Soils of Tripura- an Overview

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Chapter–I

TRIPURA AT A GLANCE

The State Tripura characterized by varied physiography and climate is endowed with a variety of land use types and agricultural systems. With over sixty percent area under forests and wastelands, the cultivated area is hardly 25 percent. The per capita availability of land is about 0.97 ha. Notwithstanding small arable land resource, the agriculture remains to be main source of livelihood to the people of mountainous regions. The major food crops of the region are cereals, pulses, oilseeds and potato (Anonymous, 1998). Rice is the main crop followed by maize in this region. The agro-climatic conditions of the region are suitable for the production of temperate to sub-tropical fruits such as pineapple, citrus, mango, litchi, guava, banana, pineapple, jackfruit etc.

The areas are also suitable for the production of ancillary horticultural produce like flowers (orchids, gladiolus, marigold, chrysanthemum, cut flowers), spices tea, edible bamboo etc. Of late, the region is witnessing rapid strides in the transformation of consumption based hill economy to production based one with diversification of least remunerative cropping systems with off- season vegetables, edible bamboo, aromatic and medicinal plants, organic farming and host of agri-enterprises. The state is showing increase in area and production of fruits and off-season vegetables over the years. For sustaining the new ventures and improving the overall agricultural productivity in this state, concerted efforts towards removal of different production constraints confronting agriculture should be taken.

Table 1.1: Land used classification in Tripura (Area in Hectares)

Year	Geographical Area	Area under forest	Land put to non agricultural use	Land not available for cultivation	Permanent pasture and other grazing land	Land under misc. tree crops, groves in the net area sown, Other uncultivated land excluding fallow	Culturable waste land	Fallow land	Current fallow	Net area sown	Area sown more than once	Total cropped area
1997-98	1049169	606168	133500	—	—	27151	600	700	1050	280000	205000	485000
1998-99	1049169	606168	133500	—	—	25500	600	700	1701	289000	200880	488000
1999-00	1049169	606168	134500	—	—	27151	600	700	1050	279080	200000	479880
2000-01	1049169	606168	—	—	—	—	—	—	—	279000	201000	480000
2001-02	1049169	606168	—	—	—	—	—	—	—	280000	205000	485000
2002-03	(P)10,49,169	606168	—	—	—	—	—	—	2350	2,80,000	2,10,000	4,90,000
2003-04	(P)10,49,169	606168	—	—	—	—	—	—	2605	2,80,000	2,13,000	4,93,000
2004-05	1049169	606168	—	—	—	—	—	—	2605	2,80,000	2,12,000	4,92,000
2005-06	1049169	606168	—	—	—	—	—	—	2500	2,80,000	2,15,000	4,94,760

— Information not available

Source : Directorate of Agriculture, Govt. of Tripura

The impaired soil health as a result of unfavourable soil and environmental conditions is one of the major factors affecting soil and crop productivity in this region. Presently, the productivity of major crops of the region is generally low.

Tripura is a tiny and land locked hilly state of the North-east India with a geographical area of 10492 sq. km and a total population of 36, 71,032 (as per 2011 census). Agriculture is the main livelihood of the state. It offers the largest avenue of employment to its workforce. But the state has been facing some serious problems of undulation, soil degradation, water logging etc. because of its topographical situation. As a result, agriculture has not been fully explored and flourished in the state. Its geographical and political position makes the state vulnerable to various problems and it is also the concern of the state.

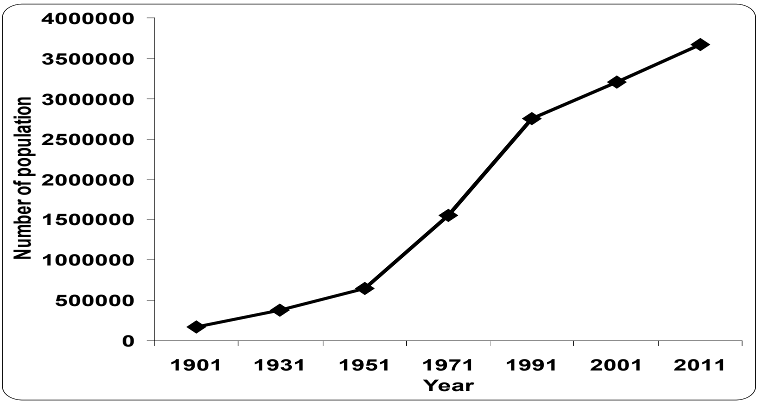


Fig.1.1: Population of Tripura during last 110 years

This picturesquely beautiful state in the lap of hill is surrounded by Bangladesh in the west, south and north. Its North-Eastern and Western boundaries are separated by Assam and Mizoram states, respectively. The state lies within the latitudes 22°56/ N -24°32/N and between the longitudes 91° 09' E – 92°20' E. Of the total area of 10,49,169 hectares, an area of about 6,06,150 hectares, i.e., near 60% of land is under forest area.

Tripura is a land of hills and dales. About 70% of the area of the state is covered by hills and hillocks which are locally known as 'tilla'. The remaining 30% are plain land and locally called as 'lunga'. There are 10 rivers originating from the highest hill rage 'Betling Sib' and they flow towards western direction through narrow valleys to Bangladesh.

Table 1.2: Major achievements in agricultural development in Tripura during 1972 - 2010

Sl. No.	Parameters	Unit	1972	1978	1998	2010
1	Net Cropped Area	Ha	242,500	244,000	280,000	—
2	Gross Cropped Area	Ha	377,000	392,000	485,00	—
3	Cropping Intensity	%	155	161	173	176
4	Area Under Food Grains	Ha	280,746	312,108	271,695	253,597
5	Production of Food Grains	MT	273,079	375,348	547,460	647,710
6	Productivity of Food Grains	Kg/Ha	973	1,203	2,015	2,547
7	Production of Rice	MT	270,840	368,360	491,430	640,034
8	Productivity of Rice	Kg/Ha	978	1,201	2,078	2,607
9	Productivity of Jhum	Kg/Ha	690	674	605	991
10	Area Under Sri	Ha	—	—	—	59,577
11	Area Under HYV Paddy	Ha	25,660	116,060	220,055	230,805
12	Production of HYV Certified Paddy Seed	MT	—	—	28	4,440
13	Hyv Seed Replacement Rate (Paddy)	%	—	—	3	33

14	Use Of Chemical Fertilizers (N.P.K)	Kg/Ha	—	—	25	39
15	Production of Bio-Fertilizer	MT	—	—	1	258
16	Number of Kishan Credit Cards Distributed	Nos.	—	—	—	1,32,893 (Cumulative since inception)
17	No of Cold Storages					
	i) Government	Nos.	—	—	2	7
	ii) Private	Nos.	—	—	1	4
	Total		—	—	3	11
18	Capacity of Cold Storages :					
	i) Government	MT	—	—	3000	14000
	ii) Private	MT	—	—	2000	36500
	Total		—	—	5000	50500
19	Farmers Trained	—	—	—	7150	70000
20	No. of Soil Testing Laboratories :					
	i) Static	Nos.	1	1	2	2
	ii) Mobile	Nos.	—	—	1	4
21	No. of Soil Sample Analyzed (Yearly)	Nos.	3000	3571	5494	12189
22	No. of SA Offices	Nos.	—	10	17	22
23	No. of Agri. Offices	Nos.	—	10	17	22

Department of Agriculture, Government of Tripura.

The climate is characterized by warm and humid tropical climate with three distinct seasons namely, summer, rainy and winter. The maximum temperature in April-May is near about 35°C and the minimum temperature in January normally is 7-8°C. The relative humidity is about 70-80%. The average normal rainfall in the state is about 2100 mm, most of which is received between May to September. In general, the soil of the lunga land is acidic and sandy loam which is favourable for the cultivation of paddy, jute and mesta.

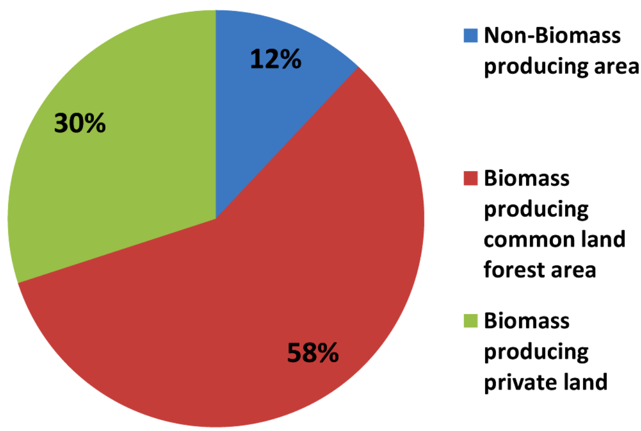


Fig. 1.2: Land use pattern in the State

Physiographic Description

Physiographically Tripura may be divided into three broad categories:

- The hill ranges
- Undulating and/or hilly high lands of narrow and broken plateau
- Low land and river valleys.

The hill ranges run in north-south direction alternating with narrow valleys. They originate from the plains of Sylhet in Bangladesh to the north and proceed southwards and join the hills of Chittagang hill tract in Bangladesh. The elevation of the hills gradually increases in the south. Jampui is the eastern most range with highest elevation and Baramura-Deotamura is the westernmost range with lowest elevation of 244 m. Besides these there are numbers of low hill detached from the main hill ranges.

The five principal hill ranges running parallel in north-south direction are the Jampui, the Sakhantang, the Longtarai, the Atharamura and the Baramura the travers that state from west to eastward direction.

Besides, there are a number of slightly undulating and not very broad valleys. The five broad longitudinal valleys are: i) Agartala-Udaipur-Sabroom: ii) Khowai-Teliamura-Amarpur: iii) Kamalpur-Ambassa-Gandacherra; iv) Kailashahar-Kumarghat-Chawmanu; and v) Dharmanagar-Panisagar-Kanchanpur. Within the major valley portions, there are numerous isolated hillocks attaining an elevation of 20-30 m above the valley floor.

Drainage and River System

The drainage system of Tripura is characterized by straight flowing seasonal water courses of number of rivers. These rivers tend to get flooded during rainy season but remain mostly dry at rest of the years. These rivers originate in the hills of the state and flow towards western direction through narrow valleys to Bangladesh.

Gomati, Manu and Khowai are the three main river systems of the state. In addition, Muhuri, Howrah and Dhalai are small rivers running in the state. Besides, there are innumerable streams and streamlets flowing down from hills and hillocks. These streams are very shallow in depth and remain almost dry in the summer and winter season. But during the rainy season they overflow and sometimes cause floods and damage to the field crops.

Hydrological Scenario

Tripura lies primarily under Meghna basin and its three sub-basins are Barak, Gomati and Feni. There occurs 3-4 major aquifer systems in the synclinal valleys of Tripura state within 250 mts. Below ground level. The thickness of aquifers varies from valley to valley and decreases significantly towards east in Kamalpur, Kailasahar and Dharmanagar valleys. The synclinal feature of the valleys with recharge zones (mainly through rainfall infiltration in the anticlinal hills provide ideal situation for artesian wells. Moreover, the hydrological scenario reveals that shallow and deep tube wells are very much feasible in the valley parts of the state. Ground water in this state is by and large of high class. It may serve the purpose of drinking, irrigation and industrial use except in some iron ion pockets where it is above toxic level. It is estimated that 65 -70% ground water resources remain untapped and unutilized in the state of Tripura.

Soil and Its Fertility Status

Broadly, soils of Tripura have been classified into five groups:

1. *Reddish yellow-brown sandy soils:* These soils occur in the North-South oriented hill ranges crowned with lush evergreen tropical forest. These soils cover about 33% area of the state.
2. *Red loam and sandy loam soils:* These soils occur in undulating upland areas of the state. It covers about 43% area of the state.
3. *Older alluvial soils:* Soils are of recent origin of transported nature. These are mainly situated on the river terraces and high plains of the state. Nutrient rich and so suitable for farming. It covers nearly 10% area of the state.

Table 1.3: Major Soils of Tripura

Soils	Area ('000 ha)	Percent share
Alluvial soils	245.48	23 %
Red soils	800.03	77 %

4. *Younger alluvial soils:* These soils are mainly confined to the flood plains of the rivers and streams of the state. Extremely rich in plant nutrients and thus favourable for rice, jute cultivation.
5. *Lateritic soils:* These soils are confined to the west boundaries of the state. Extremely poor in plant nutrient

contents. Thus, unsuitable for agricultural operation. It covers only 5% area of the state.

By and large the soils of Tripura are acidic in nature. Excessive amount of rainfall received in the state causes a considerable leaching of exchangeable base material from surface soils resulting in drop in pH of soils. Regarding fertility status, soils of Tripura are medium in organic carbon, nitrogen and potassium content. But soils are more or less phosphorus deficient because of acidic nature of soils.

Land Use Classification

The land use classification of the state shows that more than 57.8% of the total geographical area is covered by forest. Only 26% of the total geographical area is available for agricultural purpose. Rest of 12.6% is under use of non-agricultural activities and remaining 3.6% under miscellaneous tree crops and grooves.

The limited available of cultivable land is a major natural constraint in the way of agricultural development of the state. Forest mainly covers the elevated flat land and hillocks. Bamboo is one of the major vegetation associated with '*chhan*' and '*kash*' grass. In the uplands *sal, segun, karai, hargaja, gamai, neem* are the common trees of the forest. Different species of bamboos normally grows in Tripura. In the alluvial tract *kul*, palm are grown naturally. Among fruit trees mangoes, litchi, jack fruit blackberry are common. In the steep slopes, pineapple and wild banana are grown abundantly.

Administrative and Demographic Profiles

Administratively, Tripura has been divided into eight districts viz. Dhalai, North Tripura, South Tripura, West Tripura, Sephahijala, Gomoti, Khowai and Unokoti. Tripura accounts for 0.32% of the total area of the country and for 0.31% of the total population of the nation. It is a land of mixed community. All the ethnic religious groups- Hindu, Muslim, tribes, Buddhist, Christian, Jain co-exist in the state. There are 19 sub-tribes in the state with their own cultural identity. Thus, state has unique diversity.

Human Resources

In Tripura the pace of socio-economic changes is very slow and limited. It is mainly due to the isolation of the state from the rest of the country and due to lack of occupational diversification. But the overall consciousness of the people makes the state a land of rich human resource. In 2000, the estimated birth and death rate in this state were 16.5 and 5.4 per thousand populations which were much lower than national average of 25.8 and 8.5, respectively. Here percent infant mortality rate is 41 per thousand live birth which is 68 for all Indian average. The rate of literacy is 94.95%, which is the highest in the country. Considering all these, it can be said that the progress of human resource development is very remarkable for this economically backward state.

Chapter - II

SOIL RESOURCE INVENTORY

Land itself is evidently the principal focus of land use planning. Capital, labour, management skills and technology can be moved to where they are needed. Land cannot be moved and different area offer different opportunities and different management problems. Good information about land resources is thus essential to land use planning. Soils of Tripura have developed *in situ* on various type of rocks. The dominating parent materials are gneiss and granites, underlined with chlorite – quartz, schist. Geologically this region consists of sandstone, silt stone, shale conglomerate and limestone. So far, the soils of Tripura have not been surveyed thoroughly due to hilly and poor communication and accessibilities and dense forest. But recently NBSS-LUP, ICAR, North Eastern region surveyed and published the information for necessary use. On the basis of their reports and information collected from state agricultural department, an inventory on soils of Tripura has been initiated in this chapter.

Generalities on soil series

Soil series is lowest category in Soil Texonomy (soil Survey Staff, 1999). It is considered as the most important category in the system since the soil series constitutes the fundamental unit of soil classification as well as the basic unit for soil mapping. This is also regarded as the largest landscape unit which carries the signature of physiography, climate and other imprints of soil forming factors to be considered for their best use in terms of crop planning, horticulture, plantation and other miscellaneous uses.

Soil series have been defined on the basis and kind of arrangement of horizons and in terms of various morphological (macro and micro), physical, chemical and mineralogical properties of each horizon. It could be defined comprehensively as follows:

- "A group of soils showing soil horizons, similar in differentiating characteristics and arrangements within the series control section and has developed under comparable climatic situation".
- Soil series are therefore pragmatic classes of individual soils which are specific to a particular area, the differentiate for soil series are similar to those used to define classes such as soil families, subgroups and great groups, but, the soil series allows narrower ranges to accommodate less number of soils into it thus projecting a broader vision.
- The series control section (SCS) refers to a vertical section of soil which is taken into account while distinguishing series from soil families, the upper level of SCS is below the plough layer and is normally considered as 25 cms.
- The lower limit on the other hand is extended upto the zone of biological activity (generally upto 100 cms). The area covered by a soil that falls outside the limit of any defined series leads one to identify a new series. The extent of distribution of a soil series is better linked to the scale of the map. It has been reported that a series should have a minimum of 10 hectares of area on 1 : 10,000 scale map, 1000 hectares in 1 : 1,00,000 scale map and 1,00,000 hectares in 1 : 1 million map. The area covered extent and status of soil series has been shown in Table 2.1.

Table 2.1: Extent of soil series

Area (ha)	Extent and status of soil series
< 1000	Limited identified series
1000 – 5000	In extensive tentative
5000 – 25,000	Moderately extensive established

25,000 – 50,000	Extensively established and Benchmark (tentative)
> 50,000	Very extensive Benchmark

Methods of Identifying Soil Series in Tripura

To identify soil series in Tripura the following steps were considered. The available information on soils was documented to:

i. Arrange the genetic horizons of each soils with appropriate horizon designations
ii. Dominant colour (dry, moist or rubbed) of matrix
iii. Colour of the gleyed horizons
iv. Quality and quantity of redoximorphic features such as mottles, nodules
v. Dominant structure and texture of soils
vi. Drainages conditions especially subsurface
vii. Biological activity and its extent with the pedon depth in terms of root distribution
viii. Dominant minerals in clay fractions either by X-ray diffraction data or by assessment of dominant minerals through chemical properties such as, soil CEC, clay CEC soil ECC, base saturation (BS).

Table 2.2: Soil series reported earlier in Tripura*

Physiography	Soil series	Sub-group	Physiography	Soil Series	Subgroup
Upland	Lahchara	Typic Dystrochrults	Lowland	Bisramganj	Typic Aeric Ochraqualfs
	Kathalichara	Typic Paleochrults		Balucha-ra	Typic Paleudepts
	Sarashima	Typic Paleochrults		Betchara	Typic Paleudepts
				Vidyanagar	Typic Haplaquents

**Laskar, S., Dadhwal, K. S. and Prasad, R. N. 1983. Soils of Tripura and their fertility management, ICAR Research Bulletin No. 23, New Delhi.*

Earlier seven soil series in Tripura were reported (Laskar *et al.*, 1983). Three series were identified in the uplands and four in the lowlands (Table 2.2).

With the help of the database generated during 1993 for the entire state, 48 soil series have been identified. Out of 48 soil series identified 18 soil series are grouped under the order Ultisols, 5 in Entisols, 24 in Inceptisols and 1 in Alfisols. The area-wise distribution of different soil series at the different soil orders is shown in Table.

On the basis of extent of all these 48 soils series the relative proportion of soil order, suborder, great group, subgroup and family in shown in Annexure 1.

On the basis of colour and important soil chemical properties such as base saturation, pH, CEC and sum of cations, the characteristics of each series is compared with other soil series within the same great group and subgroup. This information was useful to find out the competing series and their differentiation.

The detailed information on soil series and their differentiating criteria are shown in Annexure II. Annexure III shows the soils-site suitability for selected crops in Tripura which has been developed on the basis of soil parameters as well as crop characteristics. Besides the climatic parameters which have also been utilized to develop soil-site suitability data are shown in Annexure IV. District-wise distribution of soil series is shown in Table 2.5.

Table 2.3: Soil series and their placement in different categories in soil taxonomy

Sl. No.	Soil series	Texture	Minera-logy	Sub-group	Great group	Area (ha)
1	Kathalia	Fine	Kaolinite	Typic	Kandiualfs	44327
					Total	**44327**
2	Gandhi-gram	Fine	Kaolinite	Typic	Kandihumults	2258
3	Shibbari	Fine	Kaolinite	Typic	Kandihumults	30899
4	Fisherypara	Fine	Kaolinite	Typic	Kandiudults	4768

5	Mohanpur	Fine	Kaolinite	Typic	Kandiudults	3763
6	Ramnagar	Fine	Kaolinite	Typic	Kandihumults	3179
7	Rangthang	Fine	Kaolinite	Typic	Paleudults	11523
8	West Gandachherra	Fine	Kaolinite	Typic	Palehumults	2936
9	Anandanagar	Fine-loamy	Kaolinite	Typic	Kandiudults	1768
10	Monaipathar	Fine-loamy	Kaolinite	Typic	Paleudults	15248
11	Birchandramanu	Fine	Kaolinite	Typic	Kanhapludults	5405
12	Chhailengta-II	Fine	Mixed	Typic	Paleudults	10343
13	Jagabandhu-para	Fine-loamy	Kaolinite	Typic	Haplohumults	43114
14	Bijaynagar	Fine-loamy	Kaolinite	Typic	Palehumalts	27775
15	Betaga	Fine	Kaolinite	Typic	Paleudults	15514
16	Gamaibari	Fine	Kaolinite	Typic	Paleudults	3600
17	Harimangal-para	Fine-loamy	Kaolinite	Typic	Paleudults	38676
18	Paschim Karbok	Fine-loamy	Kaolinite	Oxic	Dystrudepts	17245
19	Gyanama	Fine	Kaolinite	Typic	Hapludults	34299

Sl. No.	Soil series	Texture	Mineralogy	Subgroup	Great group	Area (ha)
20	Patichhari	Fine	Kaolinite	Typic	Kandiudults	1958
					Total	**2,74,271**
21	Khowai	Fine-loamy	Mixed	Typic	Endoaquepts	15686
22	Dukli-II	Fine-loamy	Kaolinitic	Fluvaquentic	Endoaquepts	5281
23	Dharaichherra	Fine	Vermiculitic	Aeric	Endoaquepts	7250

24	Nayanpur	Very fine	Mixed	Typic	Endo-aquepts	43106
25	Dukli-I	Fine-loamy	Kaolin-itic	Typic	Endo-aquepts	13890
26	Anurchherra	Fine-loamy	Mixed	Typic	Dystrud-epts	6056
27	Dhanpur	Fine-loamy	Kaolin-itic	Flu-vaquentic	Dystrud-epts	39060
28	Goachand	Fine-loamy	Kaolin-itic	Aquic	Dystrud-epts	45018
29	Paschim manu	Fine	Mixed	Oxy-aquic	Dystrud-epts	29190
30	Netajinagar	Fine	Mixed	Fluventic	Dystrud-epts	35156
31	Nagichherra	Fine-loamy	Kaolin-itic	Oxic	Dystrud-epts	1061
32	Bhaktikurmar-para	Fine	Kaolin-itic	Humic	Hap-ludults	1464
33	Uttar Nali-chherra	Fine-loamy	Kaolin-itic	Oxic	Dystrud-epts	4984
34	Belianchef	Loamy-skeletal	Kaolin-itic	Oxic	Dystrud-epts	19746
35	Bilthai	Fine-loamy	Kaolin-itic	Typic	Dystrud-epts	31720
36	Bagaichherra	Fine-loamy	Mixed	Typic	Dystrud-epts	61785
37	Bagbassa	Fine	Mixed	Typic	Dystrud-epts	49747
38	Chebri	Fine-loamy	Mixed	Typic	Dystrud-epts	100317
39	Krishnapur	Coarse-loamy	Mixed	Typic	Dystrud-epts	2400

Table 2.4: Soil taxonomy of Tripura at a Glance

Category of Taxonomy	Nos.
Soil Order	4
Soil Suborders	8
Soil Great Groups	13
Soil Subgroups	23
Soil Families	42

Table 2.5: Distribution of soil series in four districts of Tripura

Sl. No.	Soil series	Soil Classification	Area (ha)
North Tripura District, Tripura			
1	Betianchef	Loamy-skeletal, Kaolinitic, Oxic Dysrrudepts	19746
2	Bagbassa	Fine. mixed, Typic Dystrudeprs	49747
3	Shibb u-i	Fine, kaolinitic, Typic Kandihu-mults	30899
4	Bagaicherra	Fmc-loamy, mixed, Typic Dystrud-epts	61785
5	Bihhat	Fine-loamy, Kaolinitic. Typic Dys-trudepts	J 1720
6	Harimangal-para	Fine-loamy, Kaolinitic, Typic Paleudults	38676
7	Anurcherra	Fine-loamy, mixed, Typic Dysr-rudepts	6056
8	Fishcrypara	Fine, Kaolinitic, Typic Kandindults	4768
9	Netejinagar	Fine, mixed, Fulventic Dystrudepts	35156
10	Chharlengta-l	Fine-loamy, mixed, Oxyaqurc Dys-trudepts	31964
11	Chhailengta-Il	Fine. mixed, Typic Paleudults	10343
12	Triguncherra	Coarse-loamy, mixed, Typic Udorthents	17617
13	Dharaicbberra	Fine-loamy, Vermiculuic, Typic Endoaquepts	7250

14	Manpui	Clayey, mixed, Lithic Dystrudepts	16238
Dhalai District, Tripura			
15	Ramnagar	Fine, Kaolinitic, Typic Kundihur-nuhs	3179
16	Mynama	Fine-loamy. kaolinmc. Aerie Endo-aquems	550
17	West Gan-dachherra	Fine, Kaolinitic, Typic Palehumulrs	2936
18	Hamori	Loamy -skeletal, mixed, Typic Dystrudepts	27362
19	Betaga	Fine-Kaolinitic, Typic Paleudults	15514
20	Bhakukumar-pam	Fine, Kaolinitic, Humic Hapludults	1464
21	Gynarna	Fine. Kaolinitic, Hunuc Hapluduhs	34299
22	Uttarnali-chherra	Fine-loamy, Kaolinitic, Oxic Dys-trudepts	4984

Table 2.6: Soils of Tripura-Soil Orders

Sl. No.	Soil Orders	Area (ha)
1	Ultisols	68.37
2	Alfisols	45.46
3	Inceptisols	833.94
4	Entisols	95.32
5	Others	6.08

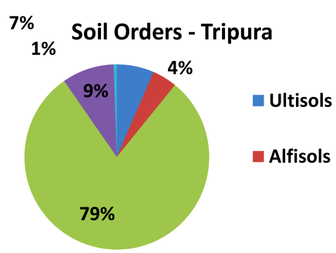


Table 2.7: Great Group of Soils of Tripura and their coverage

Sl. No.	Soil Group	Area		Soil taxonomic unit
		Sq. km	Percent	
1	Reddish yellow brown sandy soils	3, 468	33.06	a) Ultic Hapludalfs
				b) Udic Ustochrepts
				c) Typic Udorthents

2	Red loam and sandy loam soils	4, 514	43.07	a) Ultic Hapludalfs
				b)Typic Hapludalfs
				c) Typic Paleudulfs
				d)Typic Ustochrepts
				e) Typic Dystrpchrepts
				f) Udic Ustochrepts
				g) Typic Ustochrepts
3	Older alluvial soils	1, 019	9.71	a) Typic Ochraqualfs
				b)Typic Haplaquepts
4	Younger alluvial soils	980	9.34	a) Typic Udifluvents
5	Lateritic soils	510	4.86	a) Typic Palehumults
				b) Typic Plinthustults
				c) Typic Plinthudults
				d) Typic Paleudults
		10, 491	100	

Characteristics of Soil group and their Soil Series of Tripura

Reddish yellow brown sandy soils

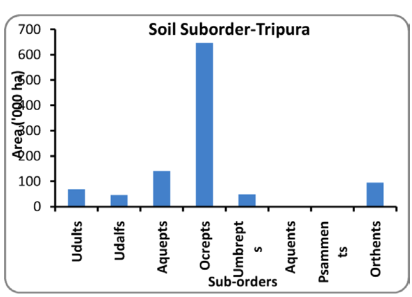
These soils are extensive, residual in nature and occurring on in the North-South oriented hill ranges, crowned with lush evergreen tropical forest, nearly continuous erosion prone, the finer fraction of the soil mantle have been leached down to the lower horizon of the soil profile, leaving the epipedon littered with a layer of coarse silty or fine sandy material of radish brown hue, surface colour usually yellowish brown. Continuous leaching under heavy rainfall, rather poor in nutrients, can support good stands of tropical forest, growth of forest maintained by quick turnover of available plant nutrient store with in the biomass of the existing forest cover. Forest cover is luxuriant. 1/3 of the geographical area of the state.

Soil Series and Characteristic

- Chhanraipara series- Ultic Hapludalfs, very dark grayish brown, sandy loam to loam soils with loam to sandy loam sub soils moderately well drained, moderately steep to steep hills slope, severely eroded under jhum cultivation.
- Ramdurgabari series- Ultic Hapludalfs, very dark greyish brown, sandy loam to loan soils with heavier sub soils, strongly sloping to moderately steep hill tops and slopes, moderately well drained, moderately to severely eroded under jhum cultivation.
- Belbari Series- Ultic Hapludalfs, very dark greyish, brown, moderately well drained, sandy loam soil with clay loam to clay subsoil, moderately eroded, under thin forest, periodical jhuming.
- Radhamoni Series- Udic Ustochrepts, very deep, very dark greyish brown to dark brown, well drained, moderately steep, and very steep hill slope, sandy loam to loam soil with lighter sub soil. Severely eroded under thin forest under jhum cultivation.
- Dhumachara Series- Typic Ustochrepts, very deep, dark brown, moderately well drained, sandy cay loam soil and sub soil, severely eroded, under shrubs and grasses.

Table 2.8: Soils of Tripura-Soil Sub-Orders

Sl. No.	Soil Sub-Orders	Area ('000 ha)
1.	Udults	68.37
2.	Udalfs	45.46
3.	Aquepts	140.35
4.	Ocrepts	645.62
5.	Umbrepts	47.97
6.	Aquents	1.10
7.	Psamments	0.20
8.	Orthents	94.02



- Naraifung series- Ultic Hapludalfs, deep dark brown, moderately well drained, sandy loam to silty loam soils, subsoil with rock fragments of 0.2-10 cm diameters with ferro manganese concretions, dense forest and jhum cultivation.

- Sankoma series- Ultic Hapludalfs,, very deep dark brown, moderately well drained on strongly sloping, sandy loam to loam soils with sandy clay loam to clay loam subsoils, moderately to severely eroded thin forest vegetation, jhum cultivation.

Red loam and sandy loam soils

These soils are also extensive, residual in nature and occurring on in the West and North valley areas and associated with numerous valleys and undulating uplands of the state. Generated from chemical decomposition of bed rocks, some fluvio-colluvial materials brought down from planks of the long parallel ranges, residuum accumulated on valley floors, generated under forest environment, fairly mature soils, Alfisols, comprising association of Ultic Hapludalfs and Typic Paleudults, covering 43% of the geographical area of the state.

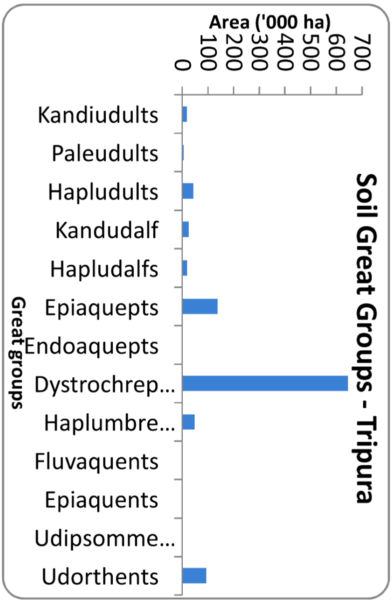
Soil Series and Characteristic

- Tuikaram Series- dark to dark brown, deep, moderately well drained, in steep slope, with clay loam subsoil, eroded under thin forest cover.
- Chandrajaipara Series- Fine loamy soil, dark greyish brown, very deep, well drained, with clay loam subsoil, severely eroded, under forest.
- Hazapara series- Coarse loamy soil, dark greyish brown, eroded, well drained, under forest.
- Jainarayanpur series- Fine loamy soil, dark brown, in steep slopes, very deep, with clay loam sub soil, severely eroded.
- Khowai series- Fine loamy, dark greyish brown, deep, well drained, sandy clay loam, under shrubs and grasses.
- Mongubari Series- Fine loam, dark greyish brown, in moderate slope, with clay subsoil, under shrubs and grasses.
- Jhukharaipara series- Fine loam, dark grey, very deep, well drained, with clay loam subsoil, under erosion.

- Kathalbagan series- Fine loamy, dark greyish brown, moderately well drained, in very steep hill slope, under forest and jhum.
- Mahamunipara series- Very dark greyish brown, very deep, in moderately steep to very steep slope, erosion prone, under moderate forest cover.
- Kathalia Series- Brown to dark brown on very steep slope, under the forest and plantation crop and jhum.
- Jagatramchara series- Very deep, very dark, on gentle to steep slope with clay loam to clay subsoil under plantation crop and jhum.
- Ambagan series- Moderately well drained, on moderate slope, subsoil clayloam, under orchard.
- Paglachar series- Very deep, dark yellow brown on steep to very steep middle hill slopes, under moderately dense forest and jhum.
- Gongrai series- Very deep, dark brown, well drained erosion prone, under forest and jhum.

Table 2.9: Soils of Tripura – Soil Great Groups

Sl. No.	Great Groups	Area ('000 ha)
1.	Kandiudults	18.95
2.	Paleudults	6.24
3.	Hapludults	43.18
4.	Kandudalf	25.85
5.	Hapludalfs	19.61
6.	Epiaquepts	137.95
7.	Endoaquepts	2.40
8.	Dystrochrepts	645.62
9.	Haplumbrepts	47.97
10.	Fluvaquents	0.60
11.	Epiaquents	0.50
12.	Udipsomments	0.20
13.	Udorthents	94.02



Older alluvial soils

Recent origin but are fairly natural soils of transported nature. These are mainly situated on the river terraces and high plains of the state. These soils are fairly rich in nutrient status, hence are suitable for farming. Alfisols (Typic Typic Ochraqualfs, at some places associated with Inceptisols0, It covers 10% of the geographical area of the state.

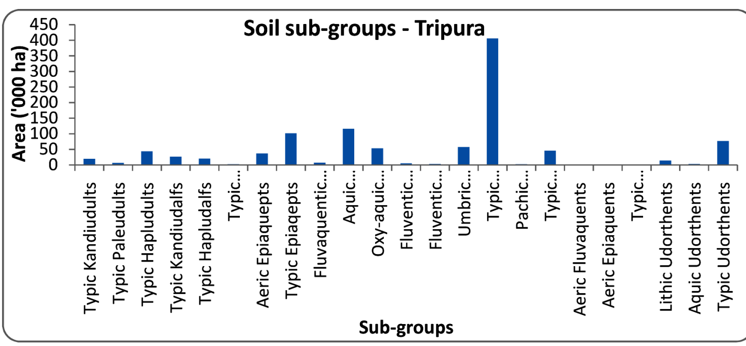
Soil Series and Characteristic

- Bakuri Series- In very gently sloping river valley, moderately well drained, covered by grasses and shrubs.
- Tuikathang series- Fine loamy soil, dark grey, very deep, moderately drained on developing valley land, usually under paddy cultivation.
- Kalachara series- Fine loamy soil, ill drained, very deep, in levelled river valley, with silty loam or clay loam subsoil, usually under paddy cultivation.
- Gangasardarbari Series- Fine loamy soil, greyish brown, very deep, well drained, on gently sloping land, with heavy clay loam subsoil, partly eroded, covered with bushes, occasionally by paddy cultivation.
- Lalpumbari series- Fine loamy soil, dark grey, very deep, moderately drained on gently sloping valley, slightly eroded, under bushes.

Table 2.10: Soils of Tripura – Soil Sub-groups

Sl. No.	Sub-groups	Area ('000 ha)
1.	Typic Kandiudults	18.95
2.	Typic Paleudults	6.24
3.	Typic Hapludults	43.18
4.	Typic Kandiudalfs	25.85
5.	Typic Hapludalfs	19.61
6.	Typic endoaquepts	2.40
7.	Aeric Epiaquepts	36.47
8.	Typic Epiaqepts	101.48

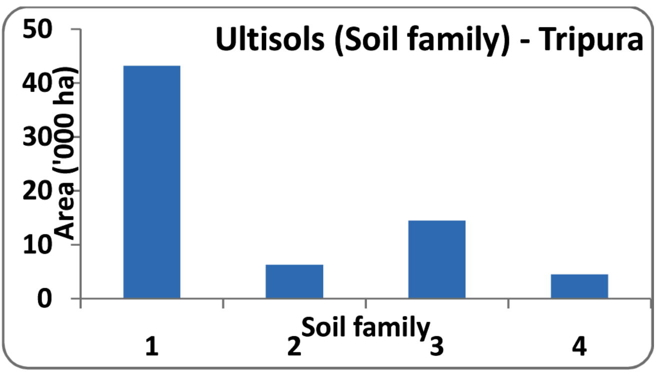
9.	Fluvaquentic Dystrochrepts	6.52
10.	Aquic Dystrochrepts	115.76
11.	Oxy-aquic Dystrochrepts	52.61
12.	Fluventic Umbric Dystrochrepts	4.98
13.	Fluventic Dystrochrepts	2.96
14.	Umbric Dystrochrepts	57.08
15.	Typic Dystrochrepts	405.71
16.	Pachic Haplumbrepts	2.25
17.	Typic Haplumbrepts	45.72
18.	Aeric Fluvaquents	0.60
19.	Aeric Epiaquents	0.50
20.	Typic Udipsamments	0.20
21.	Lithic Udorthents	14.06
22.	Aquic Udorthents	3.10
23.	Typic Udorthents	76.86



These soils are mainly confined to the flood plains of the streams like the Khowai, Howrah, Gomati and the Muhuri. Usually occur along the rivers near the peripheri of the state as the rivers debounch on to the lower plains in Bangladesh. Entisols- classifies as Typic Udifluvents, affected by floods almost every year, enriched by deposition, new layers of silt and clay as flood recede, extremely rich and favourable to produce rice , jute and mesta. Only 9% of the geographical area of the state is under this category of soils.

Table 2.11: Soil of Tripura – Ultisols (Soil family)

Sl. No.	Soil family	Area ('000 ha)	Common Name	No. of occurrence
1.	Fine-loamy, mixed, hyper-thermic, Typic Hapludults	43.18	Red soils	4
2.	Fine-loamy, mixed, hyper-thermic, Typic Paleudults	6.24	Red soils	1
3.	Fine-loamy, mixed, hyper-thermic, Typic Kandiudults	14.45	Red soils	2
4.	Fine- mixed, hyperthermic, Typic Kandiudults	4.50	Red soils	1

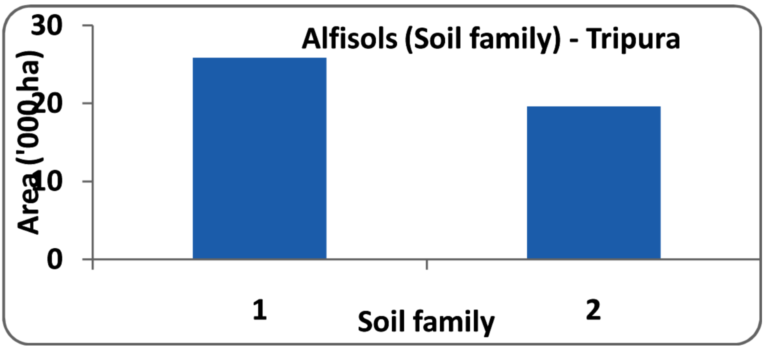


Soil Series and Characteristic

i. Janmejaynagar series- Very deep, very dark grey to very dark greyish brown, moderately well drained on very gently to gently sloping valley lands, loamy soils, slightly eroded under bushes and under occasional paddy cultivation. Liable to erosion by lateral cutting and bank collapse.

5. Lateritic soils

These soils are confined to some Moorish upland close to the western boundary of the state.Ultisols, largely Typic Palehumults With certain cases of Typic Plinthudults and Typic Plinthustults, usually barren and depled of plant nutrient, as a whole unsuitable for arable. Water soluble materials occurring in the bed rock having been washed down to the lower horizons of the soil profile, the upper part is left with a stuff which comprises the lateritic soils, coarse texture, extremely poor in nutrients, supports tolerably good vegetation consisting grasses, shrubs and bushes.



On the basis of the variation in relief and geology, the soils of the hilly terrain are grouped under three subgroups viz.:

a. High relief structural hills (sandstone)
b. Medium relief parallel ridges (Shales and siltstone)
c. Low relief structural hills and ridges (Shales)

a) Soils of high relief structural hills (sandstone)

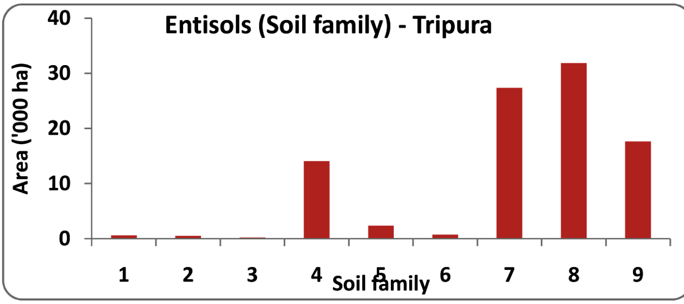
Soils of this region are deep to very deep, well to somewhat excessively drained, loamy skeletal which are developed from sandstone on very steeply sloping high relief structural hills with severe to very severe erosion hazard and moderate stoniness and mostly under dense forest vegetations. Although jhuming is a popular farming practices but the terrain condition does not permit easy access and hence the percentage area affected by jhumimg is comparatively less in the high relief hills. Taxonomically, these soils are classified as Loamy skeletal Typic Dystrochrepts, Fine loamy Umbric Dystrochrepts and Fragmental Lithic Udorthents, Fine loamy Typic Dystrochrepts, Loamy skeletal Typic Hapludalfs, Fine loamy Typic Udorthents and Fine loamy Typic Haplumbrepts.

b) Soils of medium relief parallel ridges (Shales and siltstone)

Soils of this region are deep to very deep, well to somewhat excessively drained, fine to coarse loamy soils on moderately sloping medium relief parallel ridges are developed from shales and siltstone with sever to very severe erosion hazard and slight stoniness and mostly under moderately dense forest. The area affected through jhum cultivation rice somewhat higher than in the high relief structural hills. Taxonomically, these soils are classified as Fine loamy Typic Hapludulfs, Fine loamy Umbric Dystrochrepts, Coarse loamy TypicUdorthents, Loamy over sandy Typic Dystrochrepts, Fine Typic Dystrochrepts, Coarse loamy over sandy TypicUdorthents and Fine loamy Typic Haplumbrepts.

Table 2.12: Distribution of soils of medium relief parallel ridges (Shales and siltstone)

Sl. No.	Soil family	**Area ('000 ha)**	**Common name**	**No. of occurrence**
1.	Coarse-loamy, mixed, hyperthermic, Aeric Fluvaquents	0.60	Alluvial soils	1
2.	Coarse-loamy, mixed, hyperthermic, Aeric Epiaquents	0.50	Alluvial soils	1
3.	Fine-loamy, mixed, hyperthermic, Typic Udipsamments	0.20	Alluvial soils	1
4.	Fragmental, mixed, hyperthermic, Lithic Udorthents	14.06	Red soils	2
5.	Coarse-loamy, mixed, hyperthermic, Aquic Udorthents	2.34	Alluvial	2
6.	Fine-loam, mixed, hypothermic, Aquic Udorthents	0.76	Alluvial	1
7.	Fine-loamy, mixed, hyperthermic, typic Udorthents	27.36	Red soils	2
8.	Coarse-loamy, mixed, hyperthermic, Typic Udorthents	31.86	Red soils	8
9.	Coarse-loamy over sandy, mixed, hyperthermic Typic Udorthents	17.64	Red soils	1



Moderately deep to deep, well to somewhat excessively drained, fine to coarse loamy soils on the side slopes of low relief structured hills and ridges are developed from shales with moderate to severe erosion hazard and slight stoniness. Jhuming is a common practice in this tract and sometimes 50-75% area is affected by jhum cultivation. Taxonomically, these soil Fine loamy Umbric Dystrochrepts are classified as Fine loamy Typic Dystrochrepts, Fine loamy Umbric Dystrochrepts, Loamy skeletal Umbric Dystrochrepts, Fine Typic Dystrochrepts, Fine Umbric Dystrochrepts and Fine loamy Typic Haplumbrepts.

Soils of flat topped denudational hills

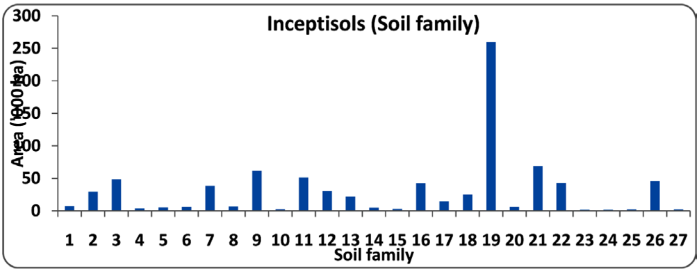
Very deep, well drained and fine loamy soils on moderately to gently sloping flat topped denudation hills are developed on sandstones with moderate erosion hazard and are under moderately dense forest. Many such soils in the southern part of the state are used for rubber cultivation. Taxonomically, the major soils are grouped under Fine loamy Typic Kandiudults, Fine loamy Typic Dystrochrepts, Fine loamy Typic Kandiudalfs, Fine loamy Aquic Dystrochrepts.the soils identified as inclusions are Fine loamy Umbric Dystrochrepts and Fine Typic Dystrochrepts.

Table 2.13: Distribution of soils of flat topped denudational hills

Sl. No.	Soil family	Area ('000 ha)	Common name	No. of occurrence
1.	Fine, mixed, hyperthermic, Aeric Epiquepts	7.26	Alluvial soil	1

2.	Fine-loamy, mixed, hyperthermic, Aeric Epiaquepts	29.21	Alluvial soils	2
3.	Fine-loamy, mixed hyperthermic, Typic Epiaquepts	48.53	Alluvial soils	6
4.	Fine-silty, mixed, hyperthermic, Typic Epiaquepts	3.32	Alluvial soils	1
5.	Fine-loamy over sandy, mixed, hyperthermic, Typic Epiaquepts	5.28	Alluvial soils	1
6.	Sandy over loamy, mixed, hyperthermic, Typic Epiaquepts	5.94	Alluvial soils	3
7.	Fine, mixed, hyperthermic, Typic Epiaquepts	38.41	Alluvial soils	1
8.	Coarse loamy over sandy, mixed, hyperthermic Fluvaquentic Dystrochrepts	6.52	Alluvial soils	1
9.	Fine-loamy, mixed, hyperthermic, Aquic Dystrochrepts	62.03	Red soils	2
10.	Fine-silty over sandy, mixed, hyperthermic, Aquic Dystrochrepts	2.7	Alluvial soils	3
11.	Fine, mixed, hyperthermic, Aquic Dystrochrepts	51.03	Alluvial soils	1
12.	Fine-loamy, mixed, hyperthermic, Oxy-aquic Dystrochrepts	30.74	Alluvial soils	1
13.	Fine, mixed, hyperthermic, Oxy-aquic Dystrochrepts	21.87	Red soils	1
14.	Fine-loamy, mixed, hyperthermic, Fluventic Umbric Dystrochrepts	4.98	Alluvial soils	6
15.	Coarse-loamy, mixed, hypothermic, Fluventic Dystrochrepts	2.96	Alluvial soils	1
16.	Fine-loamy, mixed, hyperthermic, Umbric Dystrochrepts	42.44	Red soils	2

17.	Loamy-skeletal, mixed, hyoperthermic, Umbric Dystrochrepts	14.64	Red soils	19
18.	Loamy-skeletal, mixed, hyperthermic, Typic Dystrochrepts	25.19	Red soils	1
19.	Fine-loamy, mixed, hyperthermic, Typic Dystrochrepts	259.44	Red soils	8
20.	Loamy over sandy, mixed, hyperthermic, Typic Dystrochrepts	6.06	Red soils	5
21.	Fine, mixed, hyperthermic, Typic Dystrochrepts	68.83	Red soils	1
22.	Coarse-loamy, mixed, hyperthermic, Typic Dystrochrepts	42.81	Res soils	1
23.	Clay-skeletal, mixed, hyperthermic, Typic Dystrochrepts	1.58	Red soils	1
24.	Coarse-loamy over sandy, mixed, hyperthermic, Typic Dystrochrepts	1.8	Alluvial soils	7
25.	Fine-loamy, mixed, hyperthermic, Pachic Haplumbrepts	2.25	Red soils	1
26.	Fine-loamy, mixed, hyperthermic, Typic Haplumbrepts	45.72	Red soils	7
27.	Hydric, mixed, hyperthermic, Typic Endoaquepts	2.4	Alluvial soils	1



Soils of low lying residual hills with valleys

Very deep, well drained, fine to coarse loamy soils on low lying residual hills are developed on sandstones with moderate erosion hazard under thick forest vegetations of teak and under plantation of jackfruit and cashewnuts. The major soils are grouped under Fine loamy to Coarse loamy Typic Dystrochrepts and Fine loamy Typic Hapludulfs. The soils identified as inclusions are clay skeletal Typic Dystrochrepts.

Very deep, imperfectly drained, coarse loamy soils on gently sloping interhill basin poor to moderate cultivation of paddy. These are susceptible to severe seasonal floods. The important soils are Coarse loamy Aquic Udorthents and Fine loamy Aquic Dystrochrepts

Soils of undulating plains with low mounds and narrow valleys

Deep to very deep, well drained, fine loamy soils are developed on the moderate to gently sloping undulating plains commonly known as 'tilla', with moderate erosion hazard and mostly under degraded forest and poor to moderate cultivation in some patches. These soils are reddish brown in colour and sandy loam to sandy clay loam and clay loam texture and/or coloured B horizon with Ochric or umbric epipedon and low base status. Taxonomically, these soils are classified as Fine l to Coarse loamy Typic Dystrochrepts and Fine loamy Umbric Dystrochrepts etc. Besides, very low base status and cation exchange capacities in some soils help identifying Kandic B horizons grouping them into Fine Typic Kandiudulfs. Due to low ground water level in these tillas, a severe moisture stress is common in most part of the year which affects normal cultivation in this area. The soils in the interhill basins are very deep, imperfectly to poorly drained and possess an aquic moisture regime. These are grouped as Fine loamy Typic Epiaquepts, Fine loamy Aquic Dystrochrepts. The soil identifies as inclusions are Fine loamy Oxyaquic Dystrochrepts, Fine to Coarse loamy Typic Dystrochrepts.

Soils of Interhill Valleys:

These soils are generally deep to very deep, imperfectly to moderately well drained, fine to coarse loamy and are developed on gently to moderately sloping undulating plains with low mounds and on the gently to very gently sloping interhill valleys, commonly known as 'lungas, with moderate to slight erosion hazard and mostly under cultivation. These soils are acidic and the colour varies from grey to dark brown to olive brown. Gleying of the soils with dark colour mottles in subsurface layers is common. The degree of saturation in some of the layers of the control section as evidenced by redoximorphic features and the gleying indicate an aquic moisture regime and /or episturation. Taxonomically these soils are grouped as Coarse loamy Aquic Udorthents and coarse loamyAeric Fluvaquents.Oart of this interhill valleys have an upland surface away from the main strem or river channel. Soils of these uplands do not possessaquic moisture regimes and are very deep, well drained, fine loamy with moderate erosion hazard. Taxonomically, these are grouped into Fine to Fine loamy Typic Dystrochrepts and Fine loamy Typic Haplumbrepts.

Flood Plain soils

The flood plains soils are generally acidic in nature (pH 4.8-5.1) and the colour varies from grey to light brown to olive brown and are very deep, imperfectly to very poorly drained. Coarse/fine loamy to clayey in texture, developed on very gently sloping alluvial/flood plains with moderate to severe flood hazard and slight erosion. Presence of well developed textural and/ or coloured B horizon qualifies such soils for Inceptisols. The soils remain saturated with moisture due to the physiographic position as well as the proximity of the rivers or other drainage channels. A reducing regime virtually free of dissolve oxygen is developed with characteristic redoximorphic features viz. gleying and mottles. Presence of redox deposition in one or more horizons within 60 cm of the mineral soil surface with a chroma of 2 or less and also the presence of aquic condition for some time in most years qualify soils for Dystrochrepts. Taxonomically, these soils are grouped into Fine Aeric Epiaquepts, Fine loamy Typic Epiaquepts, Fine loamy Aquic Dystrochrepts, Fine Typic Epiaquepts, Coarse loamy over sandy Fluvaquentic Dystrochrepts. North of the stae ia the particular location of these soils.

Soils of Rolling Uplands

The soils of rolling uplands are very deep, well drained, fine loamy, acidic and the colour varies from reddish brown to dark reddish brown, and are developed on moderately gently sloping disintegrated hillocks with moderate to severe erosion hazard, due to lack of proper soil conservation measure, the soils are totally exposed and are susceptible to erosion. The presence of B horizon in these soils qualifies them to Inceptisols. Taxonomically, these soils are classified as Fine loamy Typic Haplumbrepts, Fine loamy Pachic Haplumbrepts and Fine loamy Typic Dystrochrepts.

Chapter –III

SOIL FERTILITY AND ITS MANAGEMENT

Capacity of soil to hold and supply sufficient level of nutrients for optimum crop yield is referred to as soil fertility. Nutrient supplying capacity has, thus, been controlled by both soil factor as well as climate factor. As the state Tripura is predominantly hilly and characterized by varied type of soil and geographical situations, the fertility status is widely varied across the climatic gradients. Single soil factor that mostly determine the abundance of plant nutrient in soil is pH or soil reaction. It is very important particularly for soils of Tripura where more that 49.2 per cent of the soils are strongly acidic in reaction, causing deficiency and toxicity of a number of nutrients. Climatic factors like, temperature, rainfall tremendously regulates nutrient availability through decomposition of organic matter of soil. Carbon stock in Tripura soil showed a wide variability, thus nutrient availability varies accordingly. Both macro and micronutrients showed low to medium status across the length and breadth of the state. With soil being the source of nutrients to the crops, proper assessment of its nutrient status is required for each and every crop before application of any additional nutrient sources. Judicious use of external resources is one of the main criteria to raise agricultural productivity in the soils of the state.

A sizeable soil holdings of Tripura are under *jhum* cultivation that facilitates erosion of top fertile soil . This needs immediate attention to improve *jhum* cultivation with proper soil management. The nutrient consumption is, on an average around 55 kg/ha against the national average of 120 kg/ha. This is mostly due to non application of chemical fertilizers by tribal *jhumias* and partly due to lack of proper soil related knowledge. Thus, significant land holdings are default organic by nature. Proper management of those default organic lands should be developed under current perspective of organic farming of the state.

Soil reaction (pH): It is a measure of acidity or basicity which reflects the status of base saturation. Availability and toxicity of numbers of plant nutrients depends on the nature and extent of soil pH. The soil pH ranges from 3.5 – 7.1. 49.2 percent area of the state belongs to strongly acidic (5.1 – 5.5) category followed by 24.46 percent of the state under very strongly acidic (4.5 – 5.0). Due to strong acidic condition most of the arable soils of Tripura are very low in phosphorus content. Under low pH the iron and aluminium become more active thereby forming insoluble iron and aluminium phosphate rendering unavailable to crops. Soil pH strongly regulates organic matter decomposition of soil. Acidic soils only harbour acidophilic microorganisms, a small fraction of microbial community taking part in organic matter decomposition. Thus mineralization rate of organic nitrogen is also slow resulting low to medium level plant available nitrogen (PAN) in soils of Tripura.

Table 3.1: Status of soil pH in different districts of Tripura State (area in hectares)

Class	West	South	Dhalai	North	State
Extremely acidic	17419.5	10135	50145	17771	95470.5
	(5.81)	(4.70)	(19.65)	(6.30)	(9.09)
Very strongly acidic	91038.7	82239	55311	28090	256678.7
	(30.37)	(38.21)	(21.67)	(9.96)	(24.46)
Strongly acidic	150587.28	112094	58515	195085	516281.28
	(50.26)	(52.09)	(22.92)	(69.16)	(49.20)

Moderately acidic	15761.60	4971	20660	392.08	80600.6
	(5.26)	(2.31)	(8.10)	(13.90)	(7.68)
Slightly acidic	5304.00	191	123.16	1909	19720
	(1.76)	(0.10)	(4.82)	(0.68)	(1.87)

(Parenthesis indicates respective percentage)

Soil organic carbon

It plays a key role in supplying plant nutrients, building cation exchange capacity, improving soil structure, water holding capacity and soil biological activity. Organic carbon content in the soils of Tripura ranges from 0.1 to 5.42 mg kg^{-1} and three categories viz. low (< 0.75 gm kg^{-1}), medium (0.75 to 1.50 gm kg^{-1} and high (> 1.50 gm kg^{-1}) have been identified . 70.78 percent of the state belongs to medium category followed by 11.47 percent and 10.08 percent to low and high category respectively.

Table 3.2: Status of soil organic carbon of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Low	57673 (19.24)	22106 (10.27)	15869 (6.22)	24718 (8.76)	120366 (11.47)
Medium	183774 (61.32)	101001 (75.05)	160248 (62.78)	237102 (84.06)	742625 (70.78)
High	38664 (12.90)	36023 (11.09)	20830 (8.16)	20243 (7.18)	105760 (10.08)

(Parenthesis indicates respective percentage)

Macronutrients: Nutrients like nitrogen (N), phosphorus (P) and potassium (K) are considered as primary nutrients. These nutrients help in proper growth, development and yield differentiation of plants and are generally required by plants in large quantity.

Available Nitrogen: Nitrogen is an integral component of many compounds including chlorophyll and enzyme essential for plant growth. Deficiency of nitrogen decreases rate and extent of protein synthesis and results into stunted growth and develops chlorosis.

Available nitrogen content in the surface soils of Tripura ranges between 50.0 to 1206.0 kg ha^{-1} (Table 3). Soils of majority area (about 36 percent of the state) have medium status of available nitrogen (280 – 450 kg ha^{-1} and about 32 percent have low (< 280 kg ha^{-1}) available Nitrogen content. Inspite of having handsome carbon stock in Tripura soil, available nitrogen in most of the soil is medium status. This is mostly due to slow mineralization rate. Experimental results showed fair response of crop plants to applied chemical fertilizers.

Table 3.3: Status of available nitrogen of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Low	144395.13	151331	20906	22504	339136.13
	(48.18)	(70.32)	(8.19)	(7.98)	(32.32)
Medium	127306.53	36253	202756	110706	377021.53
	(42.48)	(16.88)	(40.25)	(39.25)	(35.93)
High	8410.07	22046	73285	148853	252594.07
	(2.80)	(10.24)	(28.72)	(52.77)	(24.07)

(Parenthesis indicates respective percentage)

Available Phosphorus: Phosphorus takes part in important function like photosynthesis, nitrogen fixation, crop maturation, root development, strengthening straw in cereal crops etc. The availability of phosphorus is restricted under acidic soil reaction mainly due to P-fixation as it gets fixed with aluminium and iron.

Available phosphorus content ranges from 126.0 – 1059.0 kg ha^{-1} in soils of Tripura (Table 4). Soils of about 73.0 percent area are very low (< 25 kg ha^{-1}) in available phosphorus content while about 10.29 percent area are found to be medium (25.0 – 45.0 kg ha^{-1}) in available P content. Crop response to added phosphate fertilizers has been highly correlated in different experimental studies. Due attention has to be taken for phosphorus management with special care to North district.

Table 3.4: Status of available phosphorus of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Very low	189485.69	171805	131886	177656	770502.69
	(63.22)	(79.84)	(81.84)	(98.44)	(73.43)
Low	59315.16	28318	15972	4407	108012.16
	(19.76)	(13.15)	(6.26)	(1.56)	(10.29)
Medium	22141.26	6623	14066	—	42830.26
	(7.39)	(3.08)	(5.81)	—	(4.08)
High	9169.62	2884	38383	—	47406.62
	(3.06)	(1.34)	(13.88)		(4.51)

(Parenthesis indicates respective percentage)

Available Potassium: It is important in grain formation and tuber development; it encourages crop resistance for certain fungal and bacterial diseases. Moreover, it resists the plant against few abiotic stresses.

Available potassium content in soils of Tripura ranges from 3.85 to 1155.84 kg ha^{-1} (Table 5). Most of the soils (about 51.0 percent of the state) have medium (150 – 340 kg ha^{-1}) and about 33.0 percent are low below (150 kg ha^{-1}) in available potassium content.

Table 3.5: Status of available potassium of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Low	174242.0	65685	48327	63803	349157
	(55.17)	(30.52)	(17.76)	(22.62)	(33.27)
Medium	96148.86	126970	120888	185988	52994.86
	(32.08)	(59.00)	(47.36)	(65.94)	(50.51)
High	9620.87	16975	30732	32272	89599.87
	(3.21)	(7.89)	(12.84)	(11.44)	(8.54)

(Parenthesis indicates respective percentage)

Micronutrients: Of the 18 plant nutrients known to be essential for plant growth, 9 are required in small quantity and that's why they are called micronutrients. Copper (Cu), Zinc (Zn), Manganese (Mn) and Iron (Fe) are considered most important micronutrients as their deficiency is considered severe in terms of stunted growth, low yield, dieback and even plant death.

Table 3.6: Range of micronutrient content (mg kg^{-1}) in soils of Tripura

Nutrient	Available		Total	
	Upland	Lowland	Upland	Lowland
Zinc	2.1-4.0	2.2-4.0	62.0-295	99.0-450
Copper	0.20-1.7	0.50-2.2	15.0-40.0	11.0-37.0
Iron	4.8-16.4	6.6-61.8	20100-31600	5600-32100
Manganese	11.4-33.6	12.4-37.6	277.0-437.0	173.0-625.0
Boron	0.1-2.7	0.3-1.5	83.0-110.0	18.1-182.0
Molybdenum	0.09-0.23	0.07-0.18	1.3-6.6	1.2-7.9

Available Manganese: Manganese is essential in photosynthesis and nitrogen transformation in plants. As per the critical limit of available manganese (> 2 mg kg^{-1}) majority areas of Tripura are excessively high in available manganese content. It ranges from 11.4 to 37.6 mg kg^{-1} in surface soils. All soils are sufficient in available Manganese content (> 2.0 mg kg^{-1}).

Table 3.7: Status of available manganese of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Excessive	72432.87	3207	98597	48013	222349.87
	(24.17)	(1.49)	(38.63)	(17.02)	(17.18)
Very high	121727.67	149416	92378	223924	636990.67
	(57.15)	(69.43)	(36.19)	(79.39)	(60.71)
High	32045.85	57007	5972	10126	105150.85
	(10.69)	(26.49)	(2.34)	(3.59)	(10.02)
Adeqaute	4360.34	—	—	—	4360.34
	(1.45)	—	—	—	(0.41)

(Parenthesis indicates respective percentage)

Available Iron: It promotes starch formation and seed maturation. It also helps in absorption of other nutrient elements.

Available iron content in surface soils ranges between 4.8 to 61.8 mg kg^{-1} (Table 9). As per the critical limit of available iron (> 4.5 mg kg^{-1}) soils of Tripura are sufficient in available content. This is mainly due to low soil pH under which iron remains as soluble ferrous form available to crop.

Table 3.8: Status of available iron of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Excessive	45985.39	13021	77733	148753	285492.39
	(15.34)	(6.05)	(30.46)	(52.74)	(27.21)
Very high	129221.33	100422	95343	114515	439501.33
	(43.12)	(46.67)	(37.35)	(40.60)	(41.89)
High	100104.90	96187	23871	18795	238957.90
	(10.69)	(44.69)	(9.35)	(6.66)	(22.77)
Adequate	4800.11	—	—	—	4800.11
	(1.60)	—	—	—	(0.45)

(Parenthesis indicates respective percentage)

Available copper: Copper involves in photosynthesis, respiration, protein and carbohydrate metabolism and in the use of iron.

The available copper status in surface soils of Tripura ranges between trace to 2.2 mg kg^{-1} (Table 6). Soils of Tripura are sufficient in available copper. Only 33.0 percent area shows low (< 1.0 mg kg^{-1}) available copper content.

Table 3.9: Status of available copper of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Low	126318.02	56730	62416	109957	355421.02
	(42.15)	(26.36)	(24.45)	(38.98)	(33.87)
Marginal	63149.02	32582	25033	71431	192195.02
	(21.07)	(15.14)	(9.81)	(25.33)	(18.31)

Adequate	51714.62	50042	22369	53961	178086.02
	(17.25)	(23.25)	(8.77)	(19.13)	(16.97)
High	38930.2	70276	87129	46714	243049.2
	(12.98)	(32.66)	(34.13)	(16.56)	(23.16)

(Parenthesis indicates respective percentage)

Available Zinc: Zinc plays role in protein synthesis, reproductive process of certain plants and in the formation starch and some growth hormones. It promotes seed maturation and production and also plays important role in water uptake and water relations in the plant. It also influences the activity of dehydrogenase enzymes e.g. Pyridine nucleotide, trios phosphate.

The available zinc ranges between 2.1 to 4.0 mg kg^{-1} (Table 7). Soils of Tripura about 16.40 percent area are deficient (< 0.5 mg kg^{-1}) in available zinc.

Table 3.10. Status of available zinc of Tripura State (area in ha)

Class	West	South	Dhalai	North	State
Low	27923.06	21941	26221	96015	172100
	(9.32)	(10.20)	(10.27)	(34.04)	(16.40)
Marginal	173500.08	82816	74037	151601	481954.08
	(57.89)	(34.48)	(29.00)	(53.75)	(45.93)
Adequate	57105.00	21349	73234	22395	174083
	(19.85)	(9.92)	(9.19)	(7.94)	(16.59)
High	21583.00	83524	23455	12052	140614
	(7.20)	(38.81)	(28.69)	(4.27)	(13.40)

(Parenthesis indicates respective percentage)

Soils of Tripura acidic in nature ranging from slightly acidic (6.1 to 6.5) to extremely acidic (< 4.5). 49.20 percent of the state area belongs to strongly acidic category (5.1 to 5.5). The organic carbon content are moderate. Majority of soils (36.0 percent of the state) have medium status (280 to 450 kg ha^{-1}). Soils (33.0 percent) are very low in available phosphorus content. Due to acidic nature P is fixed with Al and Fe. Most of the soils are rated as medium (140 to 340 kg ha^{-1}). Soils are sufficient in available Iron and Manganese content. About 16.40 percent area of the state are deficient (< 0.5 mg kg^{-1}) in available zinc. Soils of Tripura (33.0 percent area) are deficient in available copper (< 1.0 mg kg^{-1}).

North District

Soils of North district, Tripura have been developed on five different physiographic units. Four soils order viz. Inceptisols, Entisols, Alfisols and ultisols have been identified. Soils are slightly acidic – soil pH ranges from 3.35 to 6.70. Dominant soils are strongly acidic (pH 5.0 – 5.5) covering 69.16 percent area of North district. Organic carbon content in soils ranges from 0.1 to 5.42 gm kg^{-1}. 84.06 percent area comes under medium organic carbon content (> 0.75 gm kg^{-1}). Soils of 8.76 percent area are low (< 0.5 gm kg^{-1}) distributed in Batchhera, Samrurpur area.

Available nitrogen content of surface soils of North district ranges from 50.0 to 1131.48 kg ha^{-1}. Low (< 250 kg ha^{-1}) and medium (250 – 450 kg ha^{-1}) covers 7.98 and 39.25 percent area of the district respectively. Soils are low (< 45 kg ha^{-1}) in available phosphorus content. 98.44 percent areas are deficient in available phosphorus. Available potassium content in soils are dominantly low (< 150 kg ha^{-1}) to medium (150 – 340 kg ha^{-1}) covering 22.62 percent and 65.94 percent area respectively.

Analytical results indicate that DTPA extractable available Mn and Fe are sufficiently present in soils. The available Cu content in soil ranges between trace to 4.68 mg kg^{-1}. Soils of 38.98 percent and 25.33 percent are low to marginal in Cu content respectively. Available Zn content in surface soils ranges from trace to 54.0 mg kg^{-1}. Low (< 0.5 mg kg^{-1}) and marginal (0.05 – 1.00 mg kg^{-1}) class cover 34.04 percent and 53.75 percent of North district respectively.

South District

Soils of South district, Tripura have been developed on nine different physiographic units. Four soils orders viz. Inceptisols, Entisols, Alfisols and Ultisols have been identified. Soils are dominantly acidic, soil pH ranges from 3.7 to 6.7. Dominant soils are strongly acidic (pH 5.1 – 5.5) covering 112094 ha. which represents 52.09 percent area of South district. Organic carbon content in soils ranges from 0.1 to 3.0 gm kg^{-1}. 75.05 percent area of South district is under medium organic carbon content. Soils covering 10.27 percent of the South district belongs to low category. Available nitrogen content of surface soils of South district ranges from 6.3 to 893.13 kg ha^{-1}. Low (< 280 kg ha^{-1}) and medium (280 - 450 kg ha^{-1}) category cover 7.32 percent and 16.85 percent area respectively. Soils are very low (< 25 kg ha^{-1}) in available phosphorus content 79.84 per cent area is deficient in available phosphorus. Only 1.34 per cent area of South district have been rated as high (> 90 kg ha^{-1}) in available phosphorus in areas around Mukchhani, Tekka and Dhwajanagar villages. Available potassium content in soils are rated dominantly Medium (150 – 340 kg ha^{-1}) to Low (< 150 kg ha^{-1}) covering 59.0 percent and 30.52 percent respectively. Analytical results indicate that DTPA extractable available Mn and Fe are sufficiently present in soils. The available Cu content in soil ranges between trace to 38.5 mg kg^{-1}. 32.66 percent and 26.36 percent areas of soils are rated as high to low in available Cu content respectively. Available Zn content in surface soils ranges from Trace to 19.0 mg kg^{-1}. Low (< 0.5 mg kg^{-1}) and marginal (0.05 – 1.0 mg kg^{-1}) category cover 10.20 and 38.48 per cent area of South district respectively.

West District

Soils of West district, Tripura have been developed on eight different physiographic units. Four soil orders viz. Inceptisols, Entisols, Alfisols and Ultisols have been identified. Soils are dominantly acidic – soil pH ranges from 3.5 to 7.4. Dominant soils are strongly acidic (pH 5.1 – 5.5) covering 50.26 percent area of West district. Organic carbon content in soils ranges from 0.21 gm kg^{-1} to 3.91 gm kg^{-1}. 61.32 percent area belongs to medium category of organic carbon content (0.75 – 1.50 gm kg^{-1}). Soils of 19.24 percent area are low (< 0.75 gm kg^{-1}) dominantly distributed in Melagharh areas.

Available nitrogen content of surface soils of West district ranges from 55.8 kg ha^{-1} to 644.0 kg ha^{-1}. Low (< 280 kg ha^{-1})

and medium (280 – 450 kg ha^{-1}) category covers 48.18 and 42.48 percent area of the district respectively. Soils are low (< 45 kg ha^{-1}) in available phosphorus content. 83.01 percent areas are deficient in available phosphorus. Only 3.06 percent area have been rated as high (> 90 kg ha^{-1}) in available phosphorus in an around of Tulchindral, Indranagar and Madhupur area. Available potassium content in soils are dominantly low (< 150 kg ha^{-1}) to medium (150 – 340 kg ha^{-1}) covering 58.17 percent and 32.08 percent area respectively.

Analytical results indicate that DTPA extractable available Mn and Fe are sufficiently present in soils. The available Cu content in soils ranges between trace to 6.02 mg kg^{-1}, 42.15 percent 21.87 percent soils are low to marginal in Cu content respectively. Available Zn content in surface soils ranges from trace to 9.42 mg kg^{-1}. Low (< 0.5 mg kg^{-1}) and marginal (0.05 – 1.00 mg kg^{-1}) category cover 9.32 percent and 57.89 percent of West district respectively.

Dhalai District

Soils of Dhalai district, Tripura have been developed on five different physiographic units. Four soils orders viz. Inceptisols, Entisols, Alfisols and Ultisols have been identified. Soils are acidic – soil pH ranges from 4.1 to 7.1. Soils are dominantly strongly acidic (pH 5.1 – 5.5) covering 22.92 percent area of Dhalai district. Organic carbon content in soils ranges from 0.23 to 2.50 gm kg^{-1}. 62.78 percent area comes under the category of medium organic carbon content (> 0.75 gm kg^{-1}). Soils of 6.22 percent area are low (< 0.75 gm kg^{-1}) in organic carbon content distributed in Micchuri, Dabbari and Barabari areas.

Available nitrogen content of surface soils of Dhalai district ranges from 102.0 to 1206.0 kg ha^{-1}. Soils of low (< 280 kg ha^{-1}) and medium (280 – 450 kg ha^{-1}) category cover 8.19 and 40.25 percent area of the district respectively. Soils are deficient in available phosphorus. Available potassium content in soils are dominantly low (< 150 kg ha^{-1}) to medium (150-340 kg ha^{-1}) covering 17.76 percent and 47.36 percent area respectively.

Analytical data indicate that DTPA extractable available Mn and Fe are sufficiently present in soils. The available Cu content in soil ranges between trace to 18.8 mg kg^{-1}. Soils of 24.45 percent and 9.81 percent area are low (< 1.0 mg kg^{-1}) to marginal (1.0 – 1.5 mg kg^{-1}) in Cu content respectively. Available Zn content in surface sols ranges from trace to 62.0 mg kg^{-1}. Low (< 0.5 mg kg^{-1}) and marginal (0.05 – 1.00 mg kg^{-1}) category of available Zn content cover 10.27 percent and 29.00 percent area of Dhalai district respectively.

Nutrient Management

Fertilizer Use

In spite of rich natural resources of soil, the state has remained economically backward due to failure of achieving optimum yield of crops. The major constraint for gaps in the yields besides prevalence of age-old shifting cultivation, small holding size, acidic soils etc., is the use of fertilizer nutrients and improper management practices. Nutrient management is a complex task, particularly in a state like Tripura with large scale rural illiteracy and poverty. Efficient use of fertilizer involves problems in this area of soil testing facility, suitable nutrient carriers, method of application, accounting of residual effects, proper planning within a cropping system, complementary use of FYM, manure, vermicompost, biofertilizers, reduction in losses from the soil.

The nutrient status of soil varies from region to region, field to field, and this calls for adequate availability of soil testing facility. But in Tripura there are only two static soil and and four mobile testing laboratories in 4 districts. But they are not well equipped with modern instruments and well trained personnel with scientific temperament. Soil testing facilities should be increased for covering larger areas. The extension service regarding nutrient management available to the farmers is also very inadequate.

A small fraction of nutrient mined has been compensated through application of chemical fertilizer. This indicates continuous depletion of nutrients from soils resulting in poor productivity. Considering the fertility status of the state, application of macro and few micronutrients is required for various crops as per their need to get higher yield. Care should also be taken to handle micronutrients like iron, manganese etc. because they may cause toxicity to crop due to their excessive abundance in the soils of Tripura. The requirement of nutrients varies widely for different crops which is one the most essential factor to be considered for application of fertilizers. The variation in fertilizer consumption within the state is directly related to the available cropped area. Besides, low population density, continuity with traditional agro-techniques, lack of finance, unavailability of fertilizers (due to non availability of required rakes for dispatch of fertilizers as it is the Broad gauge upto lumding of Assam, irregularity in fertilizer supply by IFFCO, having no district level stock points of major suppliers), and skilled man power also affect the fertilizer consumption in this state. Having those constraints the state currently consume 55 kg fertilizer/hectare as against all India average 127 kg/hectare. It is not only that average consumption is low; there is also a lack of balance in the use of different types of fertilizer. The ideal ratio of NPK for the country as a whole is placed at 4:2:1 It was not reached in Tripura. The ratio is almost in proximity to 7:1.8:1. The consumption of nitrogenous fertilizer is always relatively much high. As regard NPK balance the picture was very depressing in different districts of Tripura. The lack of balance fertilizer has resulted in widespread phosphate and potash deficiency in the soil and inhibited optimum productivity.

Table No. 3.11. Consumption of Chemical Fertilizer in Tripura (M. T.)

Year/ District	Nitrogeneous	Phosphatic	Potassic	Total (NPK) (N, P_2O_5 and K_2O
1994-95	4882	1775	1034	7691
1998-99	6969	1807	985	9761
1999-2000	6326	1742	842	8910
2000-2001	7608	2707	1000	11315
2001-2002	7347	3830	2345	13522
2002-2003	5,791	2,170	1,284	9,245
2003-2004	7488	2697	2378	12563
2004-2005	9334	2582	1604	13520

2005-2006	9937	2896	2340	15173
By Dist.				
West Dist.	5498	1260	985	7743
North Dist.	899	383	302	1584
South Dist.	2997	983	875	4855
Dhalai Dist.	543	270	178	991

Source : Directorate of Agriculture, Tripura Table No. 2.6 (A)

Trend in Fertilizer Consumption

In this situation, the growth in fertilizer consumption is in encouraging state. As evident for the figure at 1961 consumption of fertilizer per hectare of cropped area was only 0.3 kg. Currently the state can claim fertilizer consumption at the tune of 42 kg per hactare. The fertilizer consumption in Tripura is increasing in such a rate that the requirement of chemical fertilizer for 2011-12 has been estimated to the level of 1, 20,500 tons.

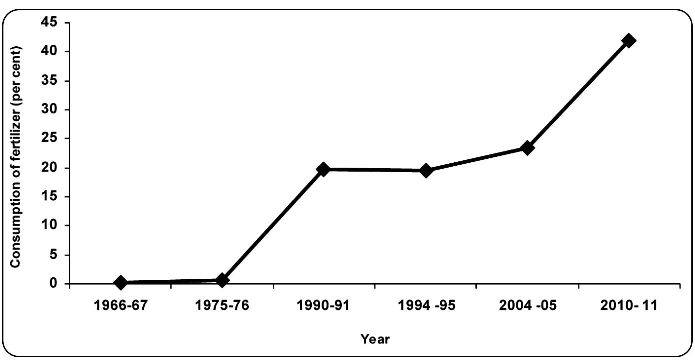


Fig. 3.1: Trend in Fertilizer Consumption in Tripura during 1966 - 2011

Crop Responses to Nutrients

The usefulness of external nutrient input to crop is manifested by its responses (in terms of uptake and yield) to the added nutrients. Nutrient content of Tripura soils is basically low to medium level, particularly of macronutrients. So, crop shows positive responses towards fertilizer application. Rice is the major crop grown widely in the state, But its productivity is low which is about 70-75% of the national average yield of rice. The major factor for poor yields are low use of nutrients through inorganic or organic sources, fixation of applied P due to high content of exchangeable Al and poor crop management practices. Based on available experimental data on response of rice, a liner response of rice upto 100 kg N /ha was found in Tripura. In upland soils of Tripura, the optimum dose of nitrogen for rainy season rice was found to be 43 kg/ha while it was 90 and 60 kg/ha in the low land fro rabi and Kharif crops, respectively. Long duration varieties responded only up to 50 kg N/ha.

Adopting integrated nutrient supply system

The soils of this region are, generally, deficient in nutrients like nitrogen, phosphorus, calcium, magnesium, sulphur, zinc, boron, molybdenum and iodine. These need to be supplied by addition of inorganic and organic fertilizers to maintain steady supply of essential nutrients to crops. But, the supplies are seldom met by the farmers by applying very little of fertilizers. The fertilizer use ($N+P_2O_5+K_2O$) is still below the national average of 127 kg/ha.

Besides inadequate use, the fertilizer use is highly imbalanced with the addition of urea alone supplying only single nutrient nitrogen. The inadequate and imbalanced fertilizer use coupled with no addition of organic manures has led to the emergence of multi-nutrient deficiencies in many areas. The deficiencies of micronutrients, particularly of zinc, are becoming more conspicuous in some areas. The continuous use of high analysis fertilizers (devoid of sulphur impurities) has made sulphur a deficient and limiting nutrient. The limiting nutrients not allowing the full expression of other nutrients lower the overall fertilizer use efficiency and crop productivity.

The application of nitrogen alone caused reduction in fertilizer response ratio primarily due to deficiencies of phosphorus and potassium. The response ratio increased with the application of phosphorus along with nitrogen, but its reduction with time was again conspicuous in the absence of potassium.

The integrated nutrient supply system envisaging conjunctive use of chemical and organic fertilizers is, therefore, the most ideal system of nutrient management. The system enhances nutrient-use efficiency, maintains soil health, enhances yields and reduces cost of cultivation. There is need to augment the supplies of organic manures (farm yard manure, green manure, compost/vermicompost) and fortified &customized fertilizers supplying secondary and micronutrients to have IPNS on a sound footing. The use of bio fertilizers is still minimal in the state and requires to be promoted by producing effective strains with enhanced shelf life. A variety of bio fertilizers that could be popularized are nitrogen fixers (Rhizobium, Azotobacter, Azospirillum), phosphate solubilising bacteria (PSB), blue-green algae, mycorrhizae and plant growth promoting rhizobacteria.

To increase fertilizer and water use efficiency System of rice intensification (SRI) has been adopted in the state successfully. 60,000 hectares area is the anticipated coverage during 2009-10 and expected to reach 80,000 hectares by 2011-12. Lesser input and greater yield has made SRI popular in the state. Application of lime in conjunction with micronutrients are being advocated in acid soil, particularly acidic soils of West and South districts, use of vermicompost to promote organic farming of fruit crops is of Government's priority. Co application of rock phosphate and phosphate solubilising bacteria showed promising result is some rice producing belt in Tripura.

Ameliorating acid soils

The state has large area under acid soils with maximum under West and South districts. Lands with pH value less than 5.5 are critically degraded with very poor physical, chemical and biological characteristics. The soils suffer due to deficiencies of phosphorus, calcium, magnesium, molybdenum and boron and toxicities of aluminium and iron. The fertilizer use is still low in the region. The productivity of the soils is, therefore, low due to poor soil health. The addition of lime to these soils neutralizes soil acidity and creates favourable environment for microbial activity, nutrient release and their availability to plants. The conjunctive use of lime and adequate fertilizers, therefore, holds key for higher productivity of these soils.

Indian Council of Agricultural Research (ICAR) has evolved a cost-effective technology for amelioration of the acid soils by conducting large number of field trials in important acid soil regions of the country, including Himalayan region (Sharma and Sarkar, 2005). Application of lime @ 2-4 q/ha along with 100 percent recommended dose of NPK fertilizers in furrows at the time of sowing promised significant increase in the yields of crops, especially legumes and pulses, over farmers' practice (Figure 8). The benefit: cost ratios were 3.4 and 3.2 for rape seed and summer green gram, respectively in Assam; 1.7 and 1.8 for maize and wheat, 12respectively in Himachal Pradesh; and 3.5 and 2.4 for maize and mustard, respectively in Meghalaya.

The crop varieties tolerant to soil acidity were Varuna and Sonmukhi of rapeseed and K851 & Sonmugu of summer green gram for Assam; Bragg, PB1 & Harasoya of soybean and ONK1, Hoyala & HPN-3 of gobhi sarson for Himachal Pradesh; and HUR-15 of french bean for Meghalaya. The state can recommend those ameliorating packages for securing higher yield. The cheap and effective liming materials must be made available for the success of acid soil amelioration programme. Although agricultural grade limestone powder and marketable lime are effective, these are not economical and available in plenty at all the places. The by-products of industries like basic slag, lime sludges, phosphogypsum and press mud etc. are rich sources of calcium and serve as cheap liming materials. The availability of basic slag is around 30 million tonnes, accumulated as waste over the years with different steel industries.

The Tata Steel Industries, Jamshedpur generate about 3 lakh tonnes of basic slag annually. Likewise, the paper mills in Assam, Nagaland, West Bengal, Orissa, Madhya Pradesh and Andhra Pradesh produce around 2 lakh tonnes of lime sludge. Besides, there are large deposits of limestone in north – eastern states of Arunachal Pradesh, Manipur, Assam, Meghalaya and Nagaland that could be exploited for producing agricultural grade lime at affordable prices. The materials should meet the specifications of at least 25% calcium oxide and be ground to > 80 mesh size. The Government should facilitate requisite tie-ups with the industry to regulate marketing and distribution of materials to farmers.

Application of lime and micronutrients

According to the survey conducted by the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, ICAR), 92% of the total rice based cropping system areas of Tripura falls under the category of extremely acidic to strongly acidic category. Application of lime as amendment to neutralize the acid soils to a certain extent had been found effective. But farmers found the complete reclamation with lime to desired level is very expensive.

Therefore, amelioration of acid soils with minimum amount of lime with balanced application of all deficient nutrients including micronutrients is required to be popularized amongst the farmers. Therefore, it is proposed that farmers may be encouraged by way of providing 50% subsidy to use of soil ameliorants (liming) and micronutrients (like Zinc, Boron) especially in the rice-based cropping system for management of soil health fertility and increasing the production as well.

Trend in Use of Bio fertilizer

The stateshows encouraging trend for the production and utilization of different grade of bio fertilizers. Production of one ton of bio fertilizer in 1998 was increased to 258 tons at the end of 2009 is expected to increase to 2118 tons in the year 2010-11 by bringing three district level biofertilizer production centre through PPP mode. A large bio fertilizer production plant with 600 MT capacity has also been established in the private sector and construction of ten more mini bio fertilizer production units are nearing completion.

Strengthening Soil Testing Service

Existing soil testing laboratories are inadequate to cater the need of the farmers of the state. Infrastructural and manpower facilities are also poor. The soil testing laboratories need to be computerized and equipped with the facility for analyses of all nutrients including secondary and micro nutrients. These should be manned by soil scientists to ensure precise analyses and proper interpretation of results. The State Agricultural Departments should have a policy intervention in this regard. The state should also come forward for preparation of soil fertility maps at district and block levels in partnership with State Agricultural Universities and ICAR to have precise fertilizer recommendations. Targeted yield equation concept based on soil test value should be adopted for judicious application of chemical fertilizer for reducing cost of cultivation in one hand protection of environmental degradation on the other hand.

Nutrient Cycling and Fertility Management under *Jhum*

Jhum is the chief land use practice in North-Eastern hill region in general and particular to Tribal population of Tripura. The Jhum cycle, until recently, was more than 20 years but has now come down to an average of 4-5 years. Long cycles were possible earlier because population presence was not heavy and land availability did not limit the cycle. Due to quick *jhum* cycle, the fertility status of land fails to revitalized resulting poor crop stand. In Tripura Jhum mostly prevalent in lower elevation. During the winter months (Dec-Jan), the undergrowth is slashed, and small trees and bamboos are felled. The ecosystem components left after slash and burn lose their ability to hold the nutrients in the soil During the slash and burn phase, nitrogen is volatilized and lost from the system along with carbon and sulphur of the nutrients released into the soil through ash, much is lost by strong winds during the dry months of March – April.

The sediment loss during the cropping period could be as much as 30 tons per ha. per year. Which would be drastically reduced to about one ton per ha. per year even under a five year old fallow, The losses of nutrients through run off and percolation of water are heavy during the cropping phase and the proportional percolation loses are heavy in spite of the steep angle of the slope. In the fallow phase the losses are drastically reduced and the recovery of the system is fast.

The soil fertility changes during the cropping phase and nutrient depletion and recovery processes for both long and short *Jhum* cycles at low and high elevations and the pattern and processes involved are essentially the same. Much of the changes occur on the surface layers of the soil only.

The quality and quantity of cations released into the soil depends upon the length of the *Jhum* cycle. Under a short five year cycle the nutrients released is low compare to longer cycles. Under a ten year cycle, at lower elevations, the release of potassium is high as the slash in predominantly of bamboo (*Dendrocalamus hamiltonii*) which is an accumulation of potassium. This is reflected in the loss pattern of potassium under a ten year *Jhum* cycle compared to thirty or five year cycles.

Though carbon and nitrogen losses are heavy due to volatilization during fire, the buildup of the latter is rapid due to quick nitrification processes initiated in the soil and both elements are also added through crop and weed biomass ploughed back into the soil. During cropping, depletion of nutrient is due to rapid uptake by weeds and crops and also due to heavy losses through hydrology. In the early fallow regrowth phase, there is a rapid transfer of nutrients from the soil to vegetation component of the ecosystem as the plant cover develops and the release of nutrients back into the soil does not start until after about ten years of fallow regrowth when build up in the soil is effected through litter fall. This would be another argument that could be advanced for a minimum cycle of ten years of or more.

Frequent Imposition of a short five year cycle would result in the system starting subsequently with a lower capital. Thus in one cropping phase the system could loose as much as 600 kg. of nitrogen per ha. The natural replacement process would take about ten to fifteen years of fallow phase for total recovery of this nitrogen. Under a five year cycle a higher elevation, not more than half of this amount is recovered during fallow phase. Thus, an imposition of five year cycles four times over the same site would result In a net loss of over 1200 Kg. of nitrogen per ha. The land eventually would be desertified under such a short cycle.

After the slash and burn operation, the soil nutrient status would differ, both qualitatively and quantitatively, between the short and long *jhum* cycles. The quantitative differences are directly related to bio-mass build-up before the burn. Herbaceous community's upto about 5 years of age generally have more phosphorous, whereas the bamboo forest have of 10-20 years of age more potassium.

Bamboos being an important component of the secondary succession have a large biomass contribution to *jhum* fallows of up to about 30 years. In a comparative study of three locations in the N.E. India, the role of 4 bamboo species, namely, *Dendrocalamus hamiltonii* (a common and dominant species of all locations). *Bambosa tulda, Neohouzeou dulloa* and *Bambosa khasiana* were evaluated for their role in nutrient conservation (Rao and Ramakrishna, 1989). With the role of herbs in nutrient cycling declining after 5 years of fallow regrowth. The contribution by the Bamboo increases up to about 25-30 years. It is therefore reasonable to expect a key role for bamboos in nutrient cycling and nutrient conservation.

The four bamboo species, under consideration here, always had higher concentration of nitrogen, phosphorous, potassium than shrubs and trees, but lower concentration of calcium and magnesium. Consequently, the quantities of these elements in the bamboo component of the vegetation in 5, 10 and 15 years old fallows would be higher and would increase with fallow age because of the biomass increase the quantities released through litter, obviously would also follow a similar pattern.

So, far recorded 22 number species of bamboo are available in Tripura. Out of the 22 the following species are abundantly found and suitable for nutrient conservation.

i. *Melocanna baccifera* (Muli)
ii. *Bambosa tulda* (Mritinga)
iii. *Dendrocalamus longispathus* (Rupai)
iv. *Shizostachyum dulluoa* (Dalu)

Predominant bamboo found in Tripura
(Source: www.ecosensorium.org)

Chapter – IV

ACID SOILS OF TRIPURA AND ITS MANAGEMENT

Chemically an acid is a substance that tends to donate protons (hydrogen ions) to some other substances. Conversely, a base is any substance that tends to accept protons. Soil acidity may be defined as the soil system's proton (H+ ions) donating capacity during its transition from a given state to a reference state. It is the negative logarithm (base 10) of the H+ activity (moles per litter) in the soil solution. Soil acidity involves intensity and quantity aspects. The intensity aspect is universally characterized by the measurement of H+ ion activity, as expressed as pH. As the activity of H+ in the soil solution increases, the soil pH value decreases. Soils with pH values below pH 7 are referred to as "acid" and those with pH values above pH 7 as "alkaline"; soils at pH 7 are referred to as "neutral."

The quantity aspect is characterized, directly or indirectly, by the quantity of alkali required to titrate soil solution to some arbitrarily established endpoint. Soil acidity is a single soil factor that can influence wide variety of soil processes related to plant growth.

Thus, nature of soil acidity, its origin, behaviour and effect on plant growth must be studied thoroughly for its management. It is more important for soils of Tripura where 90% soils are acidic causing poor agricultural productivity.

Causes of Soil Acidity

Predominant factors those govern the acidity development in soils of Tripura are as follows:

- **Parent Material:** In general, the soils of the state derived from tertiary fold mountain belt, are comprising of poorly fossiliferous succession of alternating shales, mudstones, siltstones and sandstone in varying proportions. Soils of Tripura are dominated by arenaceous rocks comprise of moderately compact medium to fine grained gray to yellow sandstone, shale and muds. These acidic parent materials are the relevant factor leading to soil acidity in the state.
- **Soil Forming Processes:** Laterization of varying degree in humid to sub-humid zone with pronounced wet and dry seasons becomes imperative in the major processes involved in the development of acid soils. Under relatively temperate climate, pedogenesis of relatively high altitude soils may preclude the prospect of podzolisation being in operation. This in turn causes soil acidity.
- **Leaching of Bases:** In these soils, intense leaching due to heavy precipitation causes removal of soluble salts, readily soluble soil minerals and bases from the surface soils and relatively insoluble compounds of Al and Fe remain in soil. The nature of the compound are acidic and its oxides and hydroxides react with water and release H+ ions in soil solution and soil becomes acidic. Besides, when the soluble bases are lost, the H+ ions of the carbonic acid and other acids developed in soils replace the basic cations of the colloidal complex. As the soil gets gradually depletes of its exchangeable bases through constant leaching, it gets desaturated and becomes increasingly acid.

  $$CO_2 + H_2O = H_2CO_3$$

  $$H_2CO_3 + Ca\,CO_3 = Ca(HCO_3)\text{ Leaches out}$$

- **Physiographic situation:** Undulating physiographic situations also facilitate the extent of leaching of soluble salts thus enhancing soil acidity in uplands compared to low lying areas.
- **Nature of Vegetation:** Vegetation ranging from deciduous

forests to temperate coniferous also plays a vibrant role in acid soil genesis.

- **Organic acid:** Significant amount of under decomposed/ partly decomposed organic matter are accumulated in swampy/high altitude areas under cool climate. Organic matters undergoes microbiological decomposition resulting in accumulation of organic acids leading to soil acidity. Extractable organic matters also have role in acidity. Organic matter posses number of functional groups containing H+ ions that can contribute to the different kinds of Ph-dependent acidities.
- **Exchangeable Iron, Aluminium and their Polymers :** The contribution of Al_3^+ ion in soil acidity was put forward by Mukherjee and Chatterlee (1942 & 1945). At low pH values (below ph 4.7) most of the hydrated Al_3^+ undergoes sequential hydrolysis to monomeric and polymeric hydroxyl-aluminum complexes and hydronium ions (H_3O^+) thus lowering soil pH. Each successive step of hydrolysis occurs at a higher pH.

$$Al(H_2O)_6^{3+} + H_2O = Al(OH)\ (H_2O)_5^{2+} + H_3O^+$$

$$Al(OH)\ (H_2O)_5^{2+} + H_2O = Al(OH)_2\ (H_2O)_4^{+} + H_3O^+$$

$$Al(OH)_2\ (H_2O)_4^{+} + H_2O = Al(OH)_3\ (H_2O)_3^{+} + H_3O^+ \text{ and so on...}$$

Similarly,

$$Fe\ (H_2O)_6^{3+} + H_2O = Fe(OH)\ (H_2O)_5^{2+} + H_3O^+$$

(reaction occurs under more acidic conditions than that of Al)

Toxicity of Aluminium

The toxicity of aluminium may be greatly influenced by the accompanying cations. The toxicity of aluminium tends to decrease with an increase in the concentration of other cations such as calcium. Aluminium toxicity is a problem in both upland and lowland soils. Aluminium toxicity in soils affects plant growth in various ways:

- It restricts the root growth

- It affects various plant physiological processes like cell division, formation of DNA and respiration etc.
- It restricts the absorption and translocation of some important nutrient elements from soil to plant like phosphorus, calcium, iron and manganese etc.
- It causes wilting of plants
- It also inhibits the microbial activity in soil.

Nutrient Availability

Nutrient availability is adversely affected by soil acidity. Due to poor root growth under acidic condition ion, particularly the exchangeable bases uptake process will be retarded. Moreover, the release of exchangeable bases due to complementary ion effect will also be affected under acidic condition. Thus, deficiency of bases like calcium and magnesium are found in acid soils of Tripura.

Not only the bases, the availability of macro nutrients like phosphorus is tremendously hampered. It is evident that under acidic condition the activity of ions like iron, aluminium and manganese remains in high order. Phosphorus reacts with those ions and converts into insoluble phosphate compounds and phosphorus, thus, precipitating out for soil solution becomes unavailable to plant. In addition, phosphorus becomes fixed by hydrous oxides of iron and aluminium or by absorption and thus rendering unavailable to crop. Acidity creates imbalances in soils. In one hand, abundance of micronutrients like iron, manganese, copper and zinc increases resulting crop retardation, on the other hand, the preponderance of molybdenum and boron is very limited whereby plant availability decreases. At low pH, macronutrients like nitrogen and potassium as well as secondary nutrient like sulphur become less available due to restricted transformation of those nutrients resulting from lower microbial activities.

Microbial Activity

Abundance and preponderance on soil microbes by and large depend on soil reaction as because, each group of microorganisms has its pH maxima. Fluctuation of soil pH greatly hamper their growth and development. Acidophilic microbes like fungi and few bacteria can flourish well under acidic condition. Most of bacteria and actinomycetes thrive best and function well in soils having moderate to high pH. They show little activity when the soil pH drops below 5.5. Nitrogen fixation, both asymbiotic and symbiotic, in acid soils is greatly affected by lowering the activity of *Azotobacter* and *Rhizobium*. Microbial decomposition and transformation of different nutrients in soil are also retarded under acid soil conditions.

Lime Requirement (L.R.)

Quantity of lime required to ameliorate soil acidity could be calculated following the equation developed by Kamparth (1970).

$$\text{Tones of } CaCO_3\, ha^{-1} = 1.65 \times \text{Exchangeable } Al^{3+}$$

Besides aluminium, other acidity producing factors play dominant role in determining lime requirement of soils. Prasad et al. (1978) developed the following equation for assessing the lime requirement in acid soils.

L.R. = 0.03-0.006 pH + 0.001 organic carbon + 0.004 clay + 2.2 exchangeable acidity.

Patiram (1989) derived two L.R. equations to achieve crop suitable soil pH of 6.0 and 5.5.

LR 6.0 = 40.48-7.78 pH + 0.123 organic Carbon + 0.24 clay – 0.053 CEC - 0.341 Exchangeable (Ca +Mg) - 2.411 Exchangeable Al - 0.156 Exchangeable acidity.

LR 5.5 = 24.189 - 4.681 pH + 0.156 organic carbon + 0.060 clay – 0.482 exchangeable Al

All the lime requirement equations developed so far in North Eastern Region may be tested in Tripura for necessary adjustment if required. Laskar *et al.* (1983) estimated lime requirement of Tripura soils by different methods and reported values ranging from 0.93 to 3.38 t ha^{-1}.

The calculated values of lime requirement are sometimes observed to be quite high compared to the actual lime needs of a particular crop grown in a certain agro-climatic condition. So, farmers sometimes become frustrated to purchase such a high amount of lime from market. So, verification trial regarding crop response to liming needs to be studied in detail to recommend the lime doses.

Crop Response to Liming

Crops response differently to lime, in general, doses of lime in particular. Crops thrive well under wide range of soil pH show little response to applied lime. Whereas, other crops those grow better at specific soil pH or a narrow pH range response promptly and thus, reflected in crop yield.

Rice is the staple food in Tripura, stands well in a wide pH (5.3 – 6.5) range and is less responsive to liming. Rather Maize is medium to highly lime responsive. In a liming experiment on maize in Tripura Laskar and Dadwal, (1981) observed approximately 66.9 per cent increase in maize production over control. Furrow application reduces the quantity of lime thus, indicating enhanced efficiency of furrow applied lime.

Besides cereals, legumes are usually lime loving (Mandal *et al.,* 1996) and very little information pertaining to the effect of liming on legumes is available in Tripura. However, It was reported that cowpea and mung yielded 80.0 and 93.0 per cent increase over respective control after the application of 10 q lime ha^{-1} Soyabean showed significant response to applied lime in some soils of Tripura. The optimum dose of lime in Tripura was worked out to be 15 q ha^{-1} producing 115 per cent increase in soybean over control (Laskar and Dadhwal, 1981). Authors also reported higher response of Groundnut to liming. They observed 47.6% increases in groundnut with the application of 10 q lime ha^{-1} over control in upland soils in the state. So, the relative response of different crops to liming in Tripura was as follows: Soyabean Mung Cowpea Maize Groundnut.

According to the survey conducted by the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, ICAR), 92% of the total rice based cropping system areas of Tripura falls under the category of extremely acidic to strongly acidic category. Application of lime as amendment to neutralize the acid soils to a certain extent had been found effective. But farmers found the complete reclamation with lime to desired level is very expensive. Therefore, amelioration of acid soils with minimum amount of lime with balanced application of all deficient nutrients including micronutrients is required to be popularized amongst the farmers. Therefore, it is proposed that farmers may be encouraged by way of providing 50% subsidy to use of soil ameliorants (liming) and micronutrients (like Zinc, Boron) especially in the rice-based cropping system for management of soil health fertility and increasing the production as well.

Chapter – V

ADAPTIVE SOIL MANAGEMENT FOR ACID SOILS OF TRIPURA

Abiotic stresses such as salinity, drought, heat, acidity, nutrient deficiency or toxicity and flooding limit crop productivity in India. However, the impact of these stresses becomes more severe in state like Tripura, where they cause food and nutritional insecurity due to acidic soil, large poverty, and traditional *Jhum* cultivation. Due to acidity and resulting nutrient deficiency or toxicity render million hectares of agricultural land uncultivable thereby resulting in low outputs, poor human nutrition and reduced educational and employment opportunities. Thus, acidity stresses emerge to be one of the important factors underlying poverty for millions of people. Ironically, those stress-affected areas are the ones where majority of poor tribal people live and they have little bargaining capacity for costly liming materials.

In this scenario, it is widely urged that strategies should be adopted to ensure maximum crop stand and economic returns from acidity stressful environments. Major strategies include breeding of new crop varieties, screening and selection of the existing germplasm of potential crops, production of genetically modified (GM) crops, exogenous use of amendments etc.

In the last century, conventional breeding program and trait-based approach proved to be highly effective in improving tolerance against acidic stresses. Therefore, breeding for acid stress tolerance in crop plants have been given high research priority. However, extent and rate of progress in improving stress tolerance in crops through conventional breeding program is limited. This is due to complex mechanism of acid stress tolerance. Furthermore, techniques employed for selecting tolerant plants are time consumable and consequently expensive. During the last decade, with the use of advanced molecular tools different researchers showed some promising results in understanding molecular mechanisms of stress tolerance that became useful for developing stress tolerant genotypes in some potential crops. These findings emphasized that future research should focus on molecular, physiological and metabolic aspects of stress tolerance to facilitate the development of crops with an inherent capacity to withstand acidity stresses.

But such vertical resistance may lose its implication under upcoming multiple stress environment. For example, acidity tolerant crop plants can combat up to certain level of acidity but then lose their potentiality as the severity of acidity increases. Benefits derived from molecular breeding are also much less uniform and detectable as they depend on microclimate, rainfall and soil properties of the target environment. On the other hand, genetic engineering technology is not well suited for developing acidity-resistant plants. Stress tolerance is a complex trait, often involving the interaction of many genes, and thus beyond the capability of a rudimentary technology based on high expression of few well characterized genes. Moreover, one of the potential problems associated with GM crops is that the novel gene might be unintentionally transferred by pollination or by horizontal gene transfer to weeds or soil-borne pathogens. Such transfer could lead to the development of resistant super weed or super pathogens and possibly the destabilization of the ecosystem.

Practical problem associated with such development is of over-dependence on large seed companies and high seed price which compels the poor farmer to sink into debts further. More so, such varieties lack important traits required for sustaining under low input conservation agriculture. Thus, the poor people in rural and stressful areas will suffer the most and will require cheap and easily accessible strategies to adapt to erratic soil condition.

Under this background, conservation agriculture, an adaptive soil management, may play an important role in sustaining crop productivity under acidity environment. It is globally hypothesized that conservation agriculture restores the natural resources in soil and combats the stresses and thus, stabilize the ecosystem with an option for optimizing yield with healthiest soil. Under conservation farming, the whole production system itself acquire resistance against multiple stresses either by revitalizing the soil ecosystem with rich biodiversity of keystone species and their functioning that ensures lifeline activities of soil as well as important metabolic activities of plant even under stress or by developing horizontal crop resistance against different stresses through natural outcrossing between the crop varieties generally used in low input conventional farming. The term Induced Systemic Tolerance (IST) has been proposed for PGPR-induced physical and chemical changes that result in enhanced tolerance to abiotic stress. PGPR facilitate plant growth indirectly by reducing plant pathogens, or directly by facilitating the nutrient uptake through phytohormone production (e.g. auxin, cytokinin and gibberellins), by enzymatic lowering of plant ethylene levels and/or by production of siderophores.

Building a healthy soil is a crucial element in helping farms to cope with acidity and other stresses. Farmers now follow some management practices to build healthy soils. Zero tillage/ minimal tillage that help in soil aggregate, cover crops that reduce moisture loss from soil and crop residues that protect soils from wind and water erosion, and legume intercrops, manure and composts that enrich the soil with organic matter, are some ways to help increase water infiltration, hold water once it gets there, make nutrients more accessible to the plant and more efficient carbon sequestration.

Success of adaptive soil management to alleviate acidity relies on successful selection of acid tolerant native crop races with the co-adaptation of strong frontline multifaceted microbial guild. Co-adapted rhizospheric microrganisms extend necessary support the crop by virtue of elaborating biologically active substances which intern help the crop plant to survive under extreme acidity. Goodness of those microbes will be indentified and harvest for the benefit of crop production under stressful agriculture in Tripura.

The acid soils occur in 100% geographic area of Tripura. The soils are under different land uses for growing of food crops, horticulture & plantation crops and forests. The highly leached soils are generally poor in fertility and water holding capacity. A substantial area with pH value less than 5.5 is more problematic with severe deficiencies of phosphorus, calcium, magnesium and molybdenum and toxicities of aluminum and iron. The average productivity of one ton/ha of the soils is very low. The poor soil resource is one of the main factors of poverty and backwardness in the acid soil regions. In order to produce a better crop yield on acid soils, farmers are recommended to apply alkaline materials such as lime (primarily calcium carbonate) to increase the soil pH and thus eliminate Al toxicity, and to apply P fertilizer to increase the bioavailable P in soil. However, soil has a huge buffering capacity that is able to diminish the effects of all kinds of amendments. Hence the effects of practices such as applying lime and P fertilizer are usually not sustainable. Moreover, lime induced carbon dioxide emission is claimed to increase greenhouse gas load in the atmosphere. Under this background easy, farmers' friendly soil adaptive managements those help the crop plant to acclimatize in acid stress, are deemed necessary for sustainable farming particularly in acidic soils of Tripura.

Table 5.1. Extent of the acid soil in Tripura (million hectares)

pH <5.5	pH 5.5.-6.5	Total acid soil	Geog. Area	% Geog. area under acid soil
0.81	0.24	1.05	1.049	100.00

Soil stresses and related impact on soil microbes

Aluminum toxicity causes low rhizobial activity in low pH soil. Activity of *Nitrosomonas* and *Nitrobacter* mediated nitrification inhibited at highly acidic soil. Enzyme mediated biochemical transformations are also regulated by pH level of soil.

Role of Rhizosphere Microorganisms for Plant Fitness under Acid Stressed Soil

About 40% of cultivated soils globally have acidity problems leading to significant decreases in crop production despite adequate supply of mineral nutrients such as N, P and K (Herrera-Estrella 1999). In acid soils major constraints to plant growth are toxicities of hydrogen (H), aluminium (Al) and manganese (Mn) and deficiencies of P, calcium (Ca) and magnesium (Mg). Among these constraints Al toxicity is the most important yield-limiting factor (Marschner 1991). Availability of P to plant roots is limited in acidic soils, mainly, due to formation of sparingly soluble phosphate compounds with Al and Fe in acidic and Ca in alkaline soils (Marschner 1995).

Acid soil is not at all problem soil. Rather it the nature of soil as those of other soil types. Reclamation of acidic soil with the application lime stone is conventional mitigation option. But it is not a permanent solution. It recurred within year or two, thus, involve a recurring cost-unaffordable to poor farmers of universally inhabitant of acidic locality in the globe. Moreover, reclamation of acid soil by using lime increases carbon dioxide load in the environment resulting in global warming. Under this context, adaptive soil management that will help the crop plant to acclimatize in existing system without hampering the current environmental health.

Fungi by acidophilic in nature can essentially improve the plant fitness to an extreme soil pH. Especially mycorrhizal association with crop plants in acidic soil evolve adaptive mechanisms to improve plant fitness in acidic soils having low levels of available P (Marschner 1995; Dodd 2000). Mycorrhizal colonization of plants enhances their ability to explore the soil for P through the action of the fungal mycelium. This results in increased exploration of the soil for available nutrients and delivers more mineral nutrients, particularly P, to plant roots (Dodd 2000; Marschner 1998). It is estimated that the extent of fungal mycelium may be in the range of 10–100 m per cm root or per gram of soil under field conditions in P-poor soils (McGonigle and Miller 1999). In general, the contribution of mycorrhizal associations to the plant nutrient supply is larger in soils with poor availability of mineral nutrients than in soils rich in nutrients. In pot experiments, mycorrhizal colonization contributed to the total P uptake with between 70 and 80% and to the total Zn and Cu uptake with 50 and 60% in white clover (Trifolium repens). Mycorrhizal fungi also evolved adaptive mechanism to adjust acidic condition by maintaining narrow pH optima in their cells for carrying out essential enzymatic activities in acid soil (Leake and Read 1997). The colonization density of the ectomycorrhizal fungal species Cenococcum geophilum increased on beech (*Fagus sylvatica* L.) with decreasing soil pH (Kumpfer and Heyser 1986). Beside mycorrhizal fungi, bacteria can essentially improve the adaptation of plants to an extreme soil pH, although their distribution itself is controlled primarily by the soil pH (Fierer and Jackson 2006). Most prokaryotes grow at relatively narrow pH ranges close to neutrality. A general adaptation to extreme pH levels is to regulate the intracellular pH and keep it close to neutral. Some enzymes found in the bacterial outer membrane tend to have low pH optima, whereas all known cytoplasmic enzymes have pH optima from pH 5–8 (Torsvik and Ovreas 2002). Acid smart autochtonous ectomycorrhizal fungi with site-adapted rhizosphere bacteria are helpful to the crop plants to be fit in acidic soil for their growth and productivity.

Adaptive soil management for acid soils involves two principal strategies i.e. tolerance and avoidance of plants for adaptation to adverse acidic soil condition. The strategies of avoidance is more common for adaptation to acid mineral soils. Following are the adaptive soil management strategies for acid soil management:

Selection of acid loving crop plants

One of the main points of consideration while choosing crops has to be the local needs and preferences besides their agricultural suitability therein. Traditionally, farmers of acid soil regions have been growing rice irrespective of the type of land (Upland, Medium land & low land). Rice has certain degree of tolerance to soil acidity. On the other hand, cultivation of highly sensitive (towards soil acidity) field crops such as soybean, french bean, pigeon pea etc. should be tuned accurately with rhizosphere co-adapted rhizobia. The horticultural crops are seen to have tolerance or affinity to specific soil pH and according to soil reaction these are classified into following groups:

i) Slightly tolerant to acid soils
ii) Moderately tolerant to acid soils
iii) Highly tolerant to acid soils

Table 5.2: Horticultural crops grown in the NE Region along with their acidity tolerance

Slightly tolerant to acid soil (pH 6.8□6)	Moderately tolerant to acid soil (pH 6.8□5.5)	Highly tolerant to acid soil (pH 6.8□5)
FRUIT CROPS		
Mango	Pineapple	Strawberry
Citrus	Orange	Gooseberry
Banana	Litchi	Bel
Guava		
Papaya	Jackfruit	Plum
VEGETABLE CROPS		
Beet	Bean	Potato
Broccoli	Lima bean	Sweet potato
Cabbage	Carrot	
Cauliflower	Cucumber	Yam
Celery	Brinjal	Dioscoria *spp*
Spinach	Knolkhol	
Chinese	cabbage	Pea
Leek	Chilli	
	Pumpkin	
	Summer squash, Winter squash Radish, Tomato, Colocasia.	

Use of organic manure/compost:

Regular application of well decomposed organic matter in acid soils is essential to prevent sudden fluctuation of soil pH as it improves the buffering capacity of soils. Moreover, it increases the availability of P and reduces the toxicity of Fe and Al in acid soils. Fresh mulches (mostly weed biomass) of Ambrossia, Lantana etc. also reduces the adverse effect of soil acidity substantially.

Crop diversification

Location specific crop diversification with acid tolerant crops like tea, groundnut, maize etc. should be followed.

Encroaching deep soil by selecting deep rooted crop plants:

Iron and Aluminum toxicity due to acidity are predominant in surface soil. Shallow roots are heavily damaged by aluminum toxicity and turned to rudimentary one which may affect the capacity of mineral nutrient acquisition. Sub-surface deep soils are relatively less acidic. So deep rooted plant species like teak, rubber are natural choice in acidic soils. Such deep rooted plants are found in Shikaribari series of Dhalai districts and large area of South Tripura district.

Root-induced changes in rhizosphere

Plants that absorb nitrogen as NO_3^- tend to raise the pH in the rhizosphere. So, crop plant favouring NO_3^- should be incorporated in the cropping system to mitigate acid soils to some extent

Release of chelators for aluminum: *Microbes release* siderophores (iron carrier/iron loving) to scavenge iron from these mineral phases by chelating. Thereby bioavailability of get reduced resulting in low toxicity of iron in acid soils. Because of this property, they have attracted interest from biofertilizer industry.

Augmentation of autochthonous acidophilic beneficial microorganisms, particularly, mycorrhizae for increased root surface are the possible. So exploring and exploiting the potential microbial guilds are the silver line in adaptive soil management of acid soils. (Marschner)

Reduce the level of calcium removal

Adoption of less acidifying rotations e.g. inclusion of less legumes in crop rotation and less forage cutting -regular cutting of forage crops increases acidification. Legumes are fond of basic divalent cations, particularly of Ca^{2+} due to it higher root CEC.

Return plant materials to the field:

Retention of crop stubble/residues where time between crop harvest and next crop sowing is sufficiently large to decompose the stubbles is a good approach to reduce soil acidity to some extent.

Encourage maximum growth: Sowing crops as soon as possible after the first rain: reducing long fallow and growing deep-rooted summer-growing perennials are some possible adaptive interventions.

Livestock based farming system: Multiple use of manure for field application & biogas production. Biogas slurry is excellent source of organic manure.

Adoption of integrated farming system approach: Complimentarily of crop-animal-fish-birds multipurpose trees based horticulture for household food security and efficient resource utilization.

Agro-forestry intervention: Use of multipurpose tree species and hedge row species forstabilization of hilly slopes along with productivity augmentation.

Use of indigenous technological knowledge (ITK): Wisdom alive in farmers of Tripura. They still use age old wisdom to cultivate their land. Rice is cultivated in Tripura in all situations. Due to acidity iron (Fe^{2+}) toxicity is common problem in rice field. To solve the problem, farmers walk in between the rows with paddy weeder to loose the soil to get ferrous iron to insoluble ferric form. It was found that after 2/3 days of operation iron toxicity gets relieve.

Chapter – VI

MICRONUTRIENT MANAGEMENT STRATEGIES FOR SOILS OF TRIPURA

Soil information has been documented through different sources and at various scales to develop user-friendly datasets. Most have been at a small scale since the purpose of these output maps was different. The entire state of Tripura has been mapped using soil mapping units (soil family, soil series association) depending on the scale of mapping and method of soil survey. According to the survey conducted by the National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, ICAR), 92% of the total rice based cropping system areas of Tripura falls under the category of extremely acidic to strongly acidic category. Amelioration of acid soils with minimum amount of lime with balanced application of all deficient nutrients including micronutrients is required to be popularized amongst the farmers.

Micronutrients play an active role in the plant metabolism process starting from cell wall development to respiration, photosynthesis, chlorophyll formation, pollen germination particularly with B, enzyme activity, nitrogen fixation etc. The decreased amount of micronutrients in soils and their uptake by plants to such a critical level which shows their deficiency symptoms to different crops. Micronutrient does not mean that they are less important to plants than other nutrients. Plant growth and development may be retarded if any of these elements is lacking in the soil or is not adequately balanced with other nutrients. Inorganic micronutrients occur naturally in soil minerals. The parent material from which the soil developed and soil forming processes determines what the micronutrient content of the soil will be. As minerals break down during soil formation, micronutrients are gradually released in a form that is available to plants. Two sources of readily available micronutrients exist in soil: nutrients that are adsorbed onto soil colloids (very small soil particles) and nutrients that are in the form of salts dissolved in the soil solution. Organic matter is an important secondary source of some micronutrients. Most micronutrients are held tightly in complex organic compounds and may not be readily available to plants. However, they can be an important source of micronutrients when they are slowly released into a plant available form as organic matter decomposes.

Micronutrient deficiencies are widespread. 50% of world cereal soils are deficient in zinc and 30% of cultivated soils globally are deficient in iron. Soils of Tripura, exhibited widespread deficiency of boron, zinc, molybdenum and copper while that of Fe did not show any acute deficiency problem rather sometimes it becomes toxic when the soil contains more organic matter and active iron coupled with soil submergence. The fertility status with respect to available Zn, Cu, Fe, and Mn was higher in lowland than in upland soils, whereas B and Mo contents were higher in upland than in lowland soils. However, all the micronutrient cations were in the adequate range. Nearly 29% soils were deficient in B and 50% in Mo. As soil pH increased, available Zn, Cu, and B content decreased significantly in upland soils. The available Cu and Fe content increased with increase in organic C, while that of Zn and Mo decreased (Datta and Gupta, 1984; Datta and Ram, 1993). Steady growth of crop yields during recent decades (in particular through the green revolution) compounded the problem by progressively depleting soil micronutrient pools. In general, farmers only apply micronutrients when crops show deficiency symptoms, while micronutrient deficiencies decrease yields before symptoms appear (Das, 2007). Highly significant positive correlation existed between available Fe and siit, clay, Zn, Cu and Mn whereas there is a negative relationship with soil pH. Similar observations were also reported by Datta and

Ram (1993) with respect to organic carbon; clay and Cu. Some common farming practices (such as liming acid soils) contribute to widespread occurrence of micronutrient deficiencies in crops by decreasing the availability of the micronutrients present in the soil. Boron deficiency is a commonly observed micronutrient disorder in the Alfisols or acid soils in humid regions. With acute B stress in these soils, application of B decided the success or failure of crops (Dwivedi *et al.* 1990b). Rice soils – About 35% of rice growing acid soils were deficient in B and 17% in Zn. However, the content of available Mn, Fe, Cu, Co, and Mo was in the adequate range (Nongkynrih et al. 1996). Soils under different land-use systems – The total and available micronutrient status of soils of Major problems in alleviating micronutrient deficiencies include difficulty in the identification of field crop symptoms, variation in soil micronutrient status, soil pH, and intensity, and seasonal fluctuations in the levels and temperature regimes in the region, inadequate facilities and field tests to validate soil and plant micronutrients in the region.

Assessment of micronutrient deficiency can be made through visual leaf symptoms and soil and plant analyses. Response of crops to the application of micronutrients not only confirms the deficiencies but also helps in determining nutrient needs. Various agronomic approaches can be used to correct micronutrient disorders. Once a deficiency is reliably identified, it can generally be corrected by chemical amendments that suit the plant demand and farmer options. The amount, form, mode and timing are critical, especially if multiple nutrient stresses and antagonisms among nutrients are present. Toxicities are more difficult to handle than nutrient deficiencies. Direct toxicities occur when excess element is absorbed and retards physiological functions or becomes lethal to the plant. Indirect toxicity may occur through interactions; excess uptake of one nutrient may hamper the uptake, transport and utilization of another nutrient and may result in its deficiency.

Zinc (Zn)

It is the most common micronutrient disorders in wetland rice (often combined with P deficiency). Due to increase availability of Ca, Mg, Cu, Fe, Mn and P under prolonged submergence Zn availability and uptake hampered by the crops. Zinc (Zn) deficiency is the most widespread micronutrient disorder in rice, but efforts to develop cultivars with improved tolerance have been hampered by insufficient understanding of genetic factors contributing to tolerance. Zinc is essential for several biochemical processes such as cytochrome and nucleotide synthesis, enzyme activation, chlorophyll production, maintenance of membrane activity, increase rate of seed and stalk maturation. Zinc deficiencies mainly occur when soil pH is, high organic matter in soil, calcareous soils with high bicarbonate content, intensively cropped soils. Paddy soil under prolonged submerged condition cause zinc deficiency. Symptoms are common on younger or middle aged leaves. Deficiency symptoms causes brown to dusty brown spots on younger leaves (2 - 4 weeks after transplanting) in red soils, yellowing of leaves/ midrib bleaching. Symptoms are prolonged during early growth stages due to immobilization of zinc. Symptoms of zinc deficiency sometimes resemble Fe/Mn deficiencies. Zinc deficiency in rice soil is commonly known as *khaira.* The main symptom of *khaira* in rice is usually in nursery; chlorotic/yellow patches at leaf base on both sides of the midrib; restricted root growth and usually main roots turn brown. Zinc deficiency has also been associated with high bicarbonate content, a Mg: Ca ratio in soils >1, the use of high level of fertilizers, intensive cropping, use of high yielding cultivars, and irrigation with alkaline water.

The most preventing measures for zinc deficiency is selection of Zn efficient variety that is tolerant to high level of bicarbonate as well as low zinc in soil. Beside these applications of $ZnSO_4$ in nursery beds, drain the field, seedling root dipping in 2% - 4% ZnO suspension, mid season correction by spraying 0.5% $ZnSO_4$ thrice at weekly intervals between 3 - 6 WAT etc. But curative measure for correcting are application of 20 - 25 kg/ ha$ZnSO_4$ in acid soil, 22 kg Zn/ha initially followed by 5 - 10 kg Zn in the later years or 50% gypsum + 10 t GM +22 kg Zn once in 2 - 3 years in sodic soils, 1.0 - 1.5 kg/ha Zn as foliar spray at tillering stage and 2 times latter is very helpful for correct this deficiency. Plant Zn uptake from low Zn soils can be increased by Zn mobilizing chemical rhizosphere processes.

Iron (Fe)

The iron content in soil varies from 1% to 20%, averaging 3.2%, but its normal concentration in plants is only 0.005%. Iron deficiency is common in upland, high pH and aerobic soil and toxicity is one of the major constraints to lowland rice production. It disrupts the rice plant physiology in several respects. The critical iron toxicity concentration in plant tissue depends partly on the overall nutritional status of the plant. Iron helps in the formation of chlorophyll. A deficiency of iron causes chlorosis between the veins of leaves and the deficiency symptom show first in the young leaves of plants. It does not appear to be translocated from older tissues to the tip meristem and as a result growth ceases. Iron is also a structural component of non-heame molecules like ferrodoxins (stable Fe-S proteins). Ferrodoxin is the first stable redox compound of the photosynthetic electron transport chain. The main important deficiency symptoms are interveinal yellowing and chlorosis of emerging leaves, less dry matter production, reduced sugar metabolism enzymes, plants become stunted with narrow leaves. Iron deficiency causes chlorosis symptoms in rice plant due to relative immobility of iron in rive plants, interveinal chlorosis on surface of the leaf showing a fine reticulate network of green setting off chlorotic areas. The main reason for iron deficiency are low concentration of iron in upland soil, coarse textured soil, low land soil with very low organic matter content, increased rhizosphere pH etc.

Though it is the most difficult and costly micronutrient deficiency to correct it can be controlled by application of $FeSO_4$ 25 kg/ha in between rows, application of iron containing fertilizers or foliar spary of $FeSO_4$ 1% - 3% solution. Iron toxicity is caused by toxic effects of excessive Fe uptake due to large concentration of Fe in soil solution. The main important toxicity symptoms of iron are tiny brown spots on lower leaves starting from tip and spread towards the leaf, base or whole leaf coloured orange-yellow to brown. Spots combine on leaf inter-veins and leaves turn orange-brown and die. Leaves appear purple-brown if Fe toxicity is severe stunted growth, extremely limited tillering. Iron toxicity can be controlled by seed treatment with

Ca peroxide at 50% - 100% seed wt., intermittent irrigation at tillering stage and by balanced fertilization.

Manganese (Mn)

The role of manganese is regarded as being closely associated with that of iron. Manganese also supports the movement of iron in the plant. It influences auxin levels in plants and high concentrations of Mn favour the breakdown of Indole Acetic Acid (IAA), takes part in electron transport in photosystem II. Manganese deficiency is very common in upland rice, degraded paddy soil high in Fe content, accumulation of H2S, acid sandy or acid sulphate soil, excessive liming in acid soil etc. manganese deficiency can be corrected by application of farmyard manure, acid forming fertilizer (do not use urea), $MnSO_4$ or MnO at 2 - 5 kg/ha as multiple application. Chelates should be avoided as Fe and Cu displaces Mn. Manganese toxicity shows brown spots on the veins of the leaf blade and the leaf sheath in lower leaves. Plant growth are stunted and ultimately cause less number of tillering.

Boron (B)

Boron is concerned with precipitating excess cations, buffer action, regulatory effect on other nutrient elements etc., development of new cells in meristematic tissue, translocation of sugars, starches, phosphorus etc., essential for cell wall formation. Boron deficiency occurs under moister stress and dry condition which cause reduced plant height. Plants fail to produce panicles if they are affected by B deficiency at the panicle formation stage. The tips of emerging leaves are white and rolled. Soil application of B (1 - 2 kg/ha) is superior to foliar sprays. For hidden deficient, spray 0.2% boric acid or borax at pre flowering or flower head formation stages. Excess of boron appears to inhibit the formation of starch from sugars or results in the formation of B-carbohydrate complexes, resulting in retarded grain formation. The symptoms of boron toxicity are brownish leaf tips and dark brown elliptical spots on leaves, necrotic spot at panicle initiation stage. Use of boron rich ground water, excessive application of boron and high temperature are the main cause of boron toxicity. Boron toxicity can be controlled by B tolerant variety, use of irrigation water having low boron content, deep ploughing etc. Sometimes dark green leaf and brown root also occur when B is absent in soil as well as in plant.

Copper (Cu)

Copper helps in the utilization of iron during chlorophyll synthesis. Lack of copper causes iron to accumulate in the nodes of plants. It has an unique involvement in enzyme systems of plants like oxidase enzymes, terminal oxidation by cytochrome oxidase, photosynthetic electron transport mediated by plastocyanin etc. It also acts as "electron carrier" in enzymes which bring about oxidation-reduction reactions in plants. Sandy, calcareous, lateritic soil, high in organic matter induce Cu deficiency in soil. The main important deficiency symptoms of copper are chlorotic leaves, bluish green leaves, new leaves don't unroll and leaf tips give needle like appearance, reduced tillering, less pollen viability. Excessive liming in acid soil sometimes causes Cu deficiency in soil. It can be control by seeding root dipping in 1% $CuSO_4$ suspension, apply Cu at 5 - 10 kg/ha once in 5 years in the form of CuO or $CuSO_4$. Foliar application can be done during tillering to panicle initiation stage. Soil application can also be done with $CuSO_4$ as broadcasting or band placement.

Molybdenum (Mo)

Molybdenum is an essential component of the major enzyme nitrate reductase in plants. Its requirement of plants is influenced by the form of inorganic nitrogen supplied to plants, with either nitrite (2 NO^-) or ammonium (4 NH^+) effectively lowering its need. It is also reported to have an essential role in iron absorption and translocation in plants. Deficiency symptoms of Mo in rice resembles to nitrogen deficiency (older leaves become chlorotic). Necrotic spots are seen at leaf margins because of NO_3 accumulation. Molybdenum deficiency can be correct by liming of acid soils to pH 6.5 (not preferable if pH change is not desirable for other purposes). Beside these dusting with Na/NH_4 at 100 - 500 g/ha is very much beneficial. Foliar spay of Na/NH_4 molybdate at 0.1% is also beneficial.

Fixation of Micronutrients in Soil

Boron and molybdenum are generally fixed in rice soil. In case of boron main reaction occur when acid soils are limed. Lime is able to replace Al^{3+} by Ca^{2+} and produce insoluble precipitation of aluminium hydroxide/iron hydroxide. This precipitate adsorbs large quantities of boron. Soil high in organic matter also has high Boron. Molybdenum adsorbed strongly by iron/aluminium oxides. Soils high in non-crystalline iron on clay surfaces, tend to be low in available molybdenum due to fixation. Most micronutrients namely copper, zinc, boron are susceptible for fixation with soil organic matter and hence recovery of such associated micronutrients are also required to be released into the soil solution by adopting some appropriate soil management practices such as use of microorganisms, nutrient interactions, increase in the rate of mineralization etc.,

Management options

It has been reported by various scientists from different parts of Tripura that soils of Tripura state was very poor in boron, molybdenum, copper and zinc while that of Fe and Mn contents were above optimum. However, most soils of Tripura state and hence symptoms of deficiency in plants are deficient with copper, boron, molybdenum and above optimum levels in case of Fe and Mn contents in soil. The 4R (right source, right rate, right time and right method) concepts for efficient management of micro-nutrients are required to be applied in practice.

Micronutrient Fertilizers

Some of the important and commonly used micronutrient fertilizers are appended below:

Sulphate (salts)

The sulphate form of micronutrients such as Cu, Zn, Fe and Mn represent a water-soluble form that is plant available. Borate is the equivalent plant available form for B. Sulphates are the most commonly used form for field crops. Sulphates can be applied to the soil or foliage. Sulphate products, applied at agronomically recommended rates, can provide long term residual value.

Oxy sulphate

An oxysulphate is an oxide of a micronutrient that has been partially reacted with sulphuric acid. In the year of application, the oxide portion is not nearly as available as the sulphate portion. The amount of sulphate in the product varies by product. Water solubility of oxysulphates can vary greatly. It is generally accepted that a minimum of 50 per cent water solubility is required for the micronutrient to be a readily available nutrient source. In general, the higher the water solubility portion, the better. Residual value is similar to sulphates.

Oxide

Micronutrient elements (Cu, Zn, Fe, and Mn) bonded with oxygen form oxides. The bonds with oxygen are very strong, meaning these products are not soluble in water and are not in plant available form. An oxide of a micronutrient needs to be converted to a plant available form in the soil before being taken up by the plant. Oxides represent the final form to which other forms are eventually converted under western Canadian soil conditions, and may then be slowly converted back to plant available form. For crop response during the growing season, plant available forms (water-soluble forms) of micronutrients need to be used. Pure oxide forms are less commonly used under western Canadian conditions and may be of residual value.

Chelate

Micronutrients such as Cu, Fe, Mn, and Zn are held within ring-type compounds. Chelated micronutrients remain in plant-available pool for a longer period because the chelated micronutrients exhibit very less interactions with soil components preventing various harmful reactions undergoing in soils. Chelated form of micronutrients shows greater mobility in soils compared to inorganic salts. There are a large number of chelating agents. For example, a synthetic chelating agent is EDTA, and a natural chelating agent is citric acid. Chelated micronutrient products are not all equally available to the plant. Chelated micronutrients can be soil or foliar applied. Chelates are generally many times more expensive than the sulphate or oxide forms on a per pound actual micronutrient basis, but this is partly compensated for in the low recommended rate of chelate product needed to supply the micronutrient. Chelated products applied at label rates have no residual value. Soil applied chelates at recommended rates only last for one year. Follow label rates and directions. Chelates are more commonly used now than in the past. About 90-95% of soil applied inorganic form of Zn is rendered unavailable to the plants due to its harmful reactions with different soil components and hence chelated form of Zn (Zn-EDTA) is one of the most important sources which can increase the use efficiency of applied Zn with the simultaneous increase in yield of crops.

Manure

Livestock manure can be a source of micronutrients such as Cu and Zn, especially since these nutrients are often added to the feed rations. Repeated applications of manure have been shown to increase the content of available Cu and Zn.

Other forms

Carbonates and nitrates and mixtures with elemental forms are examples of other forms, but are seldom used.

Crop Responses to Micronutrient Fertilizers

In India most soils are widely deficient with zinc, boron and molybdenum to the level of about 40-50; 60 and 60-70% respectively out of other lesser magnitude of deficient micronutrients like Fe, Mn and Cu. Therefore, emphasis is to be given to manage all these deficient micronutrients for their corrections through fertilization programme considering right sources, rates and methods of applications. It has been reported that the response of cereals, millets, pulses oilseeds, vegetables and cash crops ranged from 4.5-8.9; 3.0-6.8; 3.4-5.8; 1.6-5.5; 2.0-15.3 and 3.9-96.8 q/ha respectively to the application

Table 6.1: Common micronutrient fertilizers

Micronutrient	Source	Nutrient Content (%)	Methods	Doses
Iron	Inorganic : $FeSO_4$, $7H_2O$	20.5	Soil	10-25 kg ha^{-1}
	FeS_2 (Pyrite)	20-22	Foliar	1-3% $FeSO_4$
	Chelated : Fe-EDDHA	6.0	Soil	0.5-1.0 kg ha^{-1}
Manganese	Inorganic: $MnSO_4$,$3H_2O$	26-28	Soil	5-15 kg ha^{-1} Mn
	$MnSO_4$	32	Foliar	0.5% $MnSO_4$
Copper	Inorganic : $CuSO_4$,$5H_2O$	25	Soil	3-6 kg ha^{-1}
	$CuSO_4$, H_2O	35	Foliar	0.2%
Zinc	Inorganic: $ZnSO_4$,$7H_2O$	12	Soil	5-20 kg ha^{-1}
	$ZnSO_4$, H_2O	25	Foliar	0.2-0.5%
	Chelated : Zn-EDTA	12	Soil	0.5-1 kg ha^{-1}
			Foliar	0.2-0.5%
Boron	Borax ($Na_2B_4O_7$, $10H_2O$)	11	Soil	0.5-2.0 kg ha^{-1}
	Solubor	20-21	Foliar	0.2-0.5% solution in water
Molybdenum	Sodium molybdate (Na_2MoO_4, $2H_2O$)	39	Soil	0.40-1.0 kg Mo ha^{-1}
		54	Foliar	0.05-0.10% solution in water
	Ammonium molybdate [$(NH_4)_6Mo_7O_{24}$, $4H_2O$]		Seed coating	50-100 g Kg^{-1}

Source: Das, 2007

of iron. The average response of wheat and rice was almost of equal magnitude. The average response of groundnut, onion, sunflower, tomato and sugarcane to the application of manganese was 1.1; 39.6; 5.5; 6.0 and 17.8 q/ha respectively. In case of Cu, both organic and inorganic Cu-fertilizers are used to control Cu deficiency and their efficiency in relation to crop response may vary according to nature and type of soils as well as type of crops. The application of Cu as soil and foliar shows good response to different crops including flowers especially marigold (Das, 2007). In India, various methods of Zn application to different soils and crops have been evaluated to correct its deficiency under field conditions through All India Co-ordinated Research Project on Micronutrients, ICAR, New Delhi and other research institutions and State Agricultural Universities. Most results have showed that the response of rice growing under submerged puddle conditions exhibited a greater response compared to other crops like, wheat, maize, pulses, oilseeds, vegetables etc. to the application of Zn either applied as foliar or soil. Response to Zn varied greatly among the crops in each state as well as among the states for each crop because of wide variations in the sensitivity of crops to Zn and magnitude of its deficiency in soils (Das, 2007). However, responses as large as 47, 48, 20, 12 and 8 q/ha of wheat, rice, maize, barley and oats respectively were recorded to the application of Zn in most deficient soils. Besides, Boron and Mo exhibited a greater response towards the increase in yield and quality of wheat, oilseeds and high valued vegetables.

The best practice is to broadcast and incorporate Zn as a pre-plant application. This should provide several years' effectiveness. Chelates are foliar applied to correct Zn deficiency during the growing season but have little residual value. Oxide forms of Zn may have limited effectiveness in the year of application, but may be used to provide residual effect. Oxysulphate forms may provide some immediate plant need as well as a residual effect. The higher the percentage of sulphate (soluble and plant available) fraction, the more Zn will be in the plant available form. Corn may respond to zinc fertilizer at a low level of zinc, but alfalfa will not. The soil test for zinc is the best guide to use in determining the need for a zinc fertilizer. In general, zinc may be needed for sensitive crops where: The soil is calcareous (pH is higher than 7.3 because of excess lime). The topsoil has been removed either through erosion, land leveling or terrace building. Soils are very sandy with a low organic matter content. There have been some observations that applying high rates of phosphorus without zinc on calcareous soils with a low zinc level can reduce corn yields. If zinc is included with phosphorus in these situations, yields are improved. These can be divided into four groups: 1) organic chelates; 2) organic non-chelates; 3) soluble inorganics; and 4) insoluble inorganics. The chemical characteristics of zinc sources in one group are completely different from those in another. From the standpoint of fertilizer use, the mobility of the various carriers (sources) is very important. The zinc chelates are mobile in soils and will move with the soil water. The insoluble inorganic zinc carriers (zinc oxide, zinc carbonate) are not mobile, and must be applied as small, finely divided particles, broadcast and thoroughly incorporated so the plant roots will come in contact with the zinc fertilizer. Organic non-chelated zinc carriers and the soluble inorganic carriers are soluble but not very mobile in the soil. These carriers need to be placed in the root zone to assure root-zinc contact.

Placement of Zinc Fertilizers

The mobility of the various carriers has a strong influence on the way in which zinc fertilizers are applied for crop production. When the dry sources of zinc are considered, all materials are equally effective for crop production except for the granular formulations of the insoluble inorganic compounds. For the most part, zinc fertilizers can be either broadcast and incorporated into the soil or applied in a band at planting. In general, the rate of zinc suggested for a broadcast application can be reduced by half when the zinc fertilizer is placed in a band near the seed. Plant nutrients supplied in a fertilizer are usually applied at rates sufficient to grow the current crop. With zinc, however, it may be more practical to raise the zinc level of the soil, thus assuring an adequate supply for several years. This approach requires that relatively high rates of zinc be broadcast and incorporated. Granular zinc sulfate or finely ground zinc oxide can be used for this purpose. Zinc may also be applied with irrigation water through fertigation and in that case, Zn must be freely mobile. The chelated materials are the mobile sources of zinc, and are thus appropriate sources for this practice. Effectiveness ratios, such as 10:1 or 5:1, are often used for some zinc sources.

Soils of Tripura, exhibited low to medium range of deficiency of boron, zinc, molybdenum and copper while that of Fe did not show any acute deficiency problem rather sometimes it becomes toxic at the bottom level low land situation where the soil contains more organic matter and active iron coupled with water stagnation. The fertility status with respect to available Zn, Cu, Fe, and Mn was higher in lowland than in upland soils, whereas B and Mo contents were higher in upland than in lowland soils. However, all the micronutrient cations were in the adequate range. Nearly 29% soils were deficient in B and 50% in Mo in soils of Tripura. Management strategy usually depends upon the magnitude of deficiency of micronutrients, for a low intensity or very little deficiency of any micronutrient, the application of only organic manures at the normal rate of 5 t/ha will be sufficient for the correction of their deficiency, although it should be ascertained by the soil testing.

Chapter – VII

AGRONOMIC APPROACHES FOR MANAGING SOILS OF TRIPURA

Any strategy for optimum land use is usually confronted with various constraints. Soil acidity is one such limiting factor affecting adversely crop production to a considerable extent mainly in high rainfall and light soil texture conditions. Entire arable soil of Tripura is acidic with diverse magnitude ranging between very strongly acidic (pH 4.5 – 5.0) to strongly acidic (pH 5.1 – 5.5) to moderately acidic (pH 5.6 – 6.0) to slightly acidic soil (pH 6.0 to 6.5). Most of the soil in Tripura is strongly acidic in nature. Acidity of soil creates unfavorable medium for the soil micro flora responsible for breaking down the complex organic as well as inorganic matter of the soil to more simple and soluble form. It also makes primary, secondary and micro-nutrients to remain fixed or insoluble form, which can not be taken by plants. "Phosphate fixation" in highly acid soils is an acute problem. The phosphate gets fixed with soluble iron present in acid soils. Soil pH is the indicator of its Acidity, pH value 7 indicating neutral reaction and below 7 acidic. Highly acidic soils limit crop growth and should be ameliorated for optimum crop production. Strongly acid soils with pH less than 4.5 brings down the soil micro-flora activity and increases toxicity of elements like iron, copper and aluminum. The red laterite soils of Tripura are mostly coarse textured, single grained to weakly granular and usually have low water holding capacity. Therefore, such soils suffer from severe limitations so far as successful rainfed farming is concerned.

Fertility Status of Acid Soils

Acid soils have a pH of less than 5.6 and usually below pH 5.0. The low soil pH is associated with a number of soil chemical and biological characteristics that manifest themselves as the components of the problem acid soil syndrome. These components may adversely affect plant growth. The following specific problems are associated with problem acid soils: aluminium toxicity; manganese toxicity; molybdenum deficiency; legume nodulation failures; increase in plant disease and calcium and magnesium deficiency. Hydrogen ion toxicity, decreased phosphorus availability and toxicities of some other trace elements and heavy metals have also been reported. Except the brown forest soils, the other group of acid soils are low in their organic matter and total Nitrogen status. Total Nitrogen content varied from 0.027 to 0.093% and the C/N ratio from 8 to 13.7. Most of the red and lateritic acid soils have low available Phosphorous, although the total content is adequate. The ferruginous acid soils have moderately good status of total potash.

Management of Acid Soil

Wide range of management techniques are available to farmers for reclamation of acid soil. Some of them are as old as agriculture itself. Liming is an important proposition to combat soil acidity, however, everywhere this approach does not prove economical and most of the time it is out of the reach of resource poor farmers. Accordingly, agronomic manipulations such as selection of crops and varieties, time of sowing, soil fertility management, increasing use of biofertilisers, soil conservation, tillage, mulching, green manuring, incorporation of organic matter, strip cropping, intercropping, mixed cropping, pasture management etc. are in vogue to overcome soil acidity. Thus, judicious application of lime and various degree of these cultural aspects can be practiced to formulate an integrated acid soil management programme for both eco-friendly and economic tool to conquer productivity barrier and to attain sustainable crop production in acidic soils of India.

The simple philosophy of acid soil reclamation is that it will be more effective, soil health will be improved and base forming cations will be built up in the soil exchange complex. Wherever possible, different techniques should be employed together rather than an individual approach. In some cases, this can even lead to synergy – where the combined effect of different techniques is greater than would be expected from simply adding the individual effects together. The management of acid soils should aim at improving the production potential by addition of amendment to correct the acidity and manipulate the agricultural practices so as to obtain optimum crop yields under acid condition.

Liming

Liming is a desirable practice when the soil is highly acidic and where multicropping involving acid sensitive crops is adopted. Liming improves base saturation and increase the availability of Ca and Mg. Fixation of P and Mo is reduced by inactivating the reactive constituents. Toxicity arising from excess soluble Al, Fe and Mn is corrected and there by root growth is promoted and uptake of nutrients is improved. Liming also stimulates microbial activity and encourages N_2 fixation and N mineralisation, and hence, legumes are highly benefitted from liming. A general estimate shows that about 30% of the cropped land in Northern Plateau, 18% in the central table land, 21% in Eastern Ghat region and 24% in the coastal tract of Orissa need amendment. Efficient utilisation of plant nutrients, both the native and added sources, is brought about by liming.

Treating soil with Lime ($CaCo_3$): Liming has several beneficial effects: 1) it reduces harmful acidic conditions which develop in soils and that limit the availability of some nutrients but increase toxicity of others; 2) it replaces the supply of calcium and magnesium essential for plant growth; 3) it ensures favorable conditions for effective activity of certain herbicides; and 4) it provides a suitable environment for organic materials to decompose and enhance good soil structure and tilth.

Lime requirement: In liming programme, the first and foremost thing is to assess the lime requirement of the soil for optimum yield of the crop/crops. Lime requirement is estimated on the basis of exchange acidity and percent base saturation of soil. Among the various methods proposed to determine the lime requirement, buffer equilibration methods are most handy and accurate. Modified Woodruffs buffer method has been successfully used to assess the lime requirement of acidic soils (2.02 to 6.08 tonnes/ha.). However, it has been verified in a number of field trials that the full lime requirement dose as assessed by this method, which raise the pH to 7.0 or above, is not necessary for getting optimum yields of most crops. When applied in high doses, much of the lime is lost by leaching from the top soil of light textured soils because of their low exchange capacity. Split application is recommended to minimize the leaching loss. Lime should preferably be applied in smaller doses more frequently (every alternate year) rather than in heavy dose one in three to four years. Application of full LR dose reduces P availability and causes B deficiency. Hence, excess application is harmful. The lime requirement approximately ranges from 3.5 to 15 tonnes/ha. Following points are to be considered for liming:

1. Lime application should be done in split doses.
2. It should be done in smaller doses more frequently.
3. Application of lime in furrows @ 3 Q/ha at the time of sowing is effective to the crop plants.
4. Liming application has to be done in every alternate year till the soil pH is brought to normal range.
5. The programme may be taken up on area basis. (Block/ Panchayat as unit).

Choice of Liming Material : The second important aspect is the choice of liming material. Lime should be less expensive and available within easy reach of the farmers besides suitability. Commercial lime stone or dolomite lime stone powder is costlier. Several industrial wastes have been tried in the past as alternative sources of lime. Relative efficiencies of four sources i.e. lime stone, dolomite, basic slag and lime sludge were compared in lateritic soil taking three successive crops of maize. The efficiency of the four materials were comparable. Use of lime sludge as amendment had not only raise the agricultural production but also reduced the environmental pollution in the surrounding areas of the mills. The lime sludge contains some free soda which has no adverse effect on soil and crop. Pressmud from sugar industries is also a potential source of lime. Basic slag is another useful by-product, but the cost of grinding it to desired fineness is high. Recently, Tisco slag powder in the trade name of IRL clay conditioner has become available in the market. The Ferro Chrome slag powder is being marketed in the trade name of Bhushakti. Central Rice Research Institute, Cuttack has recorded 6% and 14% increase in rice yield owing to application of basic slag. Large scale demonstration conducted at Bahalda (Mayurbhanj district) on upland rice with Tata Slag Powder showed 25% - 30% increase in rice yield.

Crust formation and moisture stress during dry spells are the two major soil physical constraints under dry land situations in the red-lateritic acid soil zone, which also enhances soil erosion. Application of organic amendments such as FYM or decomposable green leaf manures (Glyricidia) was found to be quite effective in preventing crust formation and increasing moisture retentivity of the soil. Judicious application of lime, organic amendment and phosphate benefit the crop. Lime requirements of the crop depends on soil texture (clay content), CEC and sesquioxide content of soil. In the absence of more accurate recommendation the following ready reckoner may be followed. Requirement of different quantities to raise the soil pH to 6.5 from different degradation are given in Table 7.1.

Table 7.1: Lime Requirement (LR) for different soils to raise the soil pH to 6.5

Soil pH	Lime Requirement (kg/ha)		
	Sandy loam	Loam	Clay loam
5.0	1,262	1,892	2,944
5.2	1,093	1,639	2,551
5.4	925	1,387	2,159
5.6	757	1,135	1,766
5.8	589	883	1,374
6.0	421	630	981

Soil fertility and fertilizer management in acid soil

Higher N rates are recommended in high rainfall areas to compensate leaching losses. Split application of N with small dose is preferred to single heavy dose to avoid such losses (Sanchez and Salinas, 1981). Liebig *et al.* (2006) reported decrease in soil pH level due to acidifying the nitrogen fertilizer in highly fertilized soil. Acid forming fertilisers such as ammonium chloride, ammonium sulphate, ASN, ammonium phosphate, urea, ammonium nitrate etc. should be avoided in acidic soils. Dolomitic lime stone used as a filler in the fertilizer mixture can reduce soil acidity beside supplementing Ca and Mg nutrition of the soil. High phosphate fixing capacity creates the deficiency of phosphorous in acid soil. Use of judicious quantity of rock phosphate well ahead of liming is a cheap means for P supplementation in such type of problematic soil. Somani *et al.* (1990) reported that arbascular mycorrhizae (AM) forms symbiotic association with roots of several plants and facilitates increased uptake of phosphorous in soils low in P. here the fungal hyphae of AM act as an extension of plant root system, which increases the surface area for tapping P from larger soil volume. Deficiency of several micronutrients like Zn, Cu, B, Mo, etc. are commonly observed in acid soils (Lopes, 1980). Molybdenized SSP is an important fertilizer source to meet P, S and Mo need of acid soils. In situ nutrient recycling in balance ratio can promote lush vegetation even in acidic soil. For instance, mulches recycle adequate amount of K in the soil. Excreta of grazing cattle returns upto 80% of N, P, K consumed by them (Mott, 1974). Slashing and burning of forest may increase soil pH from 4.5 to 6.5.

Cropping Systems approach to combat soil acidity

Plants vary considerably in their tolerance to some of the components of the problem acid soil syndrome. Differences in the reaction of both plant species and its varieties to varying levels of aluminium and manganese have been measured under field conditions as well as in laboratory experiments. The expression of some acid soil problems therefore is not merely one of soil chemical characteristics but rather the result of a complex interaction between the plant and the soil.

Traditionally, farmers of Tripura have been growing rice irrespective of the type of land (Upland and low land). Rice has certain amount of tolerance to soil acidity; and flooding of the field also creates favourable condition (increase in pH and availability of P, Si and K) for growth of rice. Liming is desirable for raising the productivity of several crops. The acid sensitive crops like cotton, soybean, groundnut, french bean, pigeon pea etc. are better adaptable to acid soils with proper liming. Crops are classified according to their relative response to liming. This information can be utilised in fixing suitable cropping sequence. Under rainfed conditions, highly responsive crops like cotton, soybean, pigeon pea etc. may be grown in the first year of liming, followed by medium response crops like maize and wheat in the subsequent seasons. The low responsive crops like millets, rice, barley, linsed etc. may be grown when the effect of liming has been further reduced.

Keeping leguminous plant in the cropping system of any area is another way to fight against soil acidity. Many acidophiles belong to family leguminaceae, which can contribute to the soil N status by symbiotic N fixation. For instance, pulses like cowpea, peanut, pigeon pea, mung bean, urd bean and forage legume like Centrosema, Desmodium, Pueraria, Stylosanthus, Zornius spp. etc. Nitrogenous fertilizer is not at all required for acid tolerant legumes in the acid soils, however, for other crops, N dose can be minimized when grown as intercrop/ mixed crop or taken in rotation with legumes. Table 7.2 gives an idea about different component crops and cropping system suggested in acidic soils of Tripura.

Table 7.2: Cropping system of acidic soil

Type of land	Crops	Inter cropping / sequence cropping
Higher elevation land	Mesta, Pigeonpea, Maize, Groundnut	Inter cropping of pigeonpea + Groundnut
Medium land	Finger millet, Rice (Short duration)	Rice, Finger millet, Maize, Cowpea
Low lying land	Rice	Rice-Pulse, Rice-Rapeseed

Soil erosion and shifting cultivation are major problems in hilly-tracts of the state. Agri-horticultural and agro forestry systems need to be introduced in such tracts. In general, regions receiving more than 900 mm rainfall and with a moisture storage capacity of 200 mm in the root zone, double cropping can be taken up.

Green manuring

Increase in soil acidity after incorporation of green manure is very temporary. Rather green manure supply considerable amount of bases like Ca, Mg, K to decrease Al saturation and reduce soil acidity. Yield improvement with green manuring suggests an almost equivalent substitution of legume green manure for inorganic fertilization and liming.

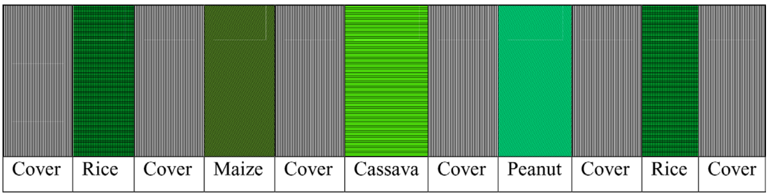
Incorporation of organic matter

It is useful if the mineral composition of the organic matter is high enough to raise soil pH. Incorporation of pressmud, which is a rich source of Ca, may be effective in reducing soil acidity by replacing Al and/ or Fe from the lattice structure.

Strip Cropping

Von Uexkull (1984) suggested a low cost acid soil management system involving legume strips as a cover crop in between the strips of food crops. The technique involves establishment of a legume cover using dolomitic lime stone and rock phosphate. The strips of cover crop are then killed after about two years, and left on the soil surface as a mulch. Food crops like maize, upland rice, peanut, mung and cassava are planted under mulch with minimum tillage. For protecting wet season crop from fungal attack, it is advisable to remove the mulch close to the crop rows.

Nitrogen need of these crops are largely met through biological N fixation by the cover crop but maintenance doses of P, K and dolomitic lime stone are needed. The cover crop is allowed to reestablish in strips from which the food crops have been harvested while killing other strips of cover crop for further cropping. In such a system of strip cropping half of the land area can be put under food crops and remaining half under a recuperative cover crop at any given time.



Choice of crops and varieties

There are some plants which grow luxuriantly only in strongly acidic soils while some are moderately tolerant to soil acidity. Similarly, within the same crop different varieties may also have preference for varying soil acidity level.

Grazing and pasture management:

Extensive grazing in high rain fall area encourage erosion losses of bases from the soil surface thus increase soil acidity. Tamartash *et al.* (2007) observed that the soil acidity increased with the grazing intensity. Arevalo *et al.* (1998) reported that centrosema (*Centrosema macrocarpum*), a leguminous forage plant, when established as a cover crop in a six-year-old peach palm (*Bactris gasipaes*) plantation reduced soil acidity and aluminum toxicity. Calcium and magnesium concentrations decreased over time as these minerals were stored in the pasture biomass, translocated to fresh peach palm fruits and/or exported to animals. Hence, to suppress soil acidity; on one side, over grazing of any land should be avoided while on the other side pasture succession should be planned well in advance.

Liming is the most common practice to raise soil pH to improve the productivity of acid soils. However, a sound knowledge of acidification processes and their relative importance can help to modify the farming system for slowing down the rate of acidification. Manipulation of fertilizer type, crops and pasture species and their cultivar, sowing time and livestock management could work as efficient management tools. The nature and extent to which the acidification process is being modified and the cost of management practices vis-à-vis liming will govern their success. Eventually an integrated approach involving liming, management changes and plant tolerance will be required to restore the productivity of acid soil.

Chapter – VIII

INDIGENOUS TECHNOLOGICAL KNOWLEDGE FOR SOIL MANAGEMENT –WISDOM ALIVE IN TRIPURA

The concept of indigenous knowledge in the context of agriculture is the traditional wisdom used for the conservation of soil and water resources for their sustainable use. These practices are the outcome of trial and error method and passed down from generation to generation, usually verbally or by practice. But in the pace of agricultural intensification these values are mostly lost. However, in the current context of declining soil heath it is the high time to think again of indigenous nutrient management which is being lost to modern agriculture and use it properly either in toto or after suitable refining it scientifically as per need of the farmers.

Soil is the most basic and vital natural resource on which agricultural production depends. Maintenance of soil fertility and productivity is, therefore, a real key to achieve sustainability in agriculture. No doubt, well frontier science based technologies appropriate for efficient management of soil fertility optimizing nutrient supplies from different sources have been developed, but many of these technologies could not find favour with farming community, in general and resource poor small and marginal farmers, in particular. Against this, there is growing realization that the present technologies need to be modifies in the light of indigenous technological knowledge (ITK) available with farmers so as to make them cost effective and acceptable to local farming communities.

Farmers possess a store-house of knowledge about their soil and various practices to restore and maintain soil fertility. Since the earliest stage of agriculture, farmers have been active in developing techniques for crop production and maintaining soil fertility. The indigenous technological knowledge available with farmers provides much needed insight into the management of soil fertility and nutrient management for sustained agricultural production, because such knowledge has been time tested and inherited from one generation to another. Moreover, indigenous technologies developed on the basis of experience gained and lessons learnt by the farmers are generally eco-friendly and do not require off-farm inputs. These technologies are at the fingertips of the farmers and thus give result invariably. In order to make use of these technologies they should be collected and fine-tuned with scientific touch.

The state of Tripura is endowed with diverse peo-edpho-meterological condition. Consequently, a spectrum of socio-economically and culturally distinct people is engaged in agriculture. The people of Tripura have evolved a large numbers of practices related to soil management systems suitable for different agro-climatic conditions of the state. They are time tested and effective for nutrient management. The systematic documentation of indigenous nutrient management practices in the form of a book chapter is necessary to conserve the agricultural heritage of Tripura from being lost. Here are few ITKs related soil nutrient management.

Use of Ash

Ash, particularly from rice husk and cowdung cake is an important material for agricultural use in the plains and valleys of Tripura. In *jhum* cultivation ash from burning of grasses weeds etc are used by the tribal people in hilly areas of the state. Ash primarily meets the deficiency of potash and supplies huge amount of silicon and it imparts friability to the seedbed soil which facilitates germination of seeds and also the easy uprooting of the seedlings. A thin film made by spreading of ash protects the seeds for the damage caused by birds. Spreading of ash mixing with kerosene oil on vegetable leaves in the morning hours is a common practice to protect the plants from the attack of insects pests, particularly jassids and red beetles. Mixing of ash with household waste helps in surface soil crust breaking, and rain water conservation This ITK practice is widely used in entire Tripura. This practice is technically feasible, inputs easily available, compatible with internal resources of the household, eco-friendly, enhance soil fertility and crop production.

Spade Insertion into the soil as indicator of irrigation requirement

Insertion of spade or digging the soil is used to test moisture content of the soil. It is a local practice to ascertain the optimum utilization of water and its penetration up to the root zone of the soil profile. Moisture content in the soil particles are necessary for increasing soil fertility. Both under rain fed and irrigated condition farmer test soil with the help of spade digging. Farmers regulate irrigation to desired soil depth by inserting spade to the soil. If it is completely inserted from front portion, it is considered to be properly irrigated. Similarly in other cases soil is thrown upside with spade and its splits into small pieces. This practice is a good indicator for farmers of Tripura to estimate proper irrigation of agricultural land. It is simple, easy to adopt and saves time as well as labour.

Moisture conservation through mulching

In Tripura many farmers use paddy straw as mulch material. Mulching conserves soil moisture in the field and also helps in maintaining soil temperature, controlling weed population. Moreover, it resists soil erosion to some extent. Mulching with farm yard manure is also used. This ITK practice is cheap and simple to adopt, conserves soil moisture, boon to the rural people for increased crop production and higher soil fertility as well as maximum use of raw material.

Indigenous compost pit

Application of compost helped to restore the fertility and soil moisture. So farmers of Tripura indigenously developed some compost pit structure in which natural earthen pit is prepared wherein cow dung, grasses, wasted vegetables were dumped, and opening of pit is closed for three months. The application of compost improve soil fertility and improves the water holding capacity of soil.

Use of pond silt

Use of pond silt (dried bottom mud of pond) in crop and plantation crops is an age-old popular practice in the state. During summer months the village ponds are dried up naturally or are dried by pumping out water in a rotation once in an interval of 5-10 years for the purpose of deepening of the pond. When bottom mass are clearly dried it is dug out and directly applied to the plantation as well as field crops. It is believed that the longer the period of interval between two successive drying of the pond, the better in the quality of pond silt in term of nutrient.

Besides, the darker the colour and lighter the weight per unit volume the richer is the pond silt in nutrients. The darker colour and the lighter weight signify the presence of large amount of humified organic matter. Many farmers reapply the silt gathered in pond or lakes to the crop field in order to improve soil fertility and physical condition like texture and structure owing to the presence of a good amount of organic matter and clay.

Silt collected from ponds and lakes are spread evenly on the field alone or in combination with FYM before sowing. Advantages of silt application include increased soil fertility and therefore improve crop yield, increased moisture content of soil, improvement in water table due to increased filtration.

Crop residue application in the field

The farmers of Tripura apply crop residues in crop field which on decomposition increase the organic matter content of soil and also improve the soil physical, chemical and biological properties of soil resulting in higher crop yield. But quantification of yield advantage after the incorporation of crop residue is a researchable issue which needs to be addressed.

Use of sand bags as erosion control measure

A sandbag is a bag or sack made of polypropylene or other sturdy material that is filled with sand or soil and is used in Tripura for gully erosion control which is very common under Tripura condition. The advantages are that the bags and the sand are inexpensive**. When empty the bags are compact and lightweight and easy to storage and transport**. They can be brought to a site empty and filled with local sand and soil.

Application of mixture of salt, ash and soil in the coconut pit before transplanting

Coconut trees need high potassium. Use of common salt (NaCl) at the time of planting coconut saplings and also almost in every year is a common age-old practice in the state. On an average, one *ser* (900 g approx.) is applied per plant. The Na in NaCl may replace non-exchangeable form of K from soil sites and make it available to the plants. This is how use of salt is beneficial to the trees. The objective of application of ash to provides potassium and sand makes root penetration easier so that productivity increases.

Use of Coconut husk inside the planting pit of plantation crops: Coconut husk increases the water holding capacity of the soil and also supplies potassium. It also helps in easy root penetration.

Penning of animal in the field: Tribal families those practice *Jhum* cultivation are nomadic in nature. They migrate from one place to another along with their cows and sheep also. The practice of penning animal in the slash and burn filed is common to *jhumian* tribal families. Wooden logs are usually used to tie the animals in the fields. Frequent shifting of animal is done so as to cover the whole field for uniform distribution of the animal dung and urine.

Present Relevance of Indigenous Technological Knowledge

The excavation and removal of sediments from the pond base helps in 1) enhancing the infiltration rate of water during the monsoon and the storage capacity of water, and ii) minimizing the chances of nitrate addition to ground water through pond base. The high infiltration rate of water in the pond helps in increasing the recharge of ground water. In such a process surface removal of nutrient coming from the runoff water is recycled by putting back all these nutrients, humified organic matter and clay in the form of pond silt. Such approach also reduces the chance of ground water pollution.

The practice of animal penning has practical value. The fresh dung left in the field rapidly dries up. The drying checks the ammonification and methane emission. The dung is usually worked into the soil and therefore, does not lose much of its fertilizer value. The urine in absorbed directly in to the soil and reduce the chances of volatilization of nitrogenous compound for being lost. Due to current short jhum cycle of 2-3 years, the fertility gets deteriorated quickly. Penning animal in field may rejuvenate the field to some extent.

Ash primarily meets the deficiency of potash and supplies huge amount of silicon and it imparts friability to the seedbed soil which facilitates germination of seeds and also the easy uprooting of the seedlings. A thin film made by spreading of ash protects the seeds for the damage caused by birds. Spreading of ash mixing with kerosene oil on vegetable leaves in the morning hours is a common practice to protect the plants from the attack of insect pests, particularly jassids and red beetles. Mixing of ash with household waste helps in surface soil crust breaking, and rain water conservation. This practice is technically feasible, inputs easily available, compatible with internal resources of the household, eco-friendly, enhance soil fertility and crop production.

Application of table salt in coconut plant has scientific relevance. Coconut plants are potassium loving crop. The Na in common salt (NaCl) may replace non-exchangeable form of K from soil sites and make it available to the plants. Thus, plant gets benefitted.Currently, relevance of salt application in coconut plants is lost due to the use of KCl as potassic fertilizer.

In general, it is observed that organic manure based farming systems encourage the build-up of soil organic matter, which reduces the erosion and runoff of inorganic matter to streams and rivers besides improving the physical, chemical, biological and biochemical properties of soils. In addition to the highest degree of yield stability, organic manure and crop residues can also reduce the pest and disease incidence by increasing species diversity, absorb and inactivate residual pesticides. Organic matter by virtue of its high CEC protects the nutrients being lost and thus, improves the use efficiency of applied chemical fertilizers.

Material used for mulching like straw, saw dust etc. are bad insulator. Small wave length rays having high energy coming from sun while fall on mulching material pass through mulching material and converted into long wave length rays of less energy. Energy is then converted to heat energy and cannot dissipate through mulching material due to their bad insulator property, thus, maintains soil temperature. Water, thus, vaporised cannot escape from soil due to mulch coverage.

Blending of Indigenous Technology with Latest Scientific Techniques

The soils of Tripura are acidic in reaction and susceptible to various kinds of degradation due to high rainfall and hill agriculture. The consumption of chemical fertilizers is below 45 kg/ha and yield of most of the crops are below the national average possibly because of the low level of adoption of package of practices and other biophysical constraints. The cost of chemical fertilizers has increased tremendously after their decontrol. In future, further increase in fertilizer price is expected due to phase wise withdrawal of concession given by Government. Under these circumstances it is deemed necessary to use locally available, time tested indigenous technologies in conjunction with modern technologies. For example, most of ITKs adopted by the local farmers are meant for organic matter enrichment in soil. So, combined use of chemical fertilizers in conjunction with crop residues/compost/pond silt/coir dust/rice husk etc will beneficial for maintain soil organic matter in one hand, increase in plant nutrient availability and fertilizer efficiency, on the other hand. This integrated approach will be the cheapest mean of providing nutrients for crop production and protecting nutrient loss in the field of poor and marginal farmers. Large numbers of experiments conducted all over the country proved that integrated use of chemical and organic can sustain the crop productivity and soil health.

The blending of the indigenous technology with latest scientific techniques holds a great promise not only for sustaining and maintaining soil fertility and crop productivity but also acts against emergence of multiple nutrient deficiencies and thus protects soil health from deterioration.

Chapter – IX

PROBLEMS AND PROSPECTS OF SHIFTING CULTIVATION (*JHUM*) IN TRIPURA

The economy of the state is basically agrarian and more than 70% population depend on agriculture for their livelihood. The state is predominantly hilly is surrounded on all side by deltaic basin of Bangladesh except for a small part in North East which adjoins Karimgang District of Assam and Mizoram. Biomass producing area is highest in the state consisting of forest area 0.61 mha and agricultural area 0.28 mha.

It is evident that fallow land is negligible in the state whereas forest area is extensively present there. So for sustainable and profitable land use it is expected that this forest land along with other land resources would be used in a scientific way. In this context every soil resource region has its own problem to be addressed very carefully and scientifically to make all types of land to be made profitably useful in future. From above detail description it is found that the radish yellow ground sandy soils belt should be kept protected under adequately thick forest cover at any cost. Experts are opinion that only limited and control felling, allowing natural regeneration of the plant cover can be permitted in this zone whereas clear – felling of the forest, especially on the hill ranges is highly detrimental to the ecological of the radish yellow bron sandy soil. The present day tribal practice of short cycle slash – and – burn of Jhum cultivation is highly damaging to this sensitive soil Jhum. The another soil region the red loam and sandy loam soils are fairly rich in nutrients and this soils usually support luxuriant growth of forest whereas these soil regions is susceptible to heavy erosion specially the areas which are located on slopping grounds. Since deep ploughing accelerates soil erosion in this soils those are not suitable for changing over to arable farming without ensuring rigorous soil conservation measures.

However, from scientific investigation it is found that crop production in limited scale by control Jhuming with the use of plough, thus not usually cause mass of soil erosion, provided the Jhum cycle is long enough to allow full regeneration of the forest cover during the periods when the land is lying fellow. Through such investigation is it also revealed that garden or plantation crops like rubber, tea, coffee, and pine apple are able to provide sufficient cover to the ground and are also profitable in using this problematic soil zone. The older alluvial soil region fairly rich in the nutrient status and are suitable for arable farming, though the greater part of the older alluvial soils is still clothed with tropical forest vegetation since river terraces are upland and slopes are subject to severe gully erosion, adequate measures of soil conservation are advised by the experts a must in the older alluvial soil zone.

The younger alluvial soil through are extremely rich and are capable to yield assured harvest of rice and Jute, this soil region is liable to erosion by lateral cutting and bank – collapse. Hence causation is needed in making intensive use of the soil in this zone along with river training work to be taken as essential to conserve the valuable soil resources which should not be allowed to be washed down to Bangladesh plains. The last and fifth soil zone is of lateritic soil.

As a whole this soil zone is unsuitable for arable farming and scientist feel that this regions should be taken under growing of grasses and other suitable plant species to keep the soil undisturbed as per as practically. Though this highly problematic soil zone covers only less than 5% of the total geographical area of the state. The proposed project envisages prospects among such general diversified and extensive problems in five soil regions of Tripura, because in every soil resource region scientist and experts are of opinion that each and every problems of soils can be successfully transform to a profitable and sustainable alternative livelihood thorough scientific methods conserving soils and water resources and using different plant species effective for particular soil regions.

REFERENCES

Acharya, C.L., Ghosh, P.K. and Subba Rao, A. (eds.) 2001. Indigenous nutrient Management Practices-wisdom alive in India. Indian Institute of Soil. Science, Bhopal.

Arevalo, L., Alegre, J., Bandy, D. and Szott, L. 1998. The effect of cattle grazing on soil physical and chemical properties in a silvopastoral system in the Peruvian Amazon. *Agroforestry Systems.* **40**(2): 109-124.

Bell, M. 1979. The exploitation of indigenous knowledge or the indigenous exploitation of knowledge whose use of what for what. *IDS Bulletin*, **10**: 44-50.

Bhattacharya, T., Sehgal, J.L. and Sarkar, Dipak 1996. Soils of Tripura for Optimising Land Use : Their kinds, distribution and suitability for major field crops and rubber.

Das, D.K. 2007. in: Micronutrients: Their behavior in soils and plants, 2nd edn. Kalyani Publishers, New Delhi, India.

Datta, M., Gupta, R.K. 1984. 'Studies on P, Ca, Zn and Fe content in soil and plant tissues as influenced by pressmud and lime'. *In J. Indian Soc. Soil Sci.,* **32**: 450-458.

Datta, M., Munna Ram. 1993. 'Status of micronutrients in some soil series of Tripura'. *In J. Indian Soc. Soil Sc.,* **41**: 776-777.

Dodd, J.C. 2000. The role of arbuscular mycorrhizal fungi in agro- and natural ecosystems. *Outlook Agric.,* **29**: 55–62.

Dwivedi, B.S., Munna Ram, Singh, B.P., Das, M., Prasad, R.N. 1990b. 'Differential response of crops to boron fertilization in acid alfisols'. *In Indian J. Agric. Sci.,* **60**: 122-127.

Kumpfer, W. and Heyser, W. 1986. Effects of stem flow Beech (*Fagus sylvatica* L.). In: Gianinazzi Pearson V, Gianinazzi S. (eds) Physiological aspects and genetical aspects of mycorrhizae. Proceedings of the 1st European Symposium on Mycorrhizae. Dijon, 1–5 July 1985, INRA, pp. 745–750.

Leake, J.R. and Read. D.J. 1997. Mycorrhizal fungi in terrestrial ecosystems. In: Wicklow D, Soderstrő́m B (eds) The Mycota IV. Experimental and microbial relationships. Springer, Berlin, pp. 281–301.

Liebig, A.A., Gross, J.R., Kronberg, S.L. Hanson, J.D., Frank , N.B. and Phillips, R.L. 2006. Soil response to long term grazing in the Northern Great Plains of North America. *Agric. Ecosyst. Environ.*, **115**: 270-276.

Lindsay, W.L. and Norvell, W.A. 1978. Development of DTPA micronutrients soil test for Zn, Fe, Mn, Cu. *Soil Sci. Soc. Am. Proceedings* **42**: 421-428.

Lopes A.S. 1980. Micronutrients in soils of the tropics as constraints to food production. In: Soil Related Constraints to Food Production in the Tropics. IRRI. Los Banos, Phillipines, 277 – 298.

Marschner, H. 1991. Mechanisms of adaptation of plants to acid soils. *Plant Soil* **134**: 1–20.

Marschner, H. 1995. Mineral nutrition of higher plants. Academic Press, London.

Marschner, H. 1998. Soil-root interface: biological and biochemical process. In: Soil chemistry and ecosystem health. SSSA Special Publication No 52. Madison, WI, pp. 191–231.

Marschner, H. 1991. Mechanisms of adaptation of plants to acid soils. In: R.J. Wright, V.C. Baligar, and R.P. Moorman (eds), Plant-soil interactions at low pH. Proceedings of the Second International Symposium on Plant-Soil Interactions at Low pH, June 24–29, 1990, Beckley, West Virginia, USA. Kluwer Academic Publisher, pp. 683–702.

McGonigle, T.P. and Miller. M.H. 1999. Winter survival of extraradical hyphae and spores of arbuscular mycorrhizal fungi in the field. *Appl. Soil Ecol.,* **12**: 41.

Mohsin, M.A. 1981. Transfer of agricultural technology in tribal areas-a question of approach. *Journal of Socio Economic Studies*, **9**: 277-88.

National Bureau of Soil Survey and Land Use Planning (NBSS & LUP, ICAR), A report on soils of Tripura. NBSS Publication. 65, NBSS & LUP, Nagpur.

Nongkynrih, P., Dkhar, P.S., Khathing, D.T. 1996. 'Micronutrient elements in acid alfisols of Meghalaya under rice cultivation'. *In J. Indian Soc. Soil Sci.,* **44**: 455-457.

Page, A.I., Miller, R.H. and Keeney, D.R. 1982. Methods of Soil Analysis, Part-II, Chemical and Microbiological Properties, Soil Sci. Am. and Am. Soc. Agron. Madison, Wisconsin, U.S.A.

Tamartash, R., Jalilvand, H. and Tatian, M.R. 2007. Effects on grazing on chemical soil properties and vegetation cover. *Pakistan J. of Biological Science.* **10**(24): 4391-4398.

Sanchez, A.P. and Salinas J.G. 1981. Low input technology for managing Oxisols and Ultisols in tropical America. *Adv. Agron.,* **34**: 279-405.

Sehgal, J.L., Saxena, R.K. and Vadivelu, S. 1987. Field Manual, Soil Resource Mapping of Different States in India, NBSS&LUP, Nagpur-440010.

Somani, L.L., Bhandari, S.C., Saxena, S.N. and Vyas, K.K. 1990. Biofertilisers. Scientific Publishers, Jodhpur. 361.

Subbaiah, B.V. and Asija, G.L. 1956. A rapid procedure for determination of available nitrogen in soil. *Current Science,* 25, 259-260.

Torsvik, V. and Ovreas, L. 2002. Microbial diversity and function in soil: from genes to ecosystems. *Curr. Opin Microbiol.,* **5**: 240–245.

Von Uexkull, H.R. 1984. Managing Acrisols in humid tropics. In: Ecology and Management of problem soils in Asia. Food and Fertiliser Technology Centre, Taiwan Book Series No. **27**: 382 – 396.