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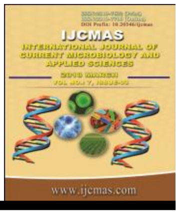

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Status of DTPA-Extractable Micronutrients in Valley Districts of Manipur

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ABSTRACT

An investigation was carried out in cultivated paddy fields of valley districts of Manipur to study the distribution of micronutrients and some soil physico-chemical properties as well as their correlation. Results revealed that most of the studied samples (71.15 per cent) belonged to clay texture and were acidic in reaction ranges between 4.9 (very strongly acid) to 6.6 (slightly acid). The soils were low in electrical conductivity varied from 0.05 to 0.26 dSm^{-1} and rich in organic carbon (0.79 to 5.82 %) having CEC value ranged from 7.9 to 27.3 meq/100 gm. Higher value of CEC might be due to close positive association between clay content and CEC. The nitrogen, phosphorus and potassium content of the samples varied from 150.53 to 614.66 kg ha^{-1}, 10.80 to 27.89 kg ha^{-1} and 106.60 to 630.45 kg ha^{-1} showing more than half of the studied samples were medium in available nitrogen content, 53.85% were low and 46.15% were medium in available P_2O_5 content and 51.92% were medium in available K_2O content. At different soil samples collected from various locations, distribution of DTPA-Fe were very high ranging from 18.21 to 75.63 mg kg^{-1}, high DTPA-Cu ranging from 0.94 to 2.90 mg kg^{-1}, well supplied DTPA-Mn ranging from 12.37 to 58.24 mg kg^{-1} and most of the soils were deficient in DTPA-Zn varied from 0.08 to 0.79 mg kg^{-1}, respectively. Further, correlation studies revealed that DTPA-extractable Fe showed a positive and significant correlation with OC (r= 0.281*), DTPA-Zn with EC (r=0.602**) and DTPA-extractable Mn showing a positive and significant correlation with pH (r= 0.286*) and clay (r= 0.279*) in soil. However, there was a negative and significant correlation with sand (r= -0.467**) in case of DTPA-extractable Mn.

Introduction

Indian soils have become deficient not only in major plant nutrients like nitrogen, phosphorus and in some cases, potash but also in secondary nutrients, like sulphur, calcium, and magnesium.

Micronutrients such as zinc, boron and to a limited extent iron, manganese, copper and molybdenum have also been reported to be deficient. Micronutrient deficiencies have become one of the major constraints in sustaining crop production in the present day exploitive agriculture. The importance of the micronutrients for different physiological processes in plant life is well understood, as they are required in smaller quantities. Therefore, when a nutrient becomes deficient in soil, the plant growth may suffer and the situation results into crop failure or loss of yield (Mengel *et al.,* 2001; Gupta, 2003; Nazakat *et al.,* 2012).

Micronutrients often act as cofactors in enzyme systems and participate in redox reactions, in addition to having several other vital functions in plants (Memon *et al.,* 2012). Most importantly, these are involved in the key physiological processes of photosynthesis and respiration (Mengel *et al.,* 2001; Gao *et al.,* 2008) and their deficiency can impede the vital physiological processes thus limiting yield of the crop (Patil *et al.,* 2008). For example, for rice (*Oryza sativa* L.), zinc deficiency is a major yield-limiting factor in several Asian countries (Wissuwa *et al.,* 2006; Rehman *et al.,* 2012). Deficiency of micronutrients has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity which has become a major constraint to production and productivity of rice, wheat and pulses. The rice-wheat cropping system, being exhaustive in terms of nutrient removal, resulted in increased pressure on native nutrient reserve of soil. The deficiency of Fe and Mn has been found to occur in this cropping system (Takkar and Nayyar, 1981).

Availability of plant nutrients to crops has a strong bearing on physico-chemical nature of soils. India has a vast area under acid soils as well as sodic soils. Productivity of such soils can be restored through well-established ameliorative techniques. Use of lime or liming materials in acid soils and that of gypsum/phosphogypsum in sodic soils has been advocated by Soil Scientists for correction of soil pH and improving physico-chemical nature of these soils. The availability of micronutrients is influenced by their distribution within the soil profile and other soil characteristics (Singh *et al.,* 1989). The distribution of micronutrients may also differ among the profiles developed on different parent materials and landforms (Verma *et al.,* 2005). Thus, there is an urgent need for correction of individual nutrient deficiency and for arresting its further spread.

Keeping these in view, the present study was undertaken to study the distribution of available micronutrients in paddy fields of valley districts of Manipur (India) as well as their correlation with some soil physico-chemical properties.

Materials and Methods

The study area is a small plain covering an extent of 1843 sq. km in the central part of the state, known as Imphal valley and situated at about 24°44’N latitude and 93°58’ E longitude, at an altitude of about 790 metres above the mean sea level (MSL). The area falls under humid subtropical climate with mild, dry winters and a hot monsoon season having transported alluvium type of soil. The valley receives annual average rainfall of about 1,320 mm, with June the wettest. Soil samples were collected from four valley districts *viz*., Imphal East, Imphal West, Thoubal and Bishnupur districts of Manipur (India) following stratified random sampling through proportional allocation. Total number of samples collected from different cultivated paddy fields of the four valley districts were 52 (Table 1).

The collected samples were processed and analyzed following standard procedures: for mechanical analysis using hydrometer method (Bouyoucous, 1927); soil pH and electrical conductivity (EC) using 1: 2.5 soil water suspensions (Jackson, 1973), CEC by leaching with 1N NH_4OAc (Jackson, 1973) and organic carbon following Walkley and Black’s rapid titration method (Walkley and Black, 1934). The samples were determined for available nitrogen (potassium permanganate method), available P_2O_5 (Bray and Kurtz No.1), neutral ammonium acetate extractable K_2O and DTPA extractable Zn, Cu, Mn and Fe following standard procedures as outlined by Jackson (1973). The relationship between various soil properties and micro-nutrients distribution were established by using simple correlation coefficient.

Results and Discussion

Soil texture

Distribution of soil separates viz., sand, silt and clay in the soil samples are presented in Table 2. Result revealed that most of the studied samples (71.15per cent) belonged to clay texture. Higher clay content of the soils of Manipur was also reported by Sarker *et al.*, (2002). However, all the remaining soils belonged to clay loam (3.85 per cent), silty clay loam (9.62 per cent), sandy clay (7.69 per cent), silty clay (5.77 per cent) or sandy loam (1.92 per cent). Sand, silt and clay fractions in the soils ranged from 06.8 to 55.9, 05.0 to 54.1 and 20.0 to 73.2 per cent, respectively.

Soils of Lanthrelloukon of Imphal East contained the highest amount of sand with a value of 55.9 per cent and the least was found in soils of Top Dasura, with a value of 06.8 per cent. The highest silt percentage was recorded in soils of Top Dasura (54.1 per cent) and the lowest in Takyel Mapal soils (05.0 per cent). Regarding clay content, the highest was found in soils of Nungoi (73.2 per cent) and lowest in Uyal soils (20.0 per cent).

Soil reaction (pH)

Soil pH (1:2.5, soil: water) values of the studied soil samples were, by and large, in the acidic range (Table 3). Most of the soil pH ranged between 4.9 (very strongly acid) to 6.6 (slightly acid). Nayak *et al.*, (1996) and Sahoo *et al.*, (2010) also reported similar acidic nature of the soils of Manipur. The acidity may be due to higher organic matter content (Nayak *et al.*, 1996). pH value was found lowest in soils of Lalpani, Nachou and NgangkhaLawai and highest in Huikap with a value of 4.9 and 6.6, respectively.

Electrical Conductivity (EC)

Data on soluble salt contents in the soil samples are presented in Table 3. Results revealed that electrical conductivity (EC) values (1:2.5, soil: water) varied from 0.05 to 0.26 dSm^{-1}. The lowest EC (0.05 dSm^{-1}) was observed in the soils of Champanagar, Kalika and Uyal and highest (0.26 dSm^{-1}) in Kangchup soil sample. Critical study of the data indicated that EC values were low (< 1 dSm^{-1}). This may be due to leaching loss of soluble salts from soils under high rainfall conditions (Brady and Weil, 1999 and Maji *et al.*, 2005). On the basis of the limit suggested by Muhr *et al.*, (1963) for judging salt problem, all the soil samples were found neutral (EC < 1.0 dSm^{-1}). The low EC of the soils may be due to low exchangeable bases. Similar observations were also reported by Sarkar *et al.*, (2002).

Organic carbon

Data on organic carbon content of the studied samples (Table 3) revealed that its content in all the samples was high ranging from 0.79 to 5.82 per cent. The maximum organic carbon content was recorded in the soils of Thokchom with a value of 5.82 per cent and the lowest (0.79 per cent) in the soil samples of Hilgat and Dibong. Higher organic carbon content in the soils might be due to mixing of organic matter during cultivation as organic residues (Thangasamy *et al.*, 2005). Sarkar *et al.*, (2002) also reported higher organic carbon content in top layer soils of Manipur. Similar findings were also supported by Saha and Bala (1995) and Sahoo *et al.*, (2010).

Cation Exchange Capacity (CEC)

The cation exchange capacity (CEC) of the paddy field soils of valley districts of Manipur are presented in Table 3. Result revealed that CEC value ranged from 7.9 to 27.3 meq/100 gm. Maximum soil samples (88.46 per cent) falls under medium range (10-25 meq/100g). Higher value might be due to close positive association between clay content and CEC (Ghosh *et al.*, 2005). On the other hand, it may perhaps be due to organic carbon in the surface layer. Further, it was also observed that soils of Lanthrel Loukon had the highest CEC with a value of 27.3 meq/100 gm and the lowest was found in soils of Champanagar with a value of 7.9 meq/100 gm.

Available Nitrogen (N)

Data on available nitrogen content (Table 3) revealed that the soil samples contained available nitrogen varying from 150.53 to 614.66 kg ha^{-1}. The highest available nitrogen content (614.66 kg ha^{-1}) was observed in soils of Waiton and lowest in Hilgat and Nongren soils with a value of 150.53 kg ha^{-1}. The variation of available nitrogen content in the soils may be due to different amount of organic carbon present in the soils which released different amounts of nitrogen into the soils (Brady and Weil, 1999). On the basis of rating as suggested by Subbiah and Asija (1956) (<250 N kg ha^{-1} for low, 250 to 500 N kg ha^{-1} for medium and > 500 N kg ha^{-1} for high), 36.54, 57.69 and 5.77 per cent soil samples fallen under low, medium and high categories, respectively. Detailed study revealed that more than half of the studied samples were medium in available nitrogen content.

Available phosphorus (P_2O_5)

Available phosphorus content in the soil varied from 10.80 to 27.89 kg ha^{-1}(Table 3). It was observed that the highest available P_2O_5 content (27.89 kg ha^{-1}) was found in the soils of Uyal and lowest (10.80 kg ha^{-1}) in soil samples collected from Dibong and Hiyangthang.

On the basis of critical limit suggested by Muhr *et al.*, (1963), all the soil samples were low. Higher available phosphorus content in surface layer might possibly be due to the confinement of crop cultivation to the rhizosphere and supplementing depleted phosphorus through external sources i.e., fertilizer and organic manure (Thangasamy *et al.*, 2005 and Kumar *et al.*, 2011).

This might be due to the fact that available P did mot leach out from the surface layer to the lower depth and is fixed by hydrated as well as amorphous oxide of Fe and Al which are potent phosphorus fixers in acidic soil (Brady and Weil, 1999).

Osodeke and Ubah (2005) also reported that at low pH, the phosphorus may be fixed as Fe and Al phosphate, which are not likely to be readily available to plants.

Available potassium (K_2O)

Data on available potassium contents in different soil samples are presented in Table 3. Results showed that available potassium content in different soil samples collected from various locations varied from 106.60 to 630.45 kg ha^{-1}. The highest available K content was recorded in soils of Ngangkha Lawai with a value of 630.45 kg ha^{-1}.

Higher available potassium content in soil surface could be attributed to release of labile K from organic residues and application of K fertilizers. Whereas, the lower potassium content in Hilgat soils (106.60 kg ha^{-1}) may be due to considerable leaching losses of soluble potassium due to high rainfall.

Table.1 Locations of the soil samples collected

District	Sub-divisions	Villages	No. of samples collected
IMPHAL EAST (4 sub-divisions)	1.Jiribam (Total villages- 51)	1. Hilgat 2. Solapur 3. Dibong 4. Lalpani 5. Champanagar	5
	2. Sawombung (Total villages- 64)	1. Tellou 2. Tangkham 3. Waiton 4. Nungoi 5. Kanglasagolmamg 6. Pangei 7. Nongren	7
	3. KeiraoBitra (Total villages- 36)	1. Kalika 2. Huikap 3. LanthrelLoukon 4. Andro	4
	4. Porompat (Total villages- 54)	1. Top Dasura 2. Wakha 3. Gangapat 4. Matai 5. Khongman	5
			TOTAL: 21
IMPHAL WEST (4 sub-divisions)	1. Lamshang (Total villages- 69)	1. Kangchup 2. AwangLeirenkabi 3. Lamshang 4. Phayeng 5. Tharoijam	5
	2. Patsoi (Total villages- 25)	1. Yurembam 2. Ghari 3. Langjing	3
	3. Lamphelpat (Total villages- 9)	1. TakyelMapal 2. MaibamLeikai	2
	4. Wangoi (Total villages- 31)	1. SangaiprouMamang 2. Lairenjam 3. Hiyangthang 4. Monsangei	4
			TOTAL: 14
THOUBAL (3 sub-divisions)	1. Thoubal (Total villages- 49)	1. Charangpatmamang 2. Uyal 3. Bengi 4. Thokchom	4
	2. Lilong (Total villages- 17)	1. Kekman 2. Choubok 3. Hoareibi	3
	3. Kakching (Total villages- 37)	1. KhakchingKhulel 2. KakchingWairi 3. Keirak 4. Wabgai	4
			TOTAL: 11
BISHNUPUR (3 sub-divisions)	1. Nambol (Total villages- 14)	1. Utlou 2. Keinou	2
	2. Bishnupur (Total villages- 13)	1. Nachou 2. Potsangbam	2
	3. Moirang (Total villages- 22)	1. NgangkhaLawai 2. Kumbi	2
			TOTAL: 6

Table.2 Particle size distribution of the soils collected from four valley districts of Manipur

Sl. No.	Villages	Soil Separates			Soil Texture
		Sand (%)	Silt (%)	Clay (%)	
1	Hilgat	27.3	43.6	29.1	Clay loam
2	Solapur	21.8	17.5	60.7	Clay
3	Dibong	22.7	35.7	41.6	Clay
4	Lalpani	28.0	42.0	30.0	Clay loam
5	Champanagar	19.3	42.5	38.2	Silty clay loam
6	Tellou	14.3	20.0	65.7	Clay
7	Tangkham	11.8	24.1	64.1	Clay
8	Waiton	16.8	14.1	69.1	Clay
9	Nungoi	16.8	10.0	73.2	Clay
10	Kanglasagolmamg	14.3	22.5	63.2	Clay
11	Pangei	11.8	22.5	65.7	Clay
12	Nongren	16.8	29.1	54.1	Clay
13	Kalika	21.8	31.6	46.6	Clay
14	Huikap	21.8	15.0	63.2	Clay
15	LanthrelLoukon	55.9	20.0	24.1	Sandy clay
16	Andro	24.3	34.1	41.6	Clay
17	Top Dasura	06.8	54.1	39.1	Clay
18	Wakha	19.3	41.6	39.1	Silty clay loam
19	Gangapat	11.0	42.0	47.0	Silty clay
20	Matai	35.9	11.6	52.5	Clay
21	Khongman	09.0	44.0	47.0	Silty clay
22	Kangchup	35.9	10.0	54.1	Clay
23	AwangLeirenkabi	38.4	13.2	48.4	Clay
24	Lamshang	45.9	10.0	44.1	Sandy clay
25	Phayeng	35.9	08.2	55.9	Clay
26	Tharoijam	44.1	14.3	41.6	Clay
27	Yurembam	38.0	19.0	43.0	Clay
28	Ghari	30.7	25.2	44.1	Clay
29	Langjing	35.9	11.6	52.5	Clay
30	TakyelMapal	35.9	05.0	59.1	Clay
31	MaibamLeikai	18.0	42.0	40.0	Silty clay loam
32	SangaiprouMamang	19.0	42.0	39.0	Silty clay loam
33	Lairenjam	32.5	10.9	56.6	Clay
34	Hiyangthang	36.6	15.0	48.4	Clay
35	Monsangei	35.9	10.0	54.1	Clay
36	Charangpatmamang	53.4	11.4	35.2	Sandy clay
37	Uyal	45.0	35.0	20.0	Sandy loam
38	Bengi	15.0	22.0	63.0	Clay
39	Thokchom	12.5	34.8	52.7	Clay
40	Kekman	13.0	37.0	50.0	Clay
41	Choubok	50.0	15.0	35.0	Sandy clay
42	Hoareibi	11.6	30.0	58.4	Clay
43	KhakchingKhulel	20.0	21.6	58.4	Clay
44	KakchingWairi	13.9	23.0	64.1	Clay
45	Keirak	14.1	21.8	64.1	Clay
46	Wabgai	14.1	20.0	65.9	Clay
47	Utlou	14.3	22.5	63.2	Clay
48	Keinou	17.5	40.0	42.5	Silty clay
49	Nachou	18.0	42.0	40.0	Silty clay loam
50	Potsangbam	14.1	30.9	55.0	Clay
51	NgangkhaLawai	20.0	25.0	55.0	Clay
52	Kumbi	20.0	35.0	45.0	Clay

Table.3 Different chemical properties of the soils collected from four valley districts of Manipur

Sl.no.	Villages	pH	EC (dSm^{-1})	OC (%)	CEC (meq100 gm^{-1})	N (kgha^{-1})	P_2O_5 (kgha^{-1})	K2O (kgha^{-1})
1	Hilgat	5.2	0.11	0.79	10.3	150.53	14.40	106.60
2	Solapur	5.3	0.11	2.82	08.5	602.11	14.40	192.19
3	Dibong	5.2	0.08	0.79	12.2	288.51	10.80	112.89
4	Lalpani	4.9	0.15	2.11	10.5	589.57	11.80	129.02
5	Champanagar	5.2	0.05	1.23	07.9	351.23	13.60	305.08
6	Tellou	6.0	0.06	3.00	14.3	326.14	20.80	416.64
7	Tangkham	5.2	0.17	2.55	13.0	288.51	27.00	158.59
8	Waiton	5.9	0.11	3.70	16.0	614.66	17.40	563.13
9	Nungoi	5.8	0.16	3.70	22.1	363.78	15.80	305.08
10	Kanglasagolmamg	5.4	0.20	3.70	13.9	401.40	18.40	268.80
11	Pangei	5.4	0.12	3.17	16.4	464.13	27.00	297.02
12	Nongren	5.8	0.08	4.23	08.0	150.53	17.20	216.38
13	Kalika	5.3	0.05	4.50	08.3	200.70	19.00	529.53
14	Huikap	6.6	0.50	3.61	13.0	288.51	26.00	396.48
15	LanthrelLoukon	5.5	0.11	4.41	27.3	225.79	26.00	606.14
16	Andro	5.2	0.18	2.56	11.6	225.79	14.40	374.97
17	Top Dasura	5.8	0.06	3.35	10.2	188.16	27.00	176.06
18	Wakha	5.4	0.07	4.41	11.0	250.88	19.00	157.24
19	Gangapat	5.7	0.08	3.00	11.2	213.25	17.20	384.38
20	Matai	5.4	0.12	3.35	17.2	220.25	25.35	310.34
21	Khongman	5.6	0.09	2.90	15.4	250.00	20.35	280.50
22	Kangchup	5.0	0.26	2.64	09.4	200.70	27.00	147.84
23	AwangLeirenkabi	5.1	0.14	3.26	11.8	263.42	26.00	353.47
24	Lamshang	5.5	0.12	3.44	24.0	275.97	17.20	275.52
25	Phayeng	5.1	0.19	2.38	10.3	225.79	25.40	176.06
26	Tharoijam	5.2	0.08	4.32	10.6	275.97	19.60	153.21
27	Yurembam	5.2	0.12	3.17	10.8	275.97	27.00	397.82
28	Ghari	5.3	0.10	4.14	10.7	351.23	15.00	196.22
29	Langjing	5.4	0.09	4.05	12.6	301.06	27.00	211.00
30	TakyelMapal	5.2	0.12	4.14	22.2	275.97	11.32	241.92
31	MaibamLeikai	5.6	0.14	4.50	21.2	280.00	15.49	300.10
32	SangaiprouMamang	5.3	0.12	4.41	19.1	263.42	27.00	400.51
33	Lairenjam	5.0	0.11	4.50	22.0	250.88	27.00	298.36
34	Hiyangthang	5.2	0.22	4.23	24.0	338.69	10.80	188.16
35	Monsangei	5.4	0.08	4.14	21.0	188.16	27.00	245.95
36	Charangpatmamang	5.3	0.08	3.79	23.1	225.79	15.60	198.91
37	Uyal	5.3	0.05	4.41	21.4	213.25	27.89	211.00
38	Bengi	5.4	0.09	3.89	23.6	238.33	27.00	209.66
39	Thokchom	5.0	0.13	5.82	19.9	275.97	27.00	280.90
40	Kekman	5.7	0.06	4.41	10.3	225.79	26.89	229.82
41	Choubok	5.8	0.06	4.58	12.0	250.88	14.80	232.51
42	Hoareibi	5.5	0.16	5.64	17.0	175.61	16.80	341.38
43	KhakchingKhulel	5.4	0.08	5.38	23.1	225.79	14.40	395.13
44	KakchingWairi	5.4	0.11	5.82	23.7	301.06	14.40	471.74
45	Keirak	5.1	0.11	5.02	21.0	338.69	26.89	423.36
46	Wabgai	5.4	0.08	5.73	18.0	288.51	27.00	202.94
47	Utlou	5.4	0.11	2.71	21.4	163.07	25.45	554.96
48	Keinou	5.5	0.13	3.00	19.3	192.00	18.45	450.45
49	Nachou	4.9	0.08	3.92	21.2	350.50	17.90	510.45
50	Potsangbam	5.1	0.09	4.29	15.6	373.20	16.40	490.00
51	NgangkhaLawai	4.9	0.08	4.84	23.5	345.00	18.45	630.45
52	Kumbi	5.0	0.08	4.26	23.2	290.80	21.10	520.20

Table.4 Distribution of micronutrients of the soils collected from four valley districts of Manipur

Sl No.	Villages	Fe (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	Zn (mg kg^{-1})
1	Hilgat	26.75	43.94	0.94	0.15
2	Solapur	38.87	12.37	1.63	0.46
3	Dibong	27.11	36.78	1.9	0.26
4	Lalpani	28.03	18.46	1.85	0.45
5	Champanagar	35.05	34.26	1.3	0.32
6	Tellou	44.44	53.34	2.6	0.11
7	Tangkham	70.01	44.83	2.9	0.3
8	Waiton	50.84	41.32	1.84	0.16
9	Nungoi	47.82	58.24	1.91	0.12
10	Kanglasagolmamg	58.93	45.47	2.06	0.18
11	Pangei	50.95	32.43	1.26	0.12
12	Nongren	36.72	55.95	1.78	0.18
13	Kalika	52.58	51.97	2.36	0.25
14	Huikap	18.21	21.36	1.15	0.79
15	LanthrelLoukon	52.29	21.59	1.94	0.41
16	Andro	68.83	35.12	1.19	0.51
17	Top Dasura	31.94	42.04	1.73	0.08
18	Wakha	56.67	19.3	1.7	0.16
19	Gangapat	44.45	34.52	1.75	0.18
20	Matai	32.45	21.45	1.81	0.1
21	Khongman	44.56	39.8	1.89	0.15
22	Kangchup	54.47	27.26	2.21	0.39
23	AwangLeirenkabi	64.25	17.91	2.51	0.43
24	Lamshang	42.21	31.96	2.06	0.42
25	Phayeng	49.62	17.72	2.25	0.32
26	Tharoijam	47.53	15.35	2.06	0.13
27	Yurembam	44.81	30.23	1.46	0.2
28	Ghari	37.6	12.94	1.36	0.13
29	Langjing	45.88	24.17	2.26	0.3
30	TakyelMapal	45.67	25.76	1.5	0.14
31	MaibamLeikai	37.65	23.24	1.36	0.09
32	SangaiprouMamang	50.04	18.51	1.62	0.18
33	Lairenjam	66.15	13.88	1.84	0.11
34	Hiyangthang	57.32	22.99	2.22	0.28
35	Monsangei	29.79	15.4	1.27	0.08
36	Charangpatmamang	67.2	28.63	1.81	0.28
37	Uyal	49.53	29.4	1.5	0.08
38	Bengi	44.88	44.05	1.67	0.12
39	Thokchom	52.55	30.07	1.68	0.2
40	Kekman	75.63	29.39	2.38	0.43
41	Choubok	53.1	24.16	2.08	0.18
42	Hoareibi	41.86	41.75	1.82	0.16
43	KhakchingKhulel	38.41	40.85	2.05	0.26
44	KakchingWairi	51.69	27.57	1.75	0.18
45	Keirak	57.59	28.08	1.87	0.15
46	Wabgai	54.29	29.33	1.76	0.13
47	Utlou	51.69	24.63	1.87	0.18
48	Keinou	50.63	23.11	1.91	0.14
49	Nachou	49.7	26.73	2.3	0.21
50	Potsangbam	50.01	35.2	1.99	0.18
51	NgangkhaLawai	47.34	34.84	2.03	0.22
52	Kumbi	43.42	32.10	2.05	0.25

Table.5 Correlation coefficient (r) between DTPA – extractable micronutrients and physico-chemical properties of soils

Soil Property	**DTPA – extractable micronutrients**			
	Fe	Mn	Cu	Zn
Sand	0.053	-0.467**	0.011	0.200
Silt	-0.170	0.200	-0.202	-0.135
Clay	0.120	0.279*	0.194	-0.070
pH	-0.264	0.286*	-0.129	0.110
EC	-0.133	-0.147	-0.126	0.602**
CEC	0.143	-0.074	-0.003	-0.240
OC	0.281*	-0.088	0.106	-0.249
N	-0.060	-0.103	0.011	0.156
P_2O_5	0.228	-0.151	0.121	-0.034
K_2O	0.117	0.118	0.108	0.020

*Critical value of r significant at 5% and ** at 1%

DTPA-extractable iron (Fe)

The DTPA-extractable Fe content of the soils were fairly high in all the studied soil samples with a value varying from 18.21 to 75.63 mg kg^{-1}(Table 4). The highest concentration of available Fe was found in the soils of Kekman and least in Huikap soils with a value of (75.63 mg kg^{-1}) and (18.21 mg kg^{-1}), respectively. Considering critical limit of 4.5 mg Fe kg $^{-1}$ soil (Lindsay and Norvell, 1978) all the soils were highly sufficient in available Fe. This may be attributed to higher organic matter because it acts as chelating agent (Kumar *et al.*, 2011).

These cationic micronutrients react with certain organic molecules to form organo metallic complexes as chelates, and the soluble chelates can increase the availability of the micronutrient and protect it from precipitation reactions. These chelates may also be synthesized by plant roots and released to the surrounding soil or may be present in soil humus (Brady and Weil, 1999).

Correlation studies revealed (Table 5) that DTPA-extractable Fe showed a positive and significant correlation with OC (r= 0.281*) in soil. The result was in conformity with the findings of Sarkar *et al.*, (2000); Sharma *et al.*, (2002) and Verma *et al.*, (2007).

DTPA-extractable manganese (Mn)

Data on distribution of DTPA-extractable Mn are shown in Table 4. DTPA-Mn content ranged from 12.37 to 58.24 mg kg^{-1} soils in soil with mean value of 30.61 mg kg^{-1}. The highest content of available Mn was found in soil of Nungoi village and lowest in Solapur village of Imphal East district with a value of 58.24 and 12.37 mg kg^{-1} soil, respectively. Considering 1.0 mg Mn kg^{-1} soil as critical level (Lindsay and Norvell, 1978), all the samples were well supplied with available Mn. The abundance of DTPA - Mn in soils of Manipur was also reported by Sarkar *et al.*, (2002).

Correlation studies (Table 5) revealed that DTPA-extractable Mn showed a positive and significant correlation with pH (r= 0.286*) and clay (r= 0.279*). Similar observations were also given by Singh *et al.*, (2006) and Tiwary and Mishra (1990) in soil. However, there was a negative and significant correlation with sand (r= -0.467**).

DTPA-extractable copper (Cu)

Results (Table 4) revealed that DTPA-extractable Cu content in different soil samples ranged from 0.94 to 2.90 mg kg^{-1} soil. It was also observed that soil of Tangkham village showed higher concentration (2.90 mg kg^{-1}) of available Cu and the lowest (0.94 mg kg^{-1}) in soil of Hilgat village. Maximum DTPA- extractable Cu recorded in these surface layer soil are in close proximity with the findings of Sharma *et al.*, (2002); Sharma *et al.*, (2005) and Athokpam *et al.*, (2013).

Taking into consideration the critical value of 0.20 mg Cu kg^{-1} (Lindsay and Norvell, 1978), all the soil samples were well supplied with available Cu. Similar findings were also made by Sen *et al.*, (1997).

DTPA-extractable Zinc (Zn)

DTPA-extractable Zn content in soil samples were analysed (Table 4) and indicated that DTPA- Zn content varied from 0.08 to 0.79 mg kg^{-1} soil. Among the different soil samples, soils collected from Huikap showed the highest DTPA- Zn content (0.79 mg kg^{-1}) and least in soils of Top Dasura, Monsangei and Uyal with a value of 0.08 mg kg^{-1}. Based on critical limit of 0.6 mg kg^{-1} soil (Lindsay and Norvell, 1978), most of the soils are deficient in Zn content and required Zn fertilization for better crop production. Sen *et al.*, (1997) and Sarkar *et al.*, (2002) also observed Zn deficiency in soils of Manipur.

Correlation studies in Table 5 showed that DTPA-Zn was positively and significantly correlated with EC (r=0.602**). The result was in conformity with the findings of Athokpam *et al.*, (2013).

The study thus indicated that the acidity of the soil may be due to higher organic matter content in soil and leaching loss of soluble salts from soils under high rainfall conditions causing low EC. Higher value of CEC might be due to close positive association between clay content and CEC and also organic carbon in the surface layer. The samples were well supplied with available Fe, Cu and Mn. The deficiency of Zn is of major concern among all the micronutrients. Organic carbonhad a prominent effect on the availability of micronutrients. Micronutrients are very important for maintaining soil health and also in increasing productivity of crops. Keeping in view the low content of Zn in soil, Zn fertilization is suggested in order to improve the nutritional status of soil and to ensure optimum crop production.

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