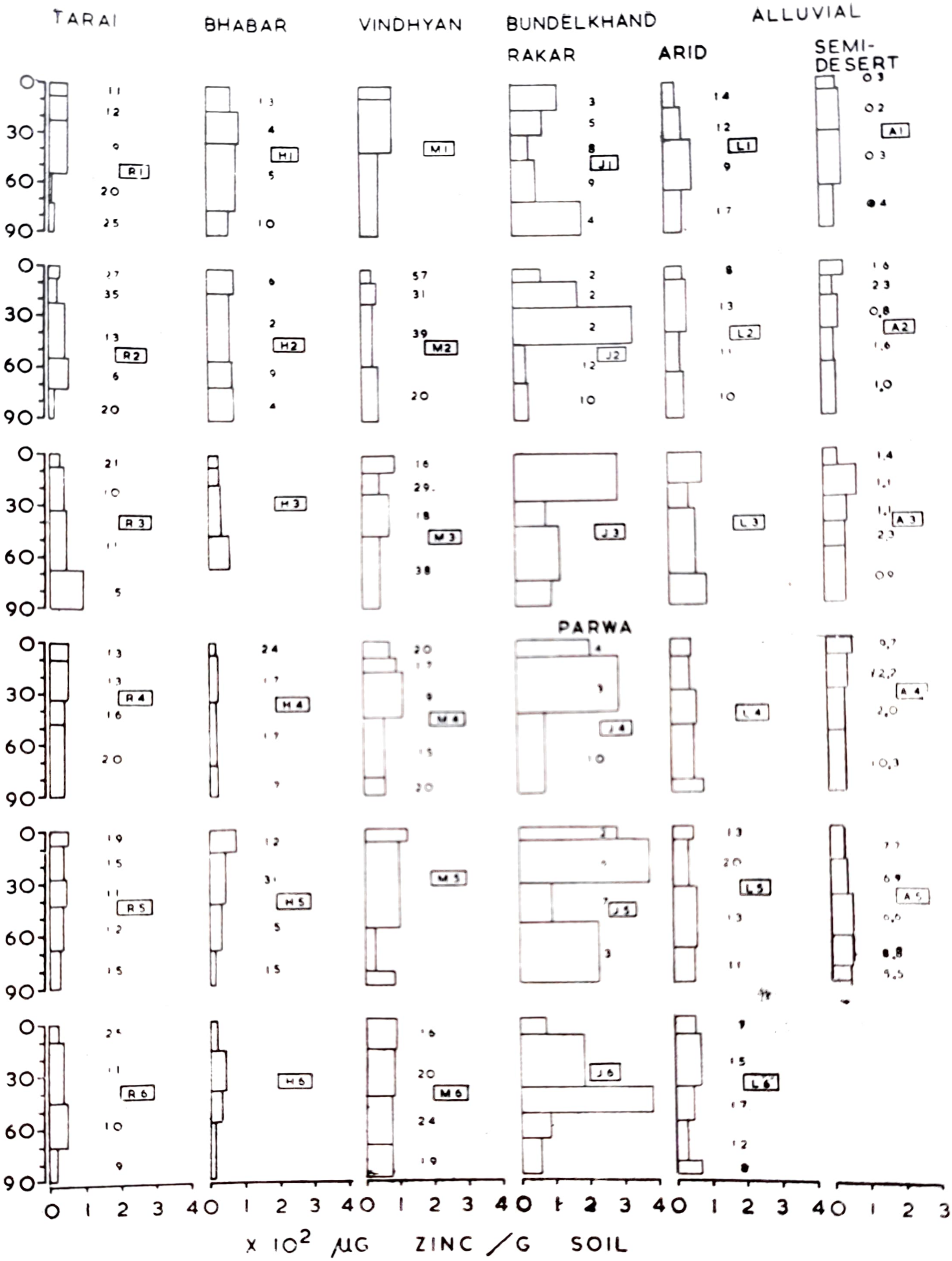
Available zinc in the soil profiles examined here ranged from 0.15 to 21.45 ppm. On the basis of available zinc the six soil types examined here could be arranged in the decreasing order: Vindhyan (6.7 to 18.2), Bundelkhand type IIA-Parwa (5.2 to 21.5 ppm) arid Alluvial (3.8 to 10.0 ppm), Bundelkhand type IB-Rakar (1.7 to 8.5 ppm), Tarai (1.6 to 9.0 ppm), Bhabhar (1.4 to 14.1 ppm), semi-desert Alluvial (0.15 to 8.5 ppm). The available zinc content of some semi-desert Alluvial soils was particularly low and suggestive of its deficiency for plant growth.

The fraction of the total zinc that constituted its available form showed marked variation in the different soil types (Text-fig. 4). While in the Vindhyan soils a very large percentage (9 to 57%) of the total zinc could be extracted as available zinc, in the semi-desert Alluvial and Bundelkhand soils a very small fraction ($<10\%$ of the total) could be extracted in the available form (Text-fig. 4). In some horizons of the semi-desert Alluvial soil profiles (Text-fig. 4) this fraction was particularly low ($<1\%$).

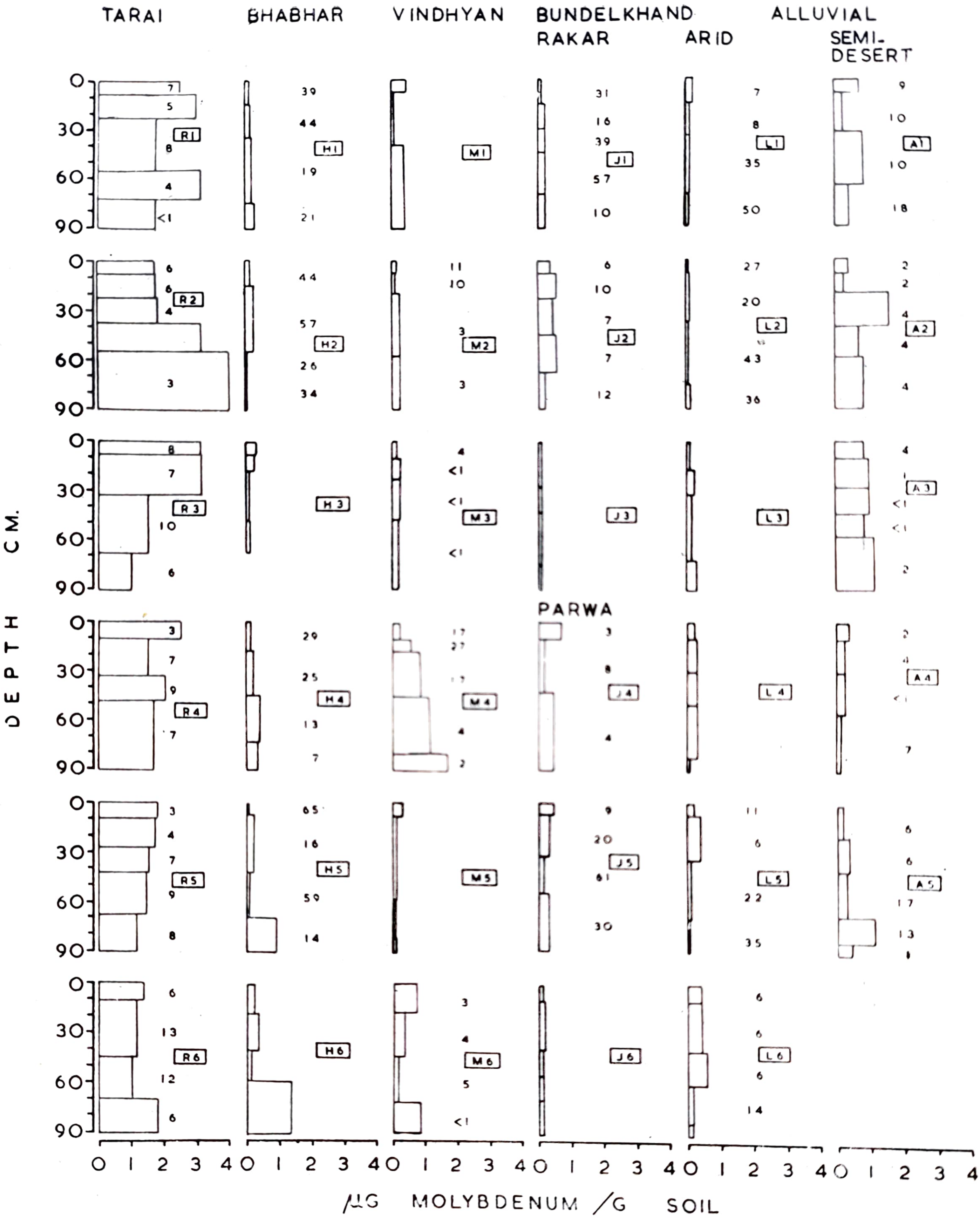
Total, as also the available zinc, in the different soil profiles examined did not show any definite trend in depthwise distribution.

MOLYBDENUM

The total molybdenum content of the U. P. soils examined here ranged from 0.049 to 3.15 ppm (Text-fig. 5). Amongst the six soil types examined the highest content of total molybdenum (1.0 to 3.15 ppm) was found in the Tarai soils. PATHAK, SHANKER



Text-fig. 4—Distribution of total and available zinc in the profiles of major soil types of Uttar Pradesh. Boxed numbers indicate the profile number and the figures against individual horizons in different soil profiles indicate available zinc as percentage of the total.



Text-fig. 5—Distribution of total and available molybdenum in the profiles of major soil types of Uttar Pradesh. Boxed numbers indicate the profile number and the figures against individual horizons in the different soil profiles available molybdenum as percentage of the total.

AND MISRA (1968) and MISRA AND MISRA (1972) also observed similar values in these and some other soils of U. P. In comparison to the Tarai soils, the molybdenum content of the other five soil types was low (0.049 to 1.68 ppm). The Bhabhar, the Rakar type of Bundelkhand soils and the arid Alluvial soils were particularly low in molybdenum (Text-fig. 5). The total molybdenum content of these soils ranged from 0.050 to 1.364, 0.099 to 0.573 and 0.049 to 0.545 ppm respectively. In fact, many of these soils contained considerably less molybdenum than the lowest values of total molybdenum reported in any soil of the world (MITCHELL, 1964). So far the lowest value of total molybdenum has been reported from the Nelson district of New Zealand. These soils are reported to contain 0.03 to 0.05 ppm molybdenum that can be extracted in HCl (RIGG, 1953). Some of our soils contained about the same values of total molybdenum which forms a larger bulk than the HCl extractable molybdenum. It thus appears that the soils under study have the lowest molybdenum content known so far in any soil.

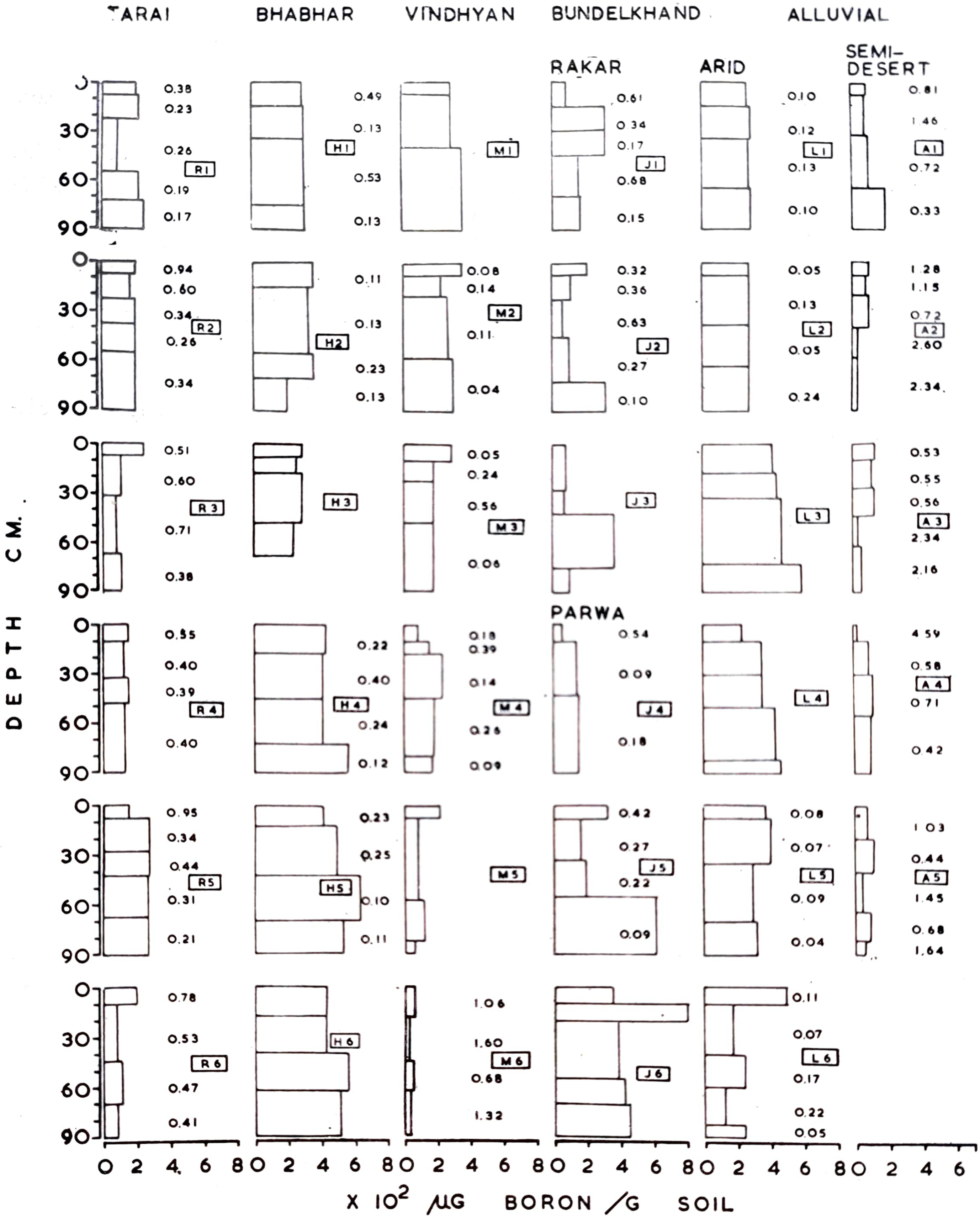
Total molybdenum did not show any definite trend in depth-wise distribution (Text-fig. 5).

As in case of total molybdenum, Tarai soils were also rich in available molybdenum. Available molybdenum in these soils ranged from 0.056 to 0.25 ppm. Concentration of available molybdenum in the other five soil types was considerably lower. On the basis of the available molybdenum content these soils could be arranged in the decreasing order; Tarai, Bhabhar, semi-desert Alluvial, Bundelkhand type IIA-Parwa, Bundelkhand type IB-Rakar, Vindhyan, and arid Alluvial. Taking 0.03 ppm molybdenum as the critical limit for deficiency (NICHOLAS & FIELDING, 1951), Tarai and Bhabhar soils could be rated as sufficient in available molybdenum. But the other soil types—Alluvial (both arid and semi-desert), Vindhyan and Bundelkhand (both Rakar and Parwa) indicate a deficiency of molybdenum. Some semi-desert soils of Mathura and Agra districts were extremely low in available molybdenum. The values of available molybdenum encountered in some of these soil profiles, as for example in the 30 to 55 cm horizon of the profile A4 from Jagner in Agra district, were markedly lower than the lowest values of available molybdenum (0.015 ppm) reported for any soil of the world (NICHOLAS & FIELDING, 1951). These observations are, however, not in conformity with SINGH AND SINGH (1966), PATHAK, SHANKER AND MISRA (1968) and MISRA AND MISRA (1972) who reported considerably higher values of molybdenum in some of the above soil types.

In the Bundelkhand (both Rakar and Parwa) and Alluvial (both semi-desert and arid) soil profiles, available molybdenum increased with increase in the depth of the profile. Trend in the depthwise distribution of molybdenum in the other soil types generally varied from profile to profile.

BORON

The total boron content of the six soil types of U. P. examined here showed wide variation (Text-fig. 6). The highest values, 202 to 630 ppm, were found in the Bhabhar soils and the lowest, 20 to 203 ppm, in the semi-desert Alluvial soils. The difference in the total boron content of the semi-desert Alluvial and arid Alluvial soils was marked. The boron content of the former being 1/3 to 1/5 that of the latter. In general, the total boron content of the U. P. soils examined here was considerably higher than that reported for other soils of India—3.75 to 100 ppm (KANWAR & RANDHAWA, 1974) and most other soils of the world—3.8 to 95 ppm (MITCHELL, 1964). In general, total boron did not show any definite trend in relation to the depth of the soil profile (Text-fig. 6).



Text-fig. 6—Distribution of total and available boron is profiles of major soil types of Uttar Pradesh. Boxed numbers indicate the profile number and the figures against individual horizons in different soil profiles indicate available boron as percentage of the total.

Availability of boron was generally inversely related to the total boron content of the soil In the semi-desert Alluvial soils, which contained the lowest amount of total boron, available boron constituted the largest fraction (0.33 to 4.95%, average 1.26%) of the total. On the other hand, in the arid Alluvial soils which were relatively rich in total boron, available boron constituted a relatively small fraction (0.04 to 0.24%; average 0.083%) of the total.

Available boron content of the soils differed considerably. Compared to other soils, the Tarai soils contained an appreciably higher concentration of boron (0.33 to 1.83 ppm). These values are considerably higher than those reported by NENE (1966). The other soils contained relatively less (0.113 to 1.64 ppm) boron in the available form. The lowest values of available boron (0.113 to 0.98 ppm) were found in the Vindhyan soils. The arid Alluvial soils also contained comparatively low values of available boron (0.121 to 0.686 ppm). Earlier, SINGH AND SINGH (1967b) reported even lower (0.09 ppm) values of available boron in some of the Alluvial soils of the State.

In Tarai soils, available boron decreased with increase in the depth of the profile. In the other soil types available boron did not show any definite trend in depthwise distribution.

CONCLUSIONS

The different soil types of Uttar Pradesh—Tarai, Bhabhar, Vindhyan, Bundelkhand and Alluvial—differ in the total and available quantities of the micronutrients. Profile samples drawn from all except the Tarai soil type reveal a potential deficiency of molybdenum that can largely be attributed to the low values of total molybdenum in these soils. Available molybdenum content of the Alluvial soils suggests that molybdenum may have a limiting effect on the productivity of crops grown in these soils, especially that of high molybdenum requiring crops like the brassicae and the legumes. The Alluvial soils are also low in both total and available manganese and copper.

Each of the different soil types examined appear to be adequate in total iron. The low availability of iron in the arid Alluvial and Rakar type of Bundelkhand soils seems to be a function of some soil characteristics (like alkaline reaction, high calcareousness) that may limit its availability, inducing iron chlorosis so widely observed in these soils.

Large differences were observed in the fraction of total zinc that could be considered as available to plants. That a sizeable proportion of the total zinc in Tarai and Bhabhar soils, which are otherwise low in it, form the available fraction, suggest that, unless somehow cycled back, these soils may soon be exhausted in this micronutrient and this may severely limit crop production. Zinc deficiency caused by restricted release of zinc from the total to the available form in the semi-desert Alluvial and Bundelkhand soils could be more advantageously overcome by adopting such agronomic practices as may render a larger proportion of the total soil zinc into the available form. Somewhat similar situation exists in respect of boron in arid Alluvial soils for while their available boron content is low they are fairly high in total boron.

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