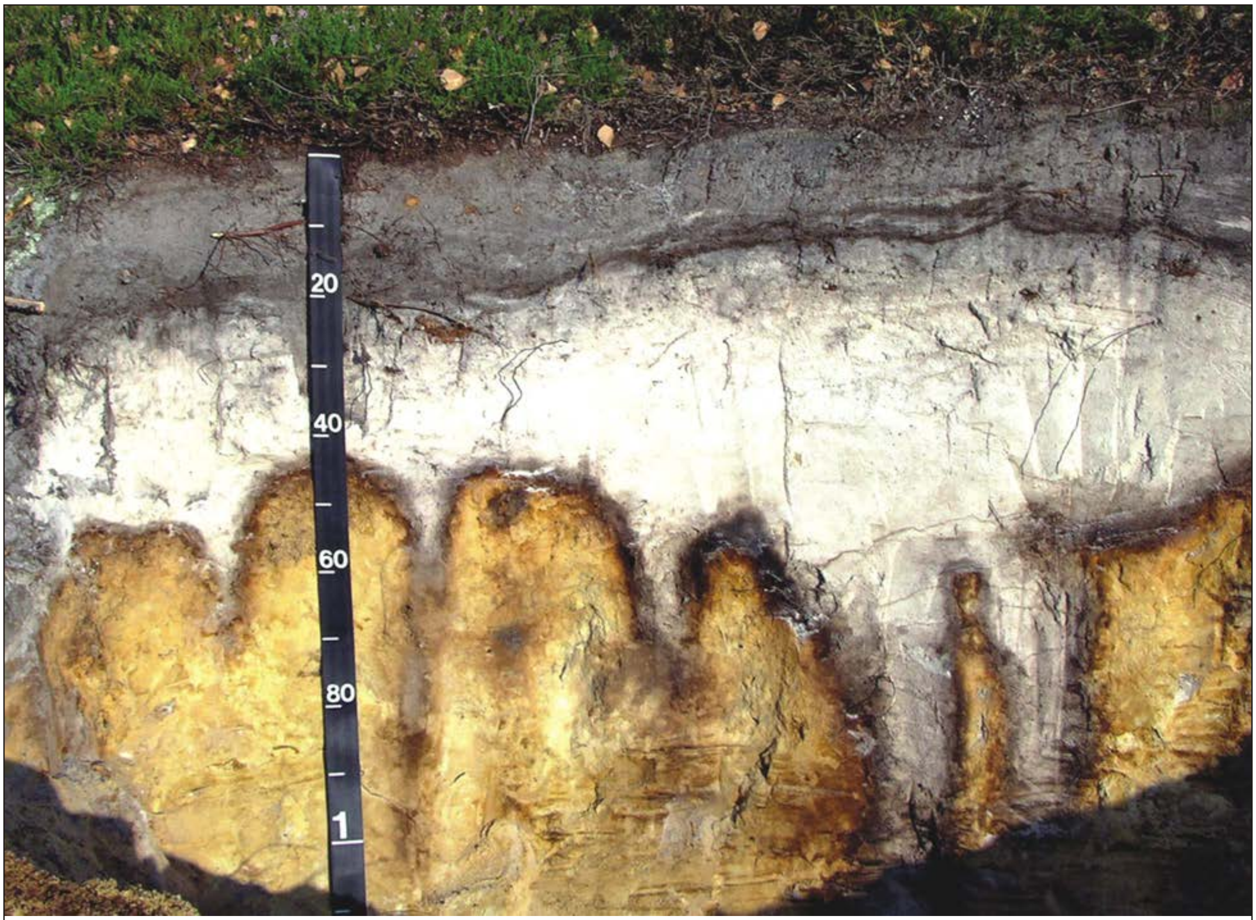

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Potassium and Phosphorus Releasing Capacity of Latosols under Tea Cultivation in South India

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Abstract: Potassium and phosphorus releasing capacity of tea soils were studied by collecting soil samples from sixteen agro climatic zones of south Indian tea growing areas. A drastic reduction in potassium release was noted even at the second extraction uniformly in all zones which confirms the fact that there is no binding site for potassium in tea soils of south India. The total releasable potassium was generally found higher in various zones of Munnar and Nilgiris region. The phosphorus release decreased gradually with successive extractions and attained a constant value during eighth or ninth extractions. The Cobb-Douglas equation worked out for potassium release indicated that the Latosols of south India could be grouped under highly responsive to medium responsive category towards externally applied potassium. The values of 'a' is the measure of degree of steepness of nutrient release from soil, which was lower for phosphorus release when compared to that of potassium. Unlike in the case of potassium no drastic reduction in phosphorus release was noted due to successive extraction.

Key words: Tea soils, potassium release, phosphorus release, Cobb-douglas equation

Introduction

During 1940s the existence of tea was threatened in south India by wide spread defoliation, debilitation and incidence of red rust. The responsible factor was identified as potassium deficiency. Since then the potassium nutrition is considered to be an important aspect for tea cultivation as much as nitrogen fertilization. The tea soils are highly withered and having kaolinite clay minerals, where there is hardly any binding site for potassium, which necessitated frequent application of potassic fertilizers (Venkatesan and Murugesan, 2006).

On the other hand tea flush shoots contain 0.24-0.32% P (Verma and Venkatesan, 2001) and hence a tea field yielding around 3000 kg of made tea per hectare per annum removes approximately 7 to 10 kg of phosphorus every year despite the retention of a considerable quantity of this nutrient through prunings and leaf litter. The removal of phosphorus is far less than the quantity removed in the case of nitrogen or potassium. Application of phosphorus in high doses in alternate years in the tea fields of south India when relatively small quantity of the element is removed unveils the fact that most of applied phosphorus is rendered unavailable to the plant system. The P fixing capacity is well recognized and documented under south Indian conditions (Ranganathan, 1976; Venkatesan and Murugesan, 2004). Although many studies have been carried out on potassium and phosphorus releasing capacity of different soils (McDowell and Sharpley, 2002; Elrashidi *et al*., 2003; Srinivasa Rao *et al*., 2003; Mittal *et al*., 2000), the relevant informations available on the tea growing soils are generally very much limited and particularly not available in the Latosols of south India, where the cultivation practices are unique. It is known that apart from fertilizers non-exchangeable K and P

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become the major source for K and P needs of tea. Therefore, characterization of soil reserve K and P and their release pattern are important as for as nutrition is concerned. The present study aims to examine the K and P release characteristics of tea soils.

Materials and Methods

Four major tea growing regions viz. Anamallais, Munnar, Nilgiris and Vandiperiyar were selected for this study. They were further divided into sixteen different agro climatic zones based on their difference in elevation, annual precipitation, temperature and physical properties of soils. From each zone, 15 to 20 soil samples were taken by using a sampling auger. The individual soil samples collected from a particular zone were mixed together by hand on a polythene sheet. The bulk quantity of the sample collected was reduced to one-third of its volume by quartering method. In the similar manner sampling was done from four different areas. The samples were air dried and passed through 2 mm sieve. The soil samples were analysed for pH, electrical conductivity, organic matter, phosphorus, potassium, bulk density, sand, silt, clay, ammonium-N and nitrate-N using standard methodologies (Subba Rao, 2001). The results are provided in Table 1.

To study the potassium release characteristics of 16 different soils, 5 g of each soil was placed in wide mouth plastic bottles, to which 25 mL of 1 N ammonium acetate was added (Hanway and Heidal, 1952). All the shaking bottles were shaken over the horizontal shaker for five minutes and filtered through whatmann No. 1 filter paper. After collecting the filtrate, 25 mL of 1 N ammonium acetate was added to the same soil to collect data on potassium content due to second extraction. Similar kind of operation was carried out 10 times consecutively using the soil. The potassium in the filtrate was estimated using Sherwood (model 410) flame photometer.

Similarly, 5 g of soil from each zone was weighed and shaken along with 25 mL of Bray II modified extractant solution for five minutes using a horizontal shaker (Bray and Kurtz, 1945). The same soil was extracted repeatedly with fresh extractant each time. After carrying out the operations for 10 times, the phosphorus content available in the filtrate was estimated using ammonium molybdate method at 882 nm (UV Visible spectrophotometer model 918, GBC software controlled). The cumulative release of both potassium and phosphorus were fitted with Cobb-Douglas exponential function ($Y = ax^b$).

Table 1: Physico-chemical properties of tea soils

Zone	pH	EC (dS m^{-1})	OM (g kg^{-1})	K (mg kg^{-1})	P (mg kg^{-1})	Clay (g kg^{-1})	Slit (g kg^{-1})	Sand (g kg^{-1})
Anamallais								
Eastern facing	4.8	0.12	59	286	28	140	80	780
Intermediate	4.4	0.15	68	217	26	190	100	710
Western facing	4.5	0.15	69	265	43	150	260	590
Munnar								
Eastern end	4.5	0.40	65	320	37	180	180	640
Lower elevation	4.7	0.22	45	305	60	110	230	660
Plateau	4.7	0.28	73	226	81	170	90	740
Top station	4.8	0.27	67	282	52	100	150	750
Western end	4.5	0.39	74	344	46	140	110	750
Nilgiris								
Coonoor	4.3	0.24	50	277	36	220	240	540
Kotagiri	4.1	0.28	72	261	33	360	190	450
Kullakamby	4.6	0.21	49	257	41	160	180	660
Kundah	4.1	0.28	77	458	41	200	160	640
Ooty	4.5	0.19	82	311	37	350	150	500
Vandiperiyar								
Elappara	4.6	0.17	51	182	30	200	150	650
Peermade	4.4	0.11	55	249	29	270	140	590
Vandiperiyar	4.4	0.29	65	257	40	190	150	660

Where Y = Cumulative nutrient
a = Degree of steepness of nutrient release
x = No. of extractions
b = Exponential constant

Results and Discussion

Extractable Potassium and Phosphorus

The data generated on potassium release due to extraction of soil with 1 N ammonium acetate K is provided in Table 2. The table indicates that the extractable potassium decreased gradually and obtained a constant value at the seventh extraction in the case of all zones of Anamallais and Munnar

Table 2: I N Ammonium acetate releasable K and cumulative K of tea soils in south India

	Extractable potassium (mg kg^{-1})									
Zones	I	II	III	IV	V	VI	VII	VIII	IX	X
Anamallais										
Eastern facing	290	80	35	20	8	5	2	2	2	1
Intermediate	205	60	30	10	5	5	2	2	2	1
Western facing	215	100	40	10	5	3	2	2	1	1
Munnar										
Eastern end	280	125	60	15	8	8	3	3	2	1
Lower elevation	315	130	30	10	6	5	2	2	2	1
Plateau	320	85	35	15	7	7	6	3	3	3
Top station	225	150	35	15	6	4	3	2	2	1
Western end	415	135	40	15	7	5	4	2	2	2
Nilgiris										
Coonoor	265	230	50	15	9	6	2	2	2	1
Kotagiri	195	140	55	15	7	5	5	3	1	1
Kullakamby	245	90	20	5	4	2	2	1	1	1
Kundah	305	110	70	20	8	3	2	2	1	1
Ooty	380	200	50	40	13	9	4	3	2	2
Vandiperiyar										
Elappara	150	50	15	10	6	3	2	2	2	1
Peermade	255	100	25	10	5	2	2	2	1	1
Vandiperiyar	250	115	30	10	4	2	2	2	2	1

	Cumulative potassium (mg kg^{-1})									
Zones	I	II	III	IV	V	VI	VII	VIII	IX	X
Anamallais										
Eastern facing	290	370	405	425	433	438	440	442	444	445
Intermediate	205	265	295	305	310	315	317	319	321	322
Western facing	215	315	355	365	370	373	375	377	378	379
Munnar										
Eastern end	280	405	465	480	488	496	499	502	504	505
Lower elevation	315	445	475	485	491	496	498	500	502	503
Plateau	320	405	440	455	462	469	475	478	481	484
Top station	225	375	410	425	431	435	438	440	442	443
Western end	415	550	590	605	612	617	621	623	625	627
Nilgiris										
Coonoor	265	495	545	560	569	575	577	579	581	582
Kotagiri	195	335	390	405	412	417	422	425	426	427
Kullakamby	245	335	355	360	364	366	368	369	370	371
Kundah	305	415	485	505	513	516	518	520	521	522
Ooty	380	580	630	670	683	692	696	699	701	703
Vandiperivar										
Elappara	150	200	215	225	231	234	236	238	240	241
Peermade	255	355	380	390	395	397	399	401	402	403
Vandiperiyar	250	365	395	405	409	411	413	415	417	418

Table 3: Bray II modified releasable P and cumulative P of tea soils of south India

	Available phosphorus (mg kg^{-1})									
Zones	I	II	III	IV	V	VI	VII	VIII	IX	X
Anamallais										
Eastern facing	110	75	40	38	37	24	24	21	20	17
Intermediate	57	51	43	39	36	25	17	15	15	14
Western facing	86	72	56	44	34	33	32	29	18	13
Munnar										
Eastern end	39	37	36	31	29	21	19	17	15	12
Lower elevation	76	54	46	41	41	31	26	26	22	16
Plateau	74	66	55	54	37	35	29	27	22	19
Top station	41	29	26	24	24	19	12	11	10	9
Western end	69	48	41	41	33	27	26	25	24	16
Nilgiris										
Coonoor	47	29	26	25	24	14	9	9	8	8
Kotagiri	61	45	37	28	20	19	15	15	14	10
Kullakamby	45	30	24	22	19	16	11	9	7	7
Kundah	48	29	25	19	14	13	10	9	8	7
Ooty	41	35	23	22	19	16	8	7	5	4
Vandiperiyar										
Elappara	68	60	50	38	31	31	27	20	18	17
Peermade	75	70	51	44	38	28	23	19	17	14
Vandiperiyar	50	47	46	45	19	18	18	16	14	12

	Cumulative phosphorus (mg kg^{-1})									
Zones	I	II	III	IV	V	VI	VII	VIII	IX	X
Anamallais										
Eastern facing	110	185	225	263	300	324	348	369	389	406
Intermediate	57	108	151	190	226	251	268	283	298	312
Western facing	86	158	214	258	292	325	357	386	404	417
Munnar										
Eastern end	39	76	112	143	172	193	212	229	244	256
Lower elevation	76	130	176	217	258	289	315	341	363	379
Plateau	74	140	195	249	286	321	350	377	399	418
Top station	41	70	96	120	144	163	175	186	196	205
Western end	69	117	158	199	232	259	285	310	334	350
Nilgiris										
Coonoor	47	76	102	127	151	165	174	183	191	199
Kotagiri	61	106	143	171	191	210	225	240	254	264
Kullakamby	45	75	99	121	140	156	167	176	183	190
Kundah	48	77	102	121	135	148	158	167	175	182
Ooty	41	76	99	121	140	156	164	171	176	180
Vandiperiyar										
Elappara	68	128	178	216	247	278	305	325	343	360
Peermade	75	145	196	240	278	306	329	348	365	379
Vandiperiyar	50	97	143	188	207	225	243	259	273	285

and Coonoor zone of Nilgiris region. In other zones of Nilgiris and Vandiperiyar region, the constant value was attained at eighth or ninth extraction. Similar observations were reported by Sharma and Swami (2000) and Pal and Mukhopadhyoy (1992) in various other soils. A drastic reduction in extractable potassium was noted in the second extraction itself, uniformly in all the zones, which confirms the fact that there are no binding sites for potassium in the tea soils of south India (Ranganathan, 1976). Western end zone of Munnar released maximum amount of potassium (415 mg kg^{-1}) during the first extraction while, it was Elappara zone of Vandiperiyar, which released lowest potassium (150 mg kg^{-1}). Even though the soils of Munnar showed higher initial concentration after sixth extraction, the concentration of potassium was almost similar to other regions.

The phosphorus release decreased gradually with successive extractions and finally attained a constant value during eighth or ninth extractions. Unlike in the case of potassium there was no drastic reduction in phosphorus due to successive extraction. Eastern facing zone of Anamallais exhibited higher phosphorus (110 mg kg^{-1}), while Eastern end zone of Munnar recorded lowest P (39 mg kg^{-1}) in the first extraction (Table 3).

Cumulative K and P

The cumulative potassium is calculated by adding K released in the previous extractions with that of the particular extraction. The cumulative K increased linearly initially and then became a curve linear. The total releasable potassium of individual zones was calculated by adding potassium content estimated in all the ten extractions. It is an important parameter, which could be considered as the measure of potassium availability index of tea soils. It varied between 322 and 445 mg kg^{-1} in Anamallais, 443 and 627 mg kg^{-1} in Munnar, 371 and 703 mg kg^{-1} in Nilgiris and 241 and 418 mg kg^{-1} in Vandiperiyar. In general the total releasable K was higher in the case of various zones of Munnar and Nilgiris regions. It is interesting to note that among various regions, Munnar and Nilgiris were located at higher elevations possessing higher organic matter (Table 1), where the releasable potassium was also higher.

The total extractable phosphorus due to ten consecutive extractions varied between 312 and 417 mg kg^{-1} in Anamallais, 205 and 418 mg kg^{-1} in Munnar 180 and 264 mg kg^{-1} in Nilgiris and 285 and 379 mg kg^{-1} in Vandiperiyar. Among all the regions even though the number of zones are higher in Nilgiris, the variation in phosphorus content was very low.

The cumulative K was plotted against the corresponding extractions with 1 N ammonium acetate using Cobb-Douglas exponential function (Fig. 1). The exponential models are given in Table 4. In the Cobb-Douglas equation ‘a’ is recognised as the measure of degree of steepness of nutrient release from soil. According to Aruna *et al*. (2001) lower the ‘a’ value, lower will be the release of nutrients from the soil and hence the response to soil applied fertilizer would be maximum and *vice versa*. Among the three zones studied in Anamallais region, based on the ‘a’ values, it could be classified that the soils of Intermediate zone are most responsive followed by the Western facing and Eastern facing zones towards the externally applied potassium. In Munnar region, the Western end soil fell in least responsive category while the other zones are equally responsive. A vast deviation in ‘a’ value was noted in the soils of Nilgiris region, which ranged between 276 and 494. Based on ‘a’ value it could be

Table 4: Response of tea soils to potassium and phosphorus application

	Potassium					Phosphorus				
Zones	Cobb Douglas equation	HR	R	PR	NR	Cobb Douglas equation	HR	R	PR	NR
Anamallais										
Eastern facing	$\ddot{U} = 339.28X^{0.0345}(0.644)$		■			$\ddot{U} = 138.63X^{0.0345}(0.953)$			■	
Intermediate	$\ddot{U} = 242.23X^{0.0350}(0.639)$	■				$\ddot{U} = 78.740X^{0.1629}(0.945)$		■		
Western facing	$\ddot{U} = 276.24X^{0.0407}(0.539)$		■			$\ddot{U} = 115.82X^{0.1500}(0.957)$			■	
Munnar										
Eastern end	$\ddot{U} = 357.02X^{0.0446}(0.592)$		■			$\ddot{U} = 54.200X^{0.1811}(0.967)$		■		
Lower elevation	$\ddot{U} = 390.40X^{0.0324}(0.512)$		■			$\ddot{U} = 96.050X^{0.1585}(0.971)$		■		
Plateau	$\ddot{U} = 369.80X^{0.0331}(0.672)$		■			$\ddot{U} = 101.16X^{0.1647}(0.962)$			■	
Top station	$\ddot{U} = 309.29X^{0.0465}(0.514)$		■			$\ddot{U} = 53.030X^{0.1579}(0.961)$	■			
Western end	$\ddot{U} = 495.29X^{0.0302}(0.559)$			■		$\ddot{U} = 86.440X^{0.1602}(0.979)$		■		
Nilgiris										
Coonoor	$\ddot{U} = 390.48X^{0.0519}(0.474)$		■			$\ddot{U} = 59.980X^{0.1416}(0.937)$	■			
Kotagiri	$\ddot{U} = 276.34X^{0.0565}(0.563)$	■				$\ddot{U} = 80.170X^{0.1392}(0.946)$			■	
Kullakamby	$\ddot{U} = 297.48X^{0.0286}(0.497)$	■				$\ddot{U} = 57.390X^{0.1408}(0.944)$	■			
Kundah	$\ddot{U} = 378.93X^{0.0416}(0.580)$		■			$\ddot{U} = 60.810X^{0.1275}(0.945)$	■			
Ooty	$\ddot{U} = 494.13X^{0.0453}(0.580)$			■		$\ddot{U} = 56.370X^{0.1387}(0.909)$	■			
Vandiperiyar										
Elappara	$\ddot{U} = 178.24X^{0.0374}(0.665)$	■				$\ddot{U} = 92.480X^{0.1580}(0.959)$		■		
Peermade	$\ddot{U} = 313.67X^{0.0322}(0.523)$		■			$\ddot{U} = 104.97X^{0.1513}(0.939)$	■			
Vandiperiyar	$\ddot{U} = 317.43X^{0.0355}(0.506)$		■			$\ddot{U} = 72.690X^{0.1619}(0.931)$		■		

HR-Highly Responsive; R-Responsive; PR-Poor Responsive; NR-Non responsive

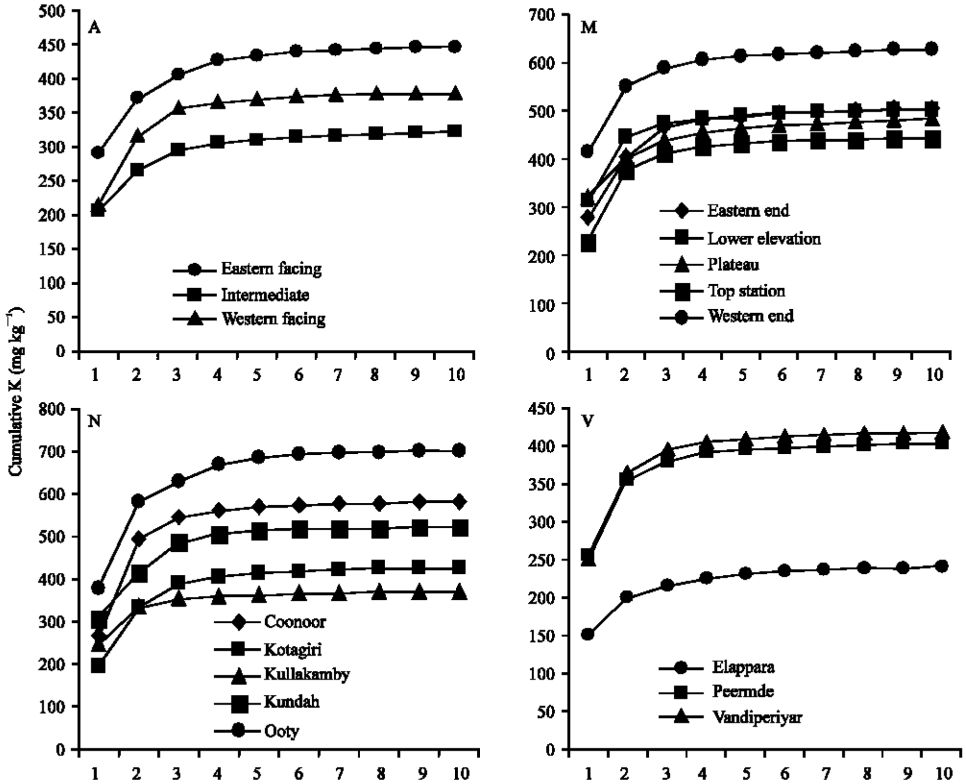

Fig. 1: Number of extractions with 1 N NH_4OAc. A-Anamallais, M-Munnar, N-Nilgiris, V-Vandiperiyar

concluded that the soils of Kotagiri and Kullakamby are very much responsive to potassium fertilizer application when compared to Kundah and Coonoor zones. The soils of Ooty zone are capable of releasing nutrients on its own for a long period and hence were the least responsive. On reviewing the data on soil physical parameters it is found that both Ooty and Western end zones have recorded maximum organic matter content. Since there are no binding sites for potassium in kaolinite soils, it is concluded that the high potassium release capacity could be attributed to the richer organic matter content. Positive and significant correlations have already been reported under various cultivation practices Ahmed and Walia (1999), Singh *et al.* (1999) and Boruah and Nath (1992). The Elappara zone of 'a' Vandiperiyar has recorded least value of 'a' and hence very much demanding to fertilizer application when compared to other two zones.

The cumulative phosphorus increased linearly first then took a slow pace. The cumulative phosphorus was plotted against the corresponding extractions and provided in Fig. 2, which indicated a linear increase at first and then become curvilinear. The Cobb-Douglas equations obtained from phosphorus releasing capacity of various tea soils are provided in Table 4. The 'a' values are very much lower when compared to those due to potassium release, which indicates that the response to phosphorus application will generally be higher than that of potassium application. This could be because the phosphorus availability is strongly influenced by acidity of the soils (Ryan *et al.*, 2001; McDowell and Sharpley, 2002). Since tea soils are acidic, the release of phosphorus from the labile pool is harder and harder.

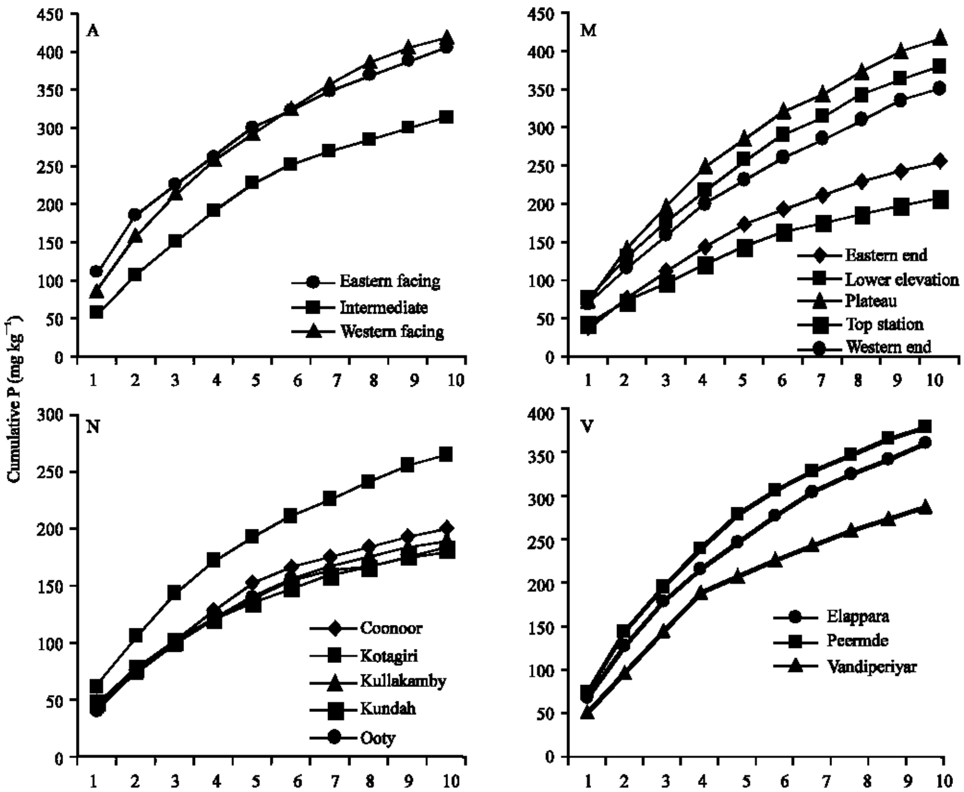

Fig. 2: Number of extractions with bray II modified solution. A-Anamallais, M-Munnar, N-Nilgiris, V-Vandiperiyar

Among various zones of Anamallais, Eastern and Western facing zones were least responsive when compared to the soils of Intermediate zone. In Munnar the a value ranged between 53 and 101, which indicate a wider variation in the release of phosphorus in tea soils. The release was maximum in Plateau zone and minimum in Top station zone, as evidenced by higher and lower 'a' value, respectively. Except in Kotagiri in the Nilgiris region, all other zones are highly responsive towards phosphorus application. Remarkable difference in 'a' was noted in Vandiperiyar region. Peermade zone had maximum 'a' value followed by Elappara zone.

Conclusions

Since majority of tea growing areas fell either in highly responsive or in responsive categories towards externally applied phosphorus and potassium, the frequency of fertilizer application shall be increased to enhance the agronomic efficiency. Although current study has dealt with only two of the several nutrients, the study can be taken as a model for the other nutrients.

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