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THE CHANGES OF CHEMICAL PROPERTIES OF FOREST SOILS IN DRY AND WET SEASONS

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ABSTRACT

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Soil selected for the present investigation was collected from a mountain of the Forestry Experiment Station of the vicinity of Seoul. The forest communities studied were three forest and a unplanted soils. The soil samples were obtained from each forest type during dry and wet seasons. And these samples were collected from four horizons of all communities respectively.

It was showed that exchangeable hydrogen was increased by rainfall, and total exchangeable base decreased in the same way. The content of nitrogen is washed away by rainfall, especially ammonium nitrogen was highly significant between dry and wet season. On the contrary, organic matter and available phosphorus were of no significant difference between dry and wet seasons. The values of pH appeared a different response in dry and wet seasons according to the plant communities. The needle-leaved forest soils showed more acidity than the broad-leaved forest soils, and the least acidity in open places. All nutrients in soil studied gradually decreased down the profiles. According to statistical analyses of the soil components among all soil horizons, total exchangeable bases in wet season indicated only significant at 1%. Exchangeable hydrogen and organic matter of the soil in dry season was particularly very low with increased depth in the profile. The fertility level of most forested soils selected for the present investigation is low according to chemical tests for available nutrient elements.

INTRODUCTION

Much information about the change of physical and chemical properties under the natural soils in relation to the vegetal pattern in the areas has been obtained by many workers.

Whiteside et al.(23) dealt with chemical and physical soil changes associated with tillage and cropping in humid areas of the United States. They found that the tilled area has less organic carbon, base exchange capacity, and exchangeable bases in the upper 12 inches of the profile, decreasing with increased depth. The smaller exchange capacity of the tilled soil was mainly due to a lower organic matter content. No difference in the mechanical composition of virgin and cultivated profiles was observed, although considerable variation within the area was noted.

Work by Coile(5) has demonstrated that the site index of loblolly and shortleaf pines in the Piedmont region of the Carolinas can be satisfactorily estimated from field examinations of the thickness of the surface soil and the physical properties of the subsoil.

Ralston(20) has studied the relationships between soils and the growth of pine species in the Atlantic Coastal Plain. He found that all categories of soils tested indicated that the growth capacity was directly proportional to the moisture equivalent percentage of the subsoil.

Paulsen(18) studied that a comparison of surface soil properties under perennial grassland areas and interspersed areas recently invaded by mesquite were analyzed for physiccal properties.

Karim and Khan(8, 9) have studied to data show the probable relation-ship between pH and different forms of phosphorus, and among vertical distribution of nitrogen, phosphorus, and potassium in some soils of East Pakistan.

Snaydon(21) has studied the variations in edaphic factors associated with the pattern of micro-distribution of white clover.

Kim(10) has studied the variation in the properties of the base exchange capacity and of the pH which might very due to the added salts in the soils. He(11) has also reported forms of phosphorus and forest types in the Duke forest.

In the previous studies of the author(2), the chemical properties in some forest soils developed on granite in the mountains of the vicinity of Seoul, Korea was presented. The soil under the broad-leaved forest has a higher nutrient indicated by available nitrogen, phosphorus, and nitrate nitrogen contents compared with that under the needle-leaved forests. On the contrary the content of organic matter and base exchange capacity in the needle-leaved forest soil is higher than it is in the broad leaved forest soils. Analyses of surface layers of soil have been cited by various investigators, however, few studies of the vertical distribution of chemical properties in soils with relation to plant communities during dry and wet season have been reported. Also, with respect to most of these studies have not been shown as yet in Korea. The investigation reported here was designed to discover with some of the differences between chemical properties during dry and wet seasons for soils of similar geological origin but occurring under different type of forest.

METHODS

Soils selected for the present investigation were collected from a mountain Forestry Experiment Station in the vicinity of Seoul. The bed rock located there chiefly consist of granitic rock. The forest communities studied were as follows: (1) Pinetum densiflorae, (2) Alnusetum japonicae, (3) Carpinetum laxiflorae, and (4) Naked soils (soils in open areas). The soil samples were collected from four horizons (A_1, A_2, B_2, and C) of the soil under the above mentioned forest types and naked soils. These samples were obtained from 4 plots in the crown perimeter of the trees in each forest type during the dry (at the end of March) and the wet (at the end of July) seasons in the year 1962. The annual precipitation for the site averaged approximately 1250 mm, of which about 40% occurred the dry season sparsely, but the remainder fell heavily during the wet season. Soil samples were dried at room temperature and passed through a 2-mm sieve to remove stones and most of the roots.

Chemical and physical analyses of soil samples were conducted according to the description in the previous paper of these series(2). The procedure to determined the amount of ammonium nitrogen in soils was done as follows: (1) A soil sample and 10% potassium chloride solution were placed in a Erlenmeyer flask and shaken for 30 minutes on a mechanical shaker. (2) The solution was allowed to stand for 10 minutes and the supernatant liquid was filtered. (3) A aliquet of the supernatant liquid was transferred to a Kjeldahl flask together with magnesium oxide and a small piece of paraffin. (4) The flask was placed on the distillation apparatus and distilled. (5) The distilate was titrated with N/14 sulphuric acid in order determined the amount of total nitrogen.

RESULTS

The Tables I, II, and III show the results of chemical analysis of the soil samples obtained from the three forest types and from an open plot in dry and wet seasons. These data show that the nutrient contents of the soils studied are closely related with each other, Chemical constituents decreased rapidly *from surface to the C horizon, but there were some differences at all depths of the soil types in dry and* wet seasons. The forest soils in the dry season contained in general more nutrients than those in the wet season. It was proved that the development of all soil profiles was different in accordance with the forest soil types.

The difference of exchange properties among the various plant communities is in general not so apparent. But it is appeared that these contents decreased further more in unplanted plots than in planted areas both in dry and wet seasons. The amount of total available nitrogen, phosphorus, organic matter and basic ions in the soils was found to be much greater in dry season than that in wet season. The total quantity of exchangeable bases decreased much more in the Pinetum densiflorae in wet season and did less in the Alnusetum japonicae or the Carpintum laxiflorae soil. But a marked increase in total quantity of exchangeable hydrogen in wet season occurred in all forest soils. A decrease in total quantity of exchangeable hydrogen in the dry season was, in the average, 66.7 percent of that in the wet season. According to the results of analysis of variance among all soil horizons in dry and wet seasons, exchangeable hydrogen and organic matter were only significant at 5% in dry season, whereas, the exchangeable base was significant at 1% (Table VII). In soil types of Pinetum densiflorae and Alnusetum japonicae the per cent base saturation is a little higher in dry season than in wet season, but in forest soil of Carpinetum laxiflorae the stated property is different. Furthermore, it shows, in general, the same tendency as in the total exchangeable base. The surface soil has more the content of nitrogen than in the C layers just as the exchange properties.

The content of available nitrogen decreased in a high degree in wet season in almost all forest soils except the open places.

The content of nitrate nitrogen was higher in broad-leaved trees than in needle-leaved, whereas the open places showed the least value. Both in dry and in wet seasons, the nutrient contents of soils under forest types showed that nitrate nitrogen increased approximately twice that of the unplanted areas. Except for the Pinetum densiflorae, the content of nitrate nitrogen in dry season showed the higher value than that in wet season.

Even ammonium nitrogen also decreased much in wet season than in dry season. The difference of these contents among the plant communities and the open places shows the similar tendency regardless of dry and wet seasons. The values of the "t"-test between dry and wet seasons of each nutrient in all forest soils appeared to be higher significant only in ammonium nitrogen (Table V). This result shows that its content decreases more in wet season than in dry season.

Also the content of organic matter decreased more in wet season than in dry season. But these contents showed little difference in Alnusetum japonicae and unplanted plots in wet and dry seasons. And these contents have no difference among the plant communities. The organic matter decreased rapidly from surface to C horizon in dry seasons.

The amount of available phosphorus in the various horizons of soil under different forest types investigated in dry and wet seasons varied abundantly from 0.30 ppm to 1,67 ppm. In spite of this large variation, there was appreciable similarity among the horizons of soils under the various tree types represented. Although the content of available phosphorus of surface soil under Carpinetum laxiflorae was measured greater than under other plant communities, it was not so much high as the analytic result obtained from surface soil under perennial grassland by Paulsen(18). And Wilde(24) give an available P_2O_5 content of 100 ppm as being sufficient for most forest trees, those such as light-demanding pines being said to require only 10 to 15 ppm. The soils in the areas sampled in this study contain the generally low level of available phosphorus. However, a similar value of phosphorus content was reported by Johannessen(6) who found that phosphate values in the soil are higher in forested areas than in similarly situated grassland in the Sierra Nevada in Fresno County, California. He stated that because of deeper root penetration and longer active growth period, trees produce more organic material and as a result bring up more phosphate than grassed.

Table I. The exchange properties of soils under different forest types.

Association	Horizons	Depth cm	Base exchange capacity m.e.		Total exchangeable base m.e.		Exchangeable hydrogen m.e.		Base saturation %	
			Dry	Wet	Dry	Wet	Dry	Wet	Dry	Wet
Pinetum	A_1	0-8	43.00	54.56	28.04	29.48	14.96	25.08	65.2	54.0
densiflorae	A_2	8-37	36.40	38.28	26.72	17.16	9.68	21.12	73.4	44.8
	B_2	37-60	31.12	36.08	23.64	19.36	7.48	16.72	76.0	53.9
	C	60-	32.00	30.80	24.52	15.40	7.48	15.40	76.6	50.7
	Av.		35.63	39.93	25.73	20.35	9.90	19.58	72.8	50.9
Alnusetum	A_1	0-12	38.72	50.60	23.76	24.64	14.96	25.96	61.4	48.7
japonicae	A_2	12-32	30.90	37.84	20.78	19.36	10.12	18.48	67.2	51.2
	B_2	32-52	27.28	26.40	18.04	16.28	9.24	10.12	66.1	61.7
	C	52-	28.32	40.04	19.52	18.04	8.80	22.00	68.9	45.1
	Av.		31.31	38.72	20.53	19.58	10.78	19.14	65.9	51.7
Carpinetum	A_1	0-7	43.88	47.52	28.92	28.16	14.96	19.36	65.9	59.7
laxiflorae	A_2	7-24	42.32	50.16	29.12	28.60	13.20	21.56	68.8	57.0
	B_2	24-56	39.92	33.44	26.28	26.16	13.64	7.28	65.8	78.2
	C	56-	35.08	32.56	24.52	25.52	10.56	7.04	69.9	78.4
	Av.		40.30	40.92	27.21	27.11	13.09	13.81	67.6	66.1
Naked soils	A_1	0-11	29.90	27.36	17.60	11.40	12.30	15.96	58.9	41.7
	A_2	11-38	27.06	25.92	15.84	17.56	11.22	8.36	58.5	67.7
	B_2	38-50	15.56	16.88	11.44	11.40	4.12	5.28	73.5	68.4
	C	50-	11.88	18.44	8.36	9.20	3.52	9.24	70.4	49.9
	Av.		21.10	22.10	13.31	12.39	7.79	9.71	65.5	56.9

Table II. The mineral nutrient contents of soils under different forest types.

Association	Horizone	Depth cm	Available nitrogen ppm		Nitrate nitrogen ppm		Ammonium nitrogen ppm	
			Dry	Wet	Dry	Wet	Dry	Wet
Pinetum	A_1	0-8	5.70	5.30	1.86	1.64	2.50	2.20
densiflorae	A_2	8-37	5.00	4.24	1.73	1.87	2.70	1.90
	B_2	37-60	4.52	4.02	1.76	1.67	2.66	2.00
	C	60-	4.92	4.36	1.78	1.60	2.42	2.10
	Av.		5.04	4.48	1.78	1.70	2.57	2.05
Alnusetum	A_1	0-12	6.00	5.32	2.80	2.35	2.70	2.00
japonicae	A_2	12-32	4.76	4.20	2.26	2.20	2.40	1.90
	B_2	32-52	4.96	4.80	2.28	2.18	2.60	2.30
	C	52-	4.78	4.98	2.17	2.18	2.20	2.26
	Av.		5.10	4.83	2.38	2.23	2.48	2.12
Carpinetum	A_1	0-7	6.26	4.66	3.19	2.10	2.55	2.10
laxiflorae	A_2	7-24	5.32	4.40	2.78	1.90	2.40	1.90
	B_2	24-56	5.08	5.50	2.79	1.86	2.25	2.10
	C	56-	5.20	4.30	2.69	1.80	2.45	2.00
	Av.		5.47	4.72	2.86	1.92	2.41	2.03
Naked soils	A_1	0-11	4.60	4.16	1.04	0.56	2.60	2.03
	A_2	11-38	4.48	4.66	1.08	0.55	2.45	2.00
	B_2	38-50	4.10	4.63	0.88	0.56	2.42	2.20
	C	50-	4.20	4.02	0.94	0.54	2.39	1.90
	Av.		4.35	4.37	0.99	0.55	2.47	2.03

Table III. The organic matter, available phosphorus and pH of soil under different forest types.

Association	Horizons	Depth cm	Organic matter %		Available phosphorus ppm		pH	
			Dry	Wet	Dry	Wet	Dry	Wet
Pinetum densiflorae	A_1	0–8	1.20	0.71	0.89	0.78	5.15	5.06
	A_2	8–37	0.62	0.62	0.75	0.70	5.10	5.30
	B_2	37–60	0.24	0.26	0.85	0.78	4.80	5.20
	C	60–	0.26	0.33	0.65	0.66	5.05	5.16
	Av.		0.58	0.48	0.79	0.73	5.03	5.18
Alnusetum japonicae	A_1	0–12	1.03	0.64	1.20	0.90	5.44	5.10
	A_2	12–32	0.72	0.62	1.10	1.30	5.48	4.90
	B_2	32–52	0.32	0.63	0.93	0.80	5.49	4.90
	C	52–	0.32	0.62	0.62	0.45	4.98	5.20
	Av.		0.60	0.63	0.96	0.86	5.35	5.03
Carpinetum laxiflorae	A_1	0–7	0.92	0.67	2.43	1.30	5.00	5.62
	A_2	7–24	0.93	0.70	1.65	1.70	5.10	5.55
	B_2	24–56	0.83	0.60	1.66	1.47	5.12	5.80
	C	56–	0.33	0.63	0.94	0.30	5.08	5.80
	Av.		0.75	0.65	1.67	1.19	5.08	5.69
Naked soils	A_1	0–11	0.33	0.52	0.62	0.62	5.59	5.15
	A_2	11–38	0.37	0.50	0.93	0.48	5.78	5.15
	B_2	38–50	0.36	0.50	0.72	0.92	5.90	4.98
	C	50–	0.29	0.23	0.60	0.23	5.95	5.00
	Av.		0.34	0.44	0.72	0.56	5.81	5.07

The value of pH are of statistical significance between the Carpinetum laxiflorae and open places, but it showed no such differences among plant communities as well as in dry and wet seasons. In the Carpinetum laxiflorae and Pinetum densiflorae, the pH values in wet season show higher than that in dry season. But the opposite result was obtained in the open places and Alnusetum japonicae. The needle-leaved forest soils showed more acidity than the broad-leaved forest soil. This result is similar to that in the previous paper(2), but the fact that pH-value in the naked soils increases than in the forest soils is not in agreement with the results of the previous paper. The values of pH of the various soils showed remarkable uniformity ranging from 4.98 to 5.95.

According to the results analysis of variance among all forest soils the base exchange capacity, total exchangeable base, and available and nitrate nitrogen show significant difference at 1% and 5% in dry seasons, and the total exchangeable base, exchangeable hydrogen, per cent base saturation nitrate nitrogen, and pH values in wet season.

DISCUSSION

The foregoing data show that the variations in the dry and wet season for the forest stands investigated tend to reduce the amounts of all the soil components in wet season.

Chemical properties in all the profiles studied decreased with the depth to a minimum in the C horizon. In the present case, the general occurrence of a zone of minimum chemical components below the surface layers is the result of long-term effects of leaching in parent materials of low chemical components, while high components in the surface soil reflect accumulated effects of deposition in plant materials.

The frequent rise and fall of the water table in dry and wet seasons and the physical properties of the bottomland soil are the factors which lead to the deficiency of the mineral nutrients in a lower horizon in the Korean forest soils

The forest soil in dry season has a higher nutrient capital as indicated by the content of exchangeable base compared with component under the forest soil in wet season (Table 1). The composition of these cation swarms exerts a powerful influence upon both the chemical and physical attributes of a soil. The values of chemical analysis of soil samples show higher base exchange capacity and exchangeable hydrogen of the soil in wet season in comparison with that in dry season. In wet season, soil colloids eventually become saturated with H and nutrient bases are lost by leaching. In case of heavy rainfall, H ions are formed in abundance on the surface soil. They are of no direct use to plants, and when they dominate the colloidal complex there is nothing to prevent the loss by leaching of the important basic ions, especially Ca, Mg, K, and fertility is consequently low. The degree of saturation with basic ions can always be reduced by cation exchange, wherever there are enough H ions to bring about this displacement.

Martin and Richard(14) stated that increasing exchangeable H increased the dispersing action of Na, K, and NH_4. Once displaced the bases are carried away in drainage waters. Colloids are showed to be

Table IV. Statistical analysis of the chemical properties given in Tables (I-III)
(Values of the "t"-test between dry and wet seasons of each forest soil)

Components	*Pinetum densiflorae*	*Alnusetum japonicae*	*Carpinetum laxiflorae*	Naked soil
Base exchange capacity	1.66	2.46	0.23	0.39
Total exchangeable bases	1.76	1.67	0.00	0.49
Exchangeable hydrogen	**10.80	*3.27	0.14	0.97
Base saturation	*5.67	*3.33	0.09	1.29
Available nitrogen	**6.47	1.58	*3.24	0.01
Nitrate nitrogen	1.04	1.74	**19.00	**19.00
Ammonium nitrogen	*4.08	1.84	0.46	**5.29
Organic matter	0.79	0.18	0.58	1.82
Available phosphorus	2.20	0.36	2.00	1.01
pH	0.16	1.72	**10.80	*5.25

**: Significant at the 1% level. *: Significant at the 5% level.

Table V. Statistical analysis of the chemical properties given in Tables (I-III).
(Values of the "t"-test between dry and wet seasons of all forest soils).

Base exchange capacity	2.12	Nitrate nitrogen	0.18
Total exchangeable bases	1.31	Ammonium nitrogen	**7.89
Exchangeable hydrogen	2.12	Organic matter	0.30
Base saturation	2.36	Available phosphorus	1.54
Available nitrogen	2.50	pH	0.59

Table VI. Statistical analysis of the chemical properties given in Tables (I-III)
(Values of the "F"-test among all forest soils of dry and wet seasons.)

Components	Dry		Wet	
	F-values	L.S.D	F-values	L.S.D.
Base exchange capacity	**7.06	9.35	0.56	
Total exchangeable bases	**17.04	2.18	**13.50	5.12
Exchangeable hydrogen	2.22		*4.34	8.28
Base saturation	0.19		*4.06	11.20
Available nitrogen	*3.91	0.72	0.75	
Nitrate nitrogen	**32.10	0.41	**176.70	0.16
Ammonium nitrogen	0.90		0.50	
Organic matter	1.00		0.71	
Available phosphorus	0.52		2.00	
pH	2.50		**29.60	0.17

Table VII. Statistical analysis of the chemical properties given in Table (I-III). (Values of the "F"-test among all soil horizons of dry and wet seasons).

Components	Dry		Wet	
	F-values	L.S.D.	F-values	L.S.D.
Base exchang capacity	1.70		0.40	
Total exchangeable bases	0.65		**7.40	6.30
Exchangeable hydrogen	*4.80	3.92	3.00	
Base saturation	0.27		1.60	
Available nitrogen	3.34		1.00	
Nitrate nitrogen	0.14		0.04	
Ammonium nitrogen	1.58		2.00	
Organic matter	*3.65	0.39	2.00	
Available phosphrous	0.97		2.40	
pH	0.10		0.03	

unsaturated when the adsorbed bases have thus been reduced to a very low level. Because chemical analyses of soil do not show the relative proportion of available and unavailable from of most critical elements, they are of limited value. A much more significant measure of soil fertility, as far as basic nutrients are concerned, is a determination of the quantity of exchangeable bases held by the colloids. Larger amounts of all nitrogen, organic matter, available phosphorus, and basic ions were found in dry season soils than in wet season soil.

In order to evaluate quantitatively the interrelationships among the chemical components, these data obtained in this experiments were treated statistically by analysis of variance and "t"-test to obtain the summary values (Table IV-VII).

In the Pinetum densiflorae and Alnusetum japonicae, the value of the "t"-test of each nutrient in dry and wet seasons of each forest soil was statistically significant in exchangeable hydrogen and per cent base saturation. In Table I and III it can be seen that the base exchange capacity is closely related to the organic content as indicated by loss on ignition. According to Chandler(3) the exchange capacity is closely related to the organic content.

Whiteside and Smith(23) have also reported similar result to indicate a relation between organic content and base exchange capacity. Organic matter is responsible for a large portion of the base exchange capacity in the upper part of this soil. Since the organic content is highest nutrient-storage capacity. It was found that organic matter could maintain by absorption, considerable quantities of nutrients in ionic form. The general range of exchange properties, available phosphorus, and organic matter are broadly similar to all of the same horizons of soils in dry and wet seasons respectively. The greatest concentration of exchange properties and available phosphorus in the surface soil may result from the appreciable amounts of surface organic material. Lutz and Chandler(12) stated that phosphorus is usually more abundant in the surface soil, particularly if considerable organic matter is present. According to McGeorge(15), base exchange capacity was changed by an invariable relationship with the pH values in semiarid soils. As the previous publication(2) indicated, however, the result in this study shows no similar relationship in soils developed out of granite in dry and wet seasons respectively.

In each forest type the value of "t"-test of all the soil components in dry and wet seasons was significant in the contents of available and ammonium nitrogen in Pinetum densiflorae, of available and nitrate nitrogen in Carpinetum laxiflorae, and of nitrate and ammonium nitrogen in unplanted areas. These nitrogen decrease in wet season shows that the degree of the washing by rainfall is greater than other nutrients. Nitrate nitrogen is dissolved well into soil water and ammonium nitrogen adsorbed, to a certain degree, to soil colloidal substance, but in acidic soil ammonia evaporates markedly.

It is characteristic that the content of available nitrogen is generally low in the forest soils(13).

Nitrogen is possibly the most important of the elements considered in this study but it does not appear to constitute a limiting factor in tree growth in the areas sampled. The fertility level of areas sampled is low according to chemical tests for available nutrient elements. However, a study of soil-plant relationships should be based on the reactions of plants, not on chemical and physical analyses of the soils.

Comparisons between forested and open areas or between stands in dry and wet seasons may support the view that soil fertility is being modified by the tree species. It has been recognized that forest tree species can exert an important influence on the fertility of the soils. The degree of influence exerted depends largely on the amount of nutrients taken up from the soil and later returned in organic matter to the soil. In general, hardwood species absorb more nutrients from the soil and return a higher percentage of these nutrients in leaf than do conifers.

According to Ovington(17), the assessment of soil fertility in relation to the effects have been recorded for seperate chemical elements and the difference in productivity is due primarily to the inhersent growth ability of the species rather than to initial variations in soil properties in each locality.

Although there are some differences in the amounts of chemical elements actually present, the variability of soil properties within the same horizons of the plots studied is so slight that these differences can hardly be attributed solely to the differential occurrence of tree species.

According to Moore(16) soil phosphate may be a factor of some importance affecting the distribution of Eucalypus spp.; however, it is clear from more recent work that other nutrients may be equally important.

The contents of organic matter and available phosphorus were not statistically significant, because it seem that it is caused by less washing degree by rainfall or other factors.

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