Manganese Status of Rice Soils of Kerala

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It is an established fact that manganese, like iron, is required for the nutrition of the rice plant in much larger amounts than the other micronutrients. It plays a vital role as activator in many enzymatic reactions in plants and its essentiality for optimum growth and yield of rice is now widely recognised.

The distribution of manganese in soils is governed by several factors. According to Leeper (1947) the weathering of minerals, pH, calcium carbonate content, leaching, mineralisation of organic matter and the oxidation reduction potential in soils considerably influence the level and availability of this micronutrient. The manganese status of Indian soils has been evaluated by Iyer and Rajagopalan (1936), Hoon and Dhawan (1943), Bhattacharya *et al* (1953), Mital and Roy (1953), Khanna *et al* (1954), Sharma and Motiramani (1964) and many other workers. Very few of these investigations, however, relate to rice soils. Dhamija *et al* (1956) in a study of the different categories of manganese in profiles of rice soils of Bihar, Uttar Pradesh and Punjab under varied climatic conditions concluded that the distribution of this element in soils depended on pH and organic matter content more than any other factor. They pointed out that in submerged rice soils the danger seems to be not in a deficiency of manganese, but in an excess of this element present in the soluble form which causes toxicity to the growing crop. In acid soils the danger of manganese toxicity is much greater than in soils of alkaline reaction. Aiyer (1946) opined that excess of manganese may render the Fe: Mn ratio unfavourable to rice. Mandal (1962) attributed the better growth of rice in waterlogged soil partly to the increased amount of manganese that goes into solution under the low oxygen tension prevalent in the soil solution under submerged conditions. Johnson (1924) suggested that excess manganese may be a factor in the causation of physiological diseases of rice.

In the light of the above observations, it is obvious that precise information on the amount and availability of manganese in soils is necessary for the successful cultivation of rice. The data now available on the manganese status of rice soils in India, especially in the submerged state, is very meagre. In the present investigation an attempt has been made to determine the distribution pattern of the different forms

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of manganese in some typical profiles of rice soils of Kerala and to evaluate their relation with soil characteristics. Rice is grown in this State on a variety of soils mostly under waterlogged conditions. The total area under this crop is nearly two million acres and the great majority of these soils are acid in reaction. The results of this study are reported in this paper.

Manganese occurs in the soil in different forms with divergent solubility and of unequal availability to plants. Sherman and Harmer (1942) arbitrarily classified soil manganese into three categories, viz., (i) water soluble, (ii) exchangeable, and (iii) easily reducible. Water soluble and exchangeable manganese consist of divalent manganous ions which are immediately available to plants. Easily reducible manganese is that portion of the higher oxides of this element which is reduced by readily oxidisable organic compounds, such as hydroquinone at pH 7.0. This category serves as a source of manganese to plants under suitable conditions and may be absorbed either directly in the colloidal form or by reduction at the root surface. The sum of the water soluble, exchangeable and easily reducible forms constitutes the available or "active" manganese as it is called. Although the total manganese in the soil is of secondary importance for plant growth, its significance should not be minimised as it is an index of the potential supply of this micronutrient. In the work reported here all the forms of manganese mentioned above have been studied, viz., water soluble, exchangeable, easily reducible, active and total.

Metcrials and Methods

The material for this study consisted of six typical profiles of cultivated soils from important rice growing regions in Kerala. Examination of the profiles showed that there was no clear horizon differentiation in any of them. Consequently, each profile was divided arbitrarily into two horizons, viz., a surface horizon (0-22 cm) and a subsurface horizon (22-75 cm). As the roots of the rice plant seldom go beyond 75 cm. it was felt that there was no need to examine the soils at greater depths. Horizon samples were collected from the profiles in the submerged state before the crop was planted. Samples were also collected from the same fields under dry conditions after harvest with a view to determining the influence of submergence on the different categories of manganese.

Standard procedures described by Piper (1952) and Jackson (1962) were adopted for the analysis of the soil samples. Mechanical composition was determined by the International Pipette method. Organic carbon was estimated by the rapid titration method of Walkley and Black. Soil reaction was measured in a 1 : 2.5 soil-water suspension using a Beckman pH meter. Cation exchange capacity was determined by leaching the soil with neutral normal ammonium acetate.

Manganese was estimated by Leeper's method as modified by Sherman *etal(l942).* Water soluble, exchangeable and reducible manganese were extracted from soil with distilled water, neutral normal ammonium acetate, and normal ammonium acetate containing 0.2 per cent hydroquinone respectively. Total manganese was determined in the fusion extract of soil with 1:1 hydrochloric acid. Manganese was estimated in the various extracts colorimetrically by the periodate method using a Klett colorimeter with a green filter (520 $m\mu$).

Results and Discussion.

Data pertaining to the mechanical composition of the soils used in this investigation are presented in Table I.

TABLE I

Mechanical Composition of Soils

Proile No.	Locality	Depth (cm)	Coarse sand %	Fine sand %	Silt %	Clay %	Textural class
I.	Pattambi	0-22	35,,8	23.6	9.3	29.3	sandy clay loam
		22-75	56 ?	17.3	11.5	18.2	sandy loam
II.	Monkompu	0-22	2,5	17.4	22.0	57.8	clay
		22-75	0•4	3.8	37.3	57.9	silty clay
HI.	Taliparamba	0-22	34.1	11.3	8.2	49.0	sandy clay
		22-75	49.4	10.9	10.5	30.7	sandy clay loam
IV	Mannuthy	0-22	41.7	12.2	5.2	40.1	sandy clay
		22-75	61.6	13.4	3.6	27.5	sandy clay loam
V.	Vechoor	0-22	...	1 8	21.3	69.9	clay
		22-75	I).1	1.4	47.4	44.1	silty clay
VI.	Kayamkulam	0-22	21.9	67.0	2.9	8.2	sandy
		22-75	41.7	53.4	2.9	3.6	sandy

It will be observed that the amount of clay in the different profiles shows wide variation ranging from 3.6 to 69.9 per cent. Profile V (*Kari* soil) records the maximum value followed by profile II (alluvial soil). In the majority of the profiles there is a decrease in clay content in the subsoil. The silt fraction varies from 2.9 to 47.4 per cent and profiles II and V again register much higher values than the others. The sand fractions predominate in profile VI constituting 88.9 to 95·1 per cent of the soil. The soils studied differ widely in texture ranging from sandy to clay.

Some important characteristics of the soils, viz., pH, Ca CO_3 and organic carbon content, and cation exchange capacity are reported in Table II.

The data show that all the soils are acidic in reaction. Loss of calcium and other bases due to waterlogging and prolonged leaching under heavy rainfall conditions accounts for this condition. The pH values of the submerged soils range from 2.9 to 6.4. As expected the majority of the soils in the dry condition are more acid, the pH values lying between 3.9 and 6.0. There is no regular trend in the variation in pH with depth. None of the soils contain free calcium carbonate.

The amount of organic carbon in the different profiles varies from 0.03 to 2.86 per cent. Profiles II and V are rich in this constituent indicating heavy accumulation of organic matter in these soils. The lowest values are recorded in profile VI which is sandy in texture. Except in profile II organic carbon decreases with depth.

The cation exchange capacity of the soils ranges from 2.4 to 24.2 me per cent. The

TABLE II

Chemical Characteristics of Soils

Profile No:	Locality	Depth (cm)	pH Dry	pH Submerged	$CaCO_3$ %	Organic carbon %	Cation exchange capacity me. %
I.	Pattambi	0-22	5.1	6.1	nil	0.91	24.2
		22-75	5 1	6.1	nil	0.11	21.6
II.	Monkompu	0-22	4.5	5.2	nil	2.04	15.0
		22-75	4.8	2.9	nil	2.73	17.0
III.	Taliparamba	0-22	5.2	6.4	nil	1.65	16.4
		22-75	5.2	6.3	nil	1.57	18.9
IV.	Mannuthy	0-22	5.2	5.4	nil	0.68	19.7
		22-75	5.4	5.7	nil	0.27	20.6
V.	Vechoor	0-22	3.9	4.1	nil	2.86	18.5
		22-75	6.0	5.8	nil	2.83	11.3
VI.	Kayamkulam	0-22	5.3	5,5	nil	0.14	2.4
		22-75	5.4	5.7	nil	0.03	2.3

relatively low values registered even by soils high in clay content strongly suggest that the clay present may be predominantly kaolinitic in nature.

The distribution of the different forms of manganese in the profiles under submerged and dry conditions is shown in Tables III and IV respectively.

TABLE III

Distribution of different forms of Manganese in submerged soils

Profile No.	Locality	Depth (cm)	Manganese (ppm) Water Soluble	Exchange-able	Easily reducible	Active	Total	Active x 100 / Total
I.	Pattambi	0-22	10.5	11.7	104.8	126.9	524.0	20.4
		22-75	9.4	14.2	55.2	78.7	591.0	13.3
II.	Monkompu	0-22	14:8	20.5	124.2	159.6	355.0	44.9
		22-75	14.0	17.4	109.3	141.7	367:0	38.6
III.	Taliparamba	0-22	2.1	38.9	20.2	61.2	625.0	9.8
		22-75	2.5	40.0	18.9	61.4	764.0	8.1
IV.	Mannuthy	0-22	1.8	15.3	28.9	46.1	554.0	8.3
		22-75	2.1	21.1	23.0	46.3	670.0	6.9
V.	Vechoor	0-22	13.2	49.7	75.6	138.5	382.0	36.3
		22-75	12.4	80.0	52.6	145.0	573.0	25.3
VI.	Kayamkulam	0-22	9.4	10.2	15.9	35.5	432.0	8.2
		22-75	6.9	54.9	8,9	70.7	655.0	10.8

TABLE IV

Distribution of different forms of Manganese in dry soils

Profile No.	Locality	Depth (cm)	Manganese (ppm) Water soluble	Exchange-able	Easily reducible	Active	Total	Active x 100 / Total
I.	Pattambi	0-22	1.7	16.3	9.8	27.7	550.0	5.0
		22-75	1.3	14.2	18.8	34.3	604.0	.17
II.	Monkompu	0-22	2.8	28.8	17.6	49.1	367.0	13.4
		22-75	2.8	36.6	20.0	59.4	360.0	16.5
III.	Taliparamba	0-22	1.8	17.6	12.2	31.7	611.0	5.2
		22-75	1.4	9.8	9.8	21.0	775.0	2.1
IV.	Mannuthy	0-22	0.9	18.5	16.5	35.9	516.0	7.0
		22-75	2.4	15.2	96.8	114.4	655.0	17.4
V.	Vechoor	0-22	2.3	18.4	11.4	32.1	393.0	8.2
		22-75	8.1	64.8	32.8	105.7	579.0	18.3
VI.	Kayamkulam	0-22	3.0	10.9	10.1	24.1	415.0	5.8
		22-75	1.8	14.3	7.8	23.9	647.0	3.7

Total Manganese

Total manganese in the submerged profiles varies from 355 to 625 ppm in surface soils and 367 to 764 ppm in subsoils with mean values of 479 and 603 ppm respectively. Biswas (1953) in a study of the manganese status of Indian soils recorded average values of 802.4 ppm for surface soils and 962.3 ppm for subsoils of the humid region. The lower content of this micronutrient in the rice soils of Kerala is presumably due to the largely kaolinitic composition of their clay fraction resulting in low cation exchange capacity and to the severe leaching that these soils are subject to.

The data reveal that in all the profiles there is considerable mobilisation of total manganese in the subsoil. It may be noted in this context that all the soils included in the present study are acidic in reaction and do not contain free calcium carbonate which acts as a precipitating agent and restricts the free movement of manganese. These characteristics combined with heavy rainfall favour the formation of divalent manganous ions which are very mobile and are leached down to the lower layer of the soil where they accumulate due to poor drainage conditions. Similar observations have been made by Biswas (1953) and Randhawa *et a]* (1961).

It will also be observed that the level of this element in the heavy clay soils of profiles II and V is relatively low compared to that in the light sandy soil of profile VI. The results do not show any relationship between texture and total manganese content in the soils examined. This is in conformity with the finding of Sharma and Motiramani (1964) in respect of soils of Madhya Pradesh.

The total manganese content of the profiles under dry conditions shows a variation from 367 to 611 ppm for surface horizons and 360 to 775 ppm for the lower horizons with average values of 475 and 603 ppm respectively. These values are almost identical with those for profiles in the submerged state clearly bringing out the fact that waterloyging has practically no influence on the [evel of total manganese in the soils investigated.

Water Soluble Manganese

This is the smallest of the different fractions of total manganese. It ranges from 1.8 to 14.8 ppm in the submerged profiles and constitutes less than 5 per cent of the total manganese. Dhamija *et al* (1956) found that water soluble manganese occurs in traces and was sometimes absent in paddy soils of Bihar, Uttar Pradesh and Punjab. Biswas (1953) and Saxena and Baser (1964) have also reported very low amounts, often below 1 ppm, in soils of varying texture and alkaline reaction. The higher content of this category of manganese in the rice soils of Kerala may be attributed to their acidic nature and submerged condition.

The data show that soil reaction has a marked influence on the amount of water soluble manganese. It increases as pH decreases, obviously due to formation of divalent manganous ions readily under acidic conditions. This finding corroborates the results of Biswas (1951) and Randhawa *et al* (1961). A high negative correlation ($r = -0.56$) was found to exist between pH and water soluble manganese in the soils studied.

This fraction of manganese is very small in the profiles under dry conditions, most of the values lying between 0.9 and 3.0 ppm. In general, soils in the submerged state register higher values. This observation is supported by the work of Pearsall (1950), Runge and Leon (1960) and Mandal (1961). According to Ponnamperuma (1955), the peculiar conditions prevailing in submerged rice soils, viz., virtual absence of oxygen, the metabolism of anaerobic bacteria, and the generation of powerful reducing agents by the anaerobic decomposition of organic matter, all combine to make the reduction of manganese a very efficient process. The transformation of manganic oxides to soluble manganous forms thus takes place very readily under submerged conditions.

Exchangeable Manganese

This is a bigger fraction of total manganese than the water soluble category. The amount of exchangeable manganese in the submerged profiles varies from 10.2 to 80.0 ppm. These values are higher than those reported by Biswas (1953) and other workers for soils of different climatic groups in India. This appears to be due to the lateritic origin and ferruginous nature of most of the soils examined as Robinson (1929) found that lateritic soils have an appreciable supply of exchangeable manganese and Boken (1955) observed that manganese of this category is high in soils in the presence of ferrous iron.

It is seen from the data that in the majority of the profiles there is greater concentration of this form of manganese in the subsoil. Endredy (1940), Karim *et al* (1960) and Biswas and Gawande (1964) also noted mobilisation of exchangeable manganese in the lower layers of the soil and ascribed it to the mobility of this element under acidic conditions. All the soils used in the present investigation are acid in reaction and many of them are rather strongly acid.

Biswas (1953), Khanna *et al* (1954), and Zende and Pharande (1961) found a higher level of exchangeable manganese in clayey soils and Yadav (1964) observed that manganese in this form increases progressively with increases in clay content. The results of the present study, however, do not show any consistent relationship between these two factors. It is relevant to point out in this context that Karim *et al* (1960) have reported that the exchangeable manganese content of alluvial, coastal saline and hill tract soils were similar notwithstanding textural differences.

The amount of manganese of this category in the profiles under dry conditions ranges from 9.6 to 64.8 ppm. In many of the profiles there is a diminution in exchangeable manganese when submerged. This finding is substantiated by the work of Saxena and Basu (1964) who showed that there was a marked increase in this fraction when soils were air dried and stored. Biswas and Gawande (1964) noticed that better the drainage, more is the exchangeable manganese in soil and *vice versa.*

Easily Reducible Manganese.

The content of easily reducible manganese in the submerged profiles varies widely, the values lying between 8.9 and 124.2 ppm. Profile II which is high in organic matter records the maximum value and profile VI which is predominantly sandy the minimum. In all the profiles surface accumulation of this category of manganese is apparent. In the majority of the soils this fraction constitutes the major part of the active manganese as also observed by Khanna *et al* (1954)

Easily reducible manganese ranges from 7.8 to 96.8 ppm in the profiles under dry conditions, all excepting one value falling below 32.8 ppm. The data in Tables III and IV furnish clear evidence that submergence results in significant increase in this form of manganese. This is primarily due to the favourable conditions for reduction of higher oxides of this element in waterlogged soils. Also, the formation of H_2S in submerged rice soils brings about the precipitation of copper, zinc and iron as sulphides leaving more manganese in solution as suggested by Venkateswarlu (1964).

Active Manganese

The active or available manganese in the submerged profiles ranges from 35.5 to 159.6 ppm. It is highest in profile II (alluvial soil) and lowest in profile VI (sandy soil). The influence of soil texture on this fraction of manganese is quite evident from the results and a high positive correlation ($r = +0.952$) exists between active manganese and clay content. There is also a close relationship ($r = +0.577$) between this fraction and organic carbon in the soils studied which is in accord with the findings of Dhamija *et al* (1956) and other workers.

The distribution of active manganese with depth in the submerged soils does not show any consistent trend. In profiles I and II it decreases in the subsurface layer whereas in profiles V and VI it is the reverse. In the remaining two profiles this fraction remains uniform with depth.

Submergence is seen to have a pronounced effect on this form of manganese. The amount present in the profiles under dry conditions varies from 21.0 to 114.4 ppm. These values are invariably much lower than those recorded for the submerged profiles.

The ratio of active to total manganese ranges from 6.9 to 44.9 per cent in the profiles under waterlogged conditions. The availability of this element is highest in profiles II and V which are the most acid. Biswas (1953) reported values varying from 4.0 to 40.4 per cent which is in line with the results of the present investigation. Vinayak *et aJ* (1964) found that the percentage ratio of active to total manganese was highest in non-calcareous soils with low pH and decreased with increase in pH. In the dry profiles examined this ratio lies between 3.7 and 18.3 per cent indicating much lower availability of manganese than under submerged conditions.

Manganese availability in submerged rice soils

Saxena and Basu (1964) concluded that easily reducible manganese is the only fraction which can be used for predicting the availability of this element in soils. Hoff and Mederski (1958) also considered this fraction to be a measure of the available manganese and fixed the deficiency limit as 20 ppm. Other workers have suggested that exchangeable manganese is a useful index for assessing the availability of this micronutrient and have proposed different critical limits. It must be emphasised that the deficiency limits proposed are arbitrary and will vary with climatic conditions, soil type and crop grown. However, if judged by the limits stipulated by Hoff and Mederski (1958), the available manganese status of most of the soils used in the present study is quite adequate for satisfactory crop production in their submerged state. In fact, in many of them the level is very high and there is possible danger of manganese toxicity occurring in these soils. Detailed investigations to correlate available manganese in different ranges with crop response are essential before firm conclusions can be drawn.

Summary and Conclusions

The distribution pattern of the different forms of manganese in six typical profiles of rice soils of Kerala, both under submerged and dry conditions, was studied. Water soluble, exchangeable, easily reducible, active and total manganese were determined and their relation with soil properties evaluated. In most of the soils the easily reducible fraction constitutes the major part of the active or available manganese. The influence of submergence on each of the different categories of manganese was also investigated. The availability of this micronutrient is much higher in soils in the submerged state. The results of this study underline the need for detailed investigations to correlate available manganese with crop response.

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