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Relationships Between Seedling Height Growth and Some Soil Properties in Douglas Fir (*Pseudotsuga menziesii var. viridis*) Plantations

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Abstract

In this study, four different Douglas fir stands established in the years of 1990-1991 in different planning units of Cide-Kastamonu Forest region were studied and relationships between seedling growth and some soil characteristics of these areas were investigated. A total 21 sample plots was taken to represent the study areas. Soil samples were taken regarding to the depth levels in soil profile excavated at sample plots, and seedling height (SH) and its growth in latest years were measured. Physical and chemical soil analyses were performed at laboratory. Regression and correlation analysis were performed to reveal the relationship between seedling heights and soil attributes. In the study area, significant correlations between seedling height (SH) and soil pH, available P, available water capacity, soil, sand and clay content, and slope level at $p<0.05$ level were determined.

Key Words: Douglas fir, Seedling Height, Soil properties, Cide-Kastamonu

INTRODUCTION

The demand of forests and forest raw materials are increasingly rising with population growth in Turkey as in the most of the countries in the world. A possible alternative solution of the problem is afforestation studies with fast growing tree species in suitable areas. For this purpose, several trials have been established with exotic tree species. On the other hand, some exotic tree species are also used in the afforestation studies. Of these, Douglas fir (*Pseudotsuga menziesii var. viridis*) was the first exotic tree species imported as fast growing tree species in order to compensate the demand of industrial needs.

The first forestry study with Douglas fir was conducted in the early of 1950's in Turkey. The seeds of the species were sown in Bahçeköy forest nursery and the seedlings were planted at Belgrad and Ayancık-Çangal forests. These stands still constitute the oldest Douglas fir stands [1]. But, detailed studies were conducted in 1972. For this purpose, provenance trials were started with 118 origins which were supplied from IUFRO on Marmara and Black sea regions. The limited results of these studies published at different dates [2-4].

Due to encouraging growth results in many trial sites, Douglas fir species was preferred for afforestation studies. However, some problems have been observed in time due to negligence of some factors in these studies. For example, trees in many Douglas fir plantation sites died and paled in Western Black sea region.

In this study, Douglas fir stands planted on four different sites in 1990 and 1991 which are located in Cide-Kastamonu region are studied and the relationships between seedling height growth and some soil characteristics of the sites were examined.

MATERIALS AND METHODS

The research area, located at 32° 48¹ -33° 14¹ E and 41° 45¹ – 41° 58¹ N, of Kastamonu (Cide) in Western Black Sea region of Turkey. The elevation of the site ranges from 450 m to 1100 m above sea level. The landscape in the area faces north and south, with a slope ranging from 30% to 60%.

The seedlings used in Sehdag were from Sykomish origin numbered as 1067 and 3+0 aged. The seedlings used in the other trial sites were 2+0 aged and Enumclaw origin numbered as 1025. Both origins belong to the coastal form of Douglas fir. These origins were also used in some researches conducted with Douglas fir in Turkey. Aydos-1, Aydos-2 and Guren sites were planted in 1990 and Sehdag site was planted in the autumn of 1991. Therefore, all plantations were 9 years old at the time of measurements taken in 1997. According to the reports of Forest enterprise, culture maintenances were done after plantation.

Cide-Kastamonu region in which plantations are located is under the influence of sub-Black sea climate type. The nearest meteorological observation station is located in Cide district at an altitude of 10 m. According to the long term observations, the region has an average temperature of 12.7 °C, 1250 mm

of annual precipitation and 73% of relative humidity. Average monthly precipitation during the vegetation period (April through November with monthly temperature over 10 ºC) is 93 mm and temperature is 16.1 ºC [5]. According to the Walter method, the region has not water shortage [6] climate type is very humid and vegetation type is very humid forest type [7].

A complete randomized design was applied to represent the sites and a total of 21 sampling plots were taken (400 m² each). Of these, Aydos-2 plantation site represented with 6 and the others sites represented with 5 sampling plots namely, Aydos-1, Guren and Sehdag. In the sampling plots, the heights of all Douglas fir seedlings were measured. Due to branches and ununiform shapes at the bottom of the seedlings, no measurements were taken. For each sampling plot, a soil profile in the middle of the site was excavated and absolute, physiographical soil depth and stonies were determined according to the [8]. Soil samples were taken from the various soil depths (0-20, 20-40, >40 cm) and analyzed in the laboratory for some physical (sand, silt, field capacity, wilting point , available water capacity (AWC) and chemical (organic matter, (OM%), soil reaction (pH), Ca++, Na+, K+, Fe (me/100 gr), P2O5 ppm) characteristics. The amount sand, silt, clay and soil types were determined with soil texture triangle. Some soil analyses were performed in the laboratory of Black Sea Technical University and the rest were determined in the laboratories of Eastern Black sea Forestry Research Institute. In the soil analyses, some literature were used namely as Gulcur [9](1974), Ozyuvacı [10], Kantarci [11], Karaoz [12-14].

Analysis of Variance Techniques (ANOVA) were performed to determine whether the differences among the plantation sites are significant at $p<0.05$. In order to learn under which plantation site, height growths of seedlings are significantly different, Duncan's Multiple Range Test (DMRT) was performed. After that, relationships between height growth and some soil characteristics were determined with stepwise regression and multiple correlation analyses. In these analyses, each plantation site is evaluated within individually. The analysis of data was done using the SPSS software package.

RESULTS AND DISCUSSION

Analyses of variance revealed that height growth of seedlings are differed within plantation sites at significance level of $p<0.05$.

Performing Duncan's mean separation test, 3 different groups were determined (Table 1). As can be seen in the Table, the lowest height growth was found as 46 cm in Guren site and the highest height growth was found as 146 cm in Aydos-2 plantation site. There was not any significance in terms of height growth between Sehdag and Aydos-1 plantation sites. Height growth values in Aydos-2 plantation site were higher than Guren, Sehdag and Aydos-1 as 324%, 128% and 121%, respectively. According to the values, Guren plantation site did not show sufficient height growth after 9 years (Table1).

Douglas fir origins used in this study are also used in some origin trials in our country. Average height growths of Skykomish and Enumclaw origins after 9 years are given in Table 2 [3]. When comparing the average height growths, the trees in the plantation sites were much lower than the trees in the origin trial sites (Table 1, Table 2). It might be resulted from different characteristics of the plantation sites (particularly soil properties).

According to the Çepel [8] classification, absolute soil depths for all the samples plots are determined as "very deep" and physiological soil depths are found as "medium deep". From this point of view, it might be concluded that soil depths are not a problem for the plantation sites. Soil properties of each sample plots for the plantation sites are given in Table 3, 4.

For each plantation site, correlation analysis was done in order to find out the importance and way of relationship between height growth and some soil properties (Table 4). And then, regression analysis was conducted to determine the factors of soil properties affecting the height growth (Table 5; Table 6).

In the Sehdag plantation site, negative significant correlations were determined between SH and soil properties such as, soil reaction (pH), calcium (Ca++ me/100 gr) ($p<0.01$), sodium (Na+ me/100 gr) ($p<0.05$) and available phosphorus (P_2O_5 ppm) ($p<0.01$). On the other hand, positive significant correlations were found between SH and soil properties such as, slope (%) ($p<0.01$), available water capacity (AWC) ($p<0.01$) and amount of Ferrum in the soil (Fe me/100 gr) (($p<0.05$).

Soil pH of the samples taken in Sehdag plantation site were found between 4.41 and 6.04 (at 1/2,5 disfilled water). The pH values were higher than 5 in two sample plots and were lower in three samples (Table 4).

A negative correlation ($r = -0.909$) was determined between soil pH of the samples and SH ($p<0.01$). It can be stated from the ecological point of view that SH growth lowered with higher pH values in Sehdag plantation site. It is reported that Douglas fir makes its best growth on airy, deep and pH level between from 5 to 6 in North California, Oregon and Washington [15,16]. It is also stated that Douglas fir developed well on soils which have pH values between 5.5 and 6.8 [17].

The lowest height growth in the Sehdag plantation sites were on the sample plots numbered as 1 and 2 as 88 and 114 cm, respectively. At the same time, the highest pH values were also found on these areas. It might be concluded that suitable pH values is not an adequate factor for well developed Douglas fir growth. This trend in Sehdag site was also observed in the statistical analysis as negative relationship (Tablo 4). Height growths of seedlings were 128, 126 and 125 cm for the sample areas of 3, 4 and 5, respectively. Soil reaction values on these sample plots were 4.41 as the lowest and were 4.79 as the highest. It is assumed that other site factors are more effective on height growth than soil pH values.

Soil textures of sample plots in the Sehdag plantation site are medium textured clay-loam and loamy clay. But, in general, Douglas fir develops and grows well on loose structured, high water holding capacity, well-developed, loamy, sandy-loamy or loamy sand soils [17,18]. In the study area, clay amount is accumulated especially in the physiological root depth. This might be lowered the aeration of the soils but, at the same time increases the water holding capacity.

Slope in the study area changed between 40-65% and a positive correlation ($r = 0.932$, $p<0.01$) was determined between seedling height growth and slope. This relationship is

caused from aeration of soil and it can be stated that Douglas fir grows and develops well on good aired and drained soils. Some studies indicate negative correlation between slope and height growth [18, 19, 20], while some other [21] indicates positive correlations.

A positive correlation ($r = 0.793$, $p<0.01$) was observed between available water capacity of soil samples and seedling heights. In the Table 3, the lowest available water capacity is found in the sample plot numbers of 1 and 2. Height growth of seedlings in these plots was lower than the other plantation sites. Seedling heights were measured higher on the soil where available water holding capacity is high. Similar observations are also reported by several authors [22,23].

Tablo 1. Duncan's Multiple Range Test results for seedling height growth

Plantation site	Number of sample plots	Origin	Mean (cm)[1]	Std. Deviation (cm)
Guren	5	Skykomish	46 ***a***	28.32
Sehdag	5	Enumclaw	116 ***b***	7.45
Aydos-1	5	Enumclaw	123 ***b***	5.90
Aydos-2	6	Enumclaw	149 ***c***	23.56

Table 2. Mean height growth in the origin trial sites after 9 years (Şimşek, 1979).

Origin Trial Site	Origin Name	Altitude (m)	Age	Mean (cm)
Zonguldak	Skykomish	630	9	285
Düzce	Enumclaw	520	9	346
Çenedağ	Enumclaw	440	9	291
Devrek	Skykomish	630	9	297

Calcium amounts of the soils in Sehdag were found between 0.67-14.65 (Ca++ me/100 gr). The lowest seedling height growth was found on soils which have the highest Calcium amount. On the contrary, the highest seedling height growth was measured on soils which have the lowest Calcium amount. In other words, seedling height growth was higher on the soils in which Calcium is washed away. This relation is supported by correlation analysis where a negative relationship ($r = - 0.824$, $p<0.01$) was determined. From this point of view, it might be concluded that Douglas fir seedlings are not well developed height growth on limestone.

The results of this study are supported by Şimşek [24]. He stated that Douglas fir seedlings may not grow well on soils which have high Calcium amount. A positive correlation ($r = 0.583$, $p<0.05$) was observed between Ferrum (Fe) amount of soil samples and seedling heights. Fe amounts in the study area are found between 0.028-0.085 me/100 gr.

The highest height growth was observed on the sample plots where Fe amount was high. This study confirms that Fe, as a micronutrient, is critical importance for Douglas fir seedlings during the afforestation stage. Fe amount in Sehdag was higher than the other plantation sites. There were not significant differences among Fe amount of soils of the other plantation sites (Table 4).

Height growth of Douglas fir seedlings was lower on the soil samples in which available phosphorus amounts were higher. Calcium phosphate dissolution increases when the soil pH values are 4-5 (KCI). Useable phosphate amount by the plants at this soil pH interval reaches the maximum level [11]. In the Sehdag plantation site, available phosphorus amount was the highest in the sample plot number of 1. A negative relationship was determined between height growth and useable P_2O_5 amount in the soil sample solution. It might be concluded that available phosphorus probably is not fully utilized by Douglas fir seedlings. It is observed that pH value increases is parallel to the P_2O_5 amounts in the Sehdag (Table 3).

Table 3. Soil some physical properties of each sample plots for the plantation sites (three soil depths averaged for each sample plot) and seedling height.

Sites	Sample plots	Sand (%)	Silt (%)	Clay (%)	AWC (%)	SOM (%)	pH	Ca (me/100gr)	Na (me/100gr)	Fe (me/100gr)	P2O5 (ppm)	Seedling Height (cm)
Sehdag	1	49.3	29.9	20.8	6.55	4.19	6.01	14.65	0.040	0.028	70.02	88
	2	41.6	29.3	29.1	8.34	3.92	5.64	14.65	0.039	0.012	13.58	114
	3	45.9	30.6	23.5	12.67	3.37	4.58	0.67	0.032	0.085	3.82	128
	4	49.2	26.5	24.3	13.34	4.50	4.68	2.18	0.025	0.081	13.75	126
	5	41.9	31.8	26.3	12.21	3.98	4.67	1.64	0.025	0.072	8.72	125
	Mean	45.6	29.6	24.8	10.62	3.99	5.11	6.76	0.032	0.055	21.98	116
Aydos 1	6	50.2	30.5	19.3	19.04	5.16	5.26	14.86	0.073	0.021	41.64	109
	7	36.0	36.4	27.6	27.87	5.11	4.98	10.74	0.049	0.062	53.67	127
	8	48.2	31.1	20.5	24.04	4.50	5.06	8.51	0.055	0.052	12.67	117
	9	40.2	32.5	27.3	23.77	3.52	5.12	12.87	0.061	0.025	4.13	120
	10	37.5	32.1	30.4	20.19	3.47	5.15	12.25	0.057	0.015	4.59	144
	Mean	42.4	32.5	25.0	22.98	4.35	5.11	11.84	0.059	0.035	23.34	123
Aydos 2	11	33.5	34.7	31.8	14.51	3.98	5.12	13.03	0.039	0.038	16.39	186
	12	23.8	35.7	40.5	19.72	2.69	5.04	8.48	0.042	0.031	3.18	247
	13	31.8	29.8	38.4	18.07	2.38	5.15	14.93	0.041	0.024	3.02	128
	14	25.5	37.7	36.7	20.15	3.02	4.97	7.15	0.040	0.040	3.16	87
	15	29.6	44.1	26.3	22.87	3.81	5.12	10.47	0.035	0.028	3.81	123
	16	35.8	36.4	27.8	19.72	3.67	4.99	10.78	0.034	0.057	8.17	122
	Mean	29.9	36.8	33.3	19.24	3.31	5.06	10.56	0.038	0.037	6.48	149
Guren	17	48.4	26.5	25.1	21.05	3.57	5.10	15.00	0.042	0.038	40.16	120
	18	24.9	53.4	21.7	23.96	4.22	7.29	16.29	0.036	0.002	17.20	-
	19	35.2	56.5	8.3	26.52	6.50	7.20	16.41	0.039	0.001	2.85	-
	20	25.5	42.5	31.9	20.86	4.64	5.85	15.83	0.042	0.021	6.46	-
	21	28.7	39.5	30.8	14.73	4.39	5.10	13.60	0.041	0.078	7.47	111
	Mean	32.6	43.7	23.6	21.42	4.67	6.11	15.43	0.040	0.028	14.83	115

Plants growing on the soils with high pH values have low utilizing capacity of phosphates. The amount of phosphate uptaken by the plants in acidic conditions is more than the amount of phosphate uptaken by plants in near or neutral conditions [25,26]. From this point of view, it can be stated that in the sample plots of 1 and 2 which have high pH values, Douglas fir seedlings might not fully uptake the phosphorus from the soil. The findings are supported by several researches that height growths of plants are effected by phosphorus and soil pH values [21, 23, 27].

In Sehdag study area, land slope itself explain seedling height growth as 86%. Land slope and available P of soils accounting for about 96% of the variance in seedling height. Regression equations are given below;

$SH=65.829 + 0.969.Slope$ ($R^2=0.86$)
$SH=91.042+0.60.Slope – 0.278. P_2O_5$ ($R2=0.96$)

Height growth is expressed as 97 % with slope, Ca and P_2O_5 variables. In other words, height growth is dependent with 97% on soil properties. Regression equation for height growth is given below.

$SH= 59.757+1.062\ Slope - 0.234\ P_2O_5 +0.928\ Ca$ ($R^2=0.97$)

Multiple regression equations for site index comprise the slope [28].

Table 4. Relationships between seedlings height growth and some soil properties

Soil properties	Seedling Height In Plantation Sites			
	Sehdag (n=15)	Aydos-1 (n=15)	Aydos-2 (n=18)	Guren (15)
Sand	-0.173	-0.542*	-0.230	0.945**
Silt	-0.028	0.121	-0.182	-0.709
Clay	0.225	0.763**	0.293	-0.381
SOM	-0.060	-0.206	-0.111	-0.329
pH	-0.909**	-0.152	0.198	-0.024
Ca	-0.824**	-0.131	0.047	-0.628
Na	-0.552*	-0.469	0.260	0.364
Fe 0	.583*	-0.148	-0.205	-0.778
P_2O_5	-0.913**	-0.325	0.158	0.915*
AWC	0.793**	1.000	1.000	0.856*
Slope	0.932**	1.000	1.000	-0.542*

**:p<0.05, **:p<0.01*

Each difference in the soil properties (slope, Ca and P_2O_5) has significant effects on height growth of seedlings (Table 6). In this study area, negative correlations were determined between seedling height growth and pH, Ca, P_2O_5; but positive correlations were determined for Fe, slope and AWC (Table 4).

According to the correlation Analysis for Aydos-1, significant relationship was found between seedling height growth and sand and clay amounts of the soils. A positive correlation ($r = 0.763$, $p<0.01$) was observed between clay amounts of soil samples and seedling height growths. On the other, a negative correlation ($r = -0.542$, $p<0.05$) was determined between sand amounts of soil samples and seedling height growths. Regression analysis gives seedling height growth as 58% for clay amounts (%) of soil samples. Regression equation is given below;

$SH = 78.061 + 1.813$ clay ($R^2=0.58$)

In this plantation site, clay amount of soil affect the height growth positively. This site is located on coastline and has the lowest altitude among the other study areas. Especially on dry summer days, clay quantity and type play an important role for preserving soil moisture and therefore, has positive effects on height growth. As seen in Table 4, a negative correlation was found between height growth and sand amount (%), but a positive correlation was determined between height growth and clay amount (%). Although not contributing to the regression equation, there is a negative and significant correlation between sand amount of soils and height growth which supports the above statement. Similar studies are also reported by several authors [21,27]. Some studies included the clay quantity in regression equation for site index as a indicator of productivity [29, 30].

Soil pH changes between 4.98-5.26 in Aydos-1 site. The highest height growth is determined in the sample plot of 5 in which soil pH is suitable for Douglas fir (Table 3). Moreover, this site is located on the lowest altitude and has land slope between 45-50 %.

In Aydos-2 site, there were not any significant differences determined between height and soil properties. However, in this site, the highest mean height growths were measured. This site is located on loamy-clay and clayey-loam soils with various slope steepness from 20% through 50%. Soil pH of the site changed between 4.99 and 5.15.

Table 5. Regression analyses results for the factors affecting seedling height growth

Palantation site	Model	F-ratio	P-value
Sehdag	1 ($R^2=0.86$)	86.21	0.000
	2 ($R^2=0.96$)	154.41	0.000
	3 ($R^2=0.97$)	141.31	0.000
Aydos-1	1 ($R^2=0.58$)	18.09	0.001
Guren	1 ($R^2=0.87$)	33.36	0.004
	2 ($R^2=0.97$)	514.33	0.000

In Guren plantation site, seedling height growth measurements were done on 2 sampling areas (sample plot number of 1 and 5, pH = 5.15), because there were not any seedlings on the sample plots of 2, 3 and 4. Soils of the sample plots were clayey-loam and loamy-clay. In other words, this site shows similarities with Aydos-2 by means of soil texture. On the other hand, the sample plots of 2, 3 and 4 where no seedlings were observed have pH levels between 5.85 and 7.30 and weak acidic and mid-alkaline soils. Of these, the sample plots of 2 and 3 have the lowest mean clay amounts, but the other three sample plots have the highest silt amounts. A negative correlation ($r = -0.94$; $p<0.01$) was found between height growth and sand amounts of soils for the sample plots of 1 and 5. But a positive correlation ($r = 0.85$; $p<0.05$) was observed for avail-

able water capacity. These findings support the hypothesis for Sehdag plantation site that Douglas fir seedlings develop well under suitable pH condition with only adequate soil aeration. Although sand amount has depressingly effect organic matter content of the soils, particularly, it plays an important role for aeration of heavy or fine structured soils. Higher silt amounts also fills soil pores, decrease or prevent aeration and drainage, therefore, have negative effects for uptake of mineral nutrients. Another negative factor for Guren site is the Ca++ (me/100 gr) amounts of soils. Soils in this site have the highest Ca++ among the other sites and changing between 13.60 and 16.41me/gr. It is partly resulted from the parent material which is alkaline characteristic marn.

Table 6. Regression equation coefficients effecting seedling height growth

Site	Model	Properties	Coefficient	Std. Dev.	t	Sig. Lev.
Sehdag	1	Constant	65.829	5.629	11.692	0.000
		Slope	0.969	0.104	9.285	0.000
	2	Constant	91.042	5.567	16.355	0.000
		Slope	0.60	0.089	6.741	0.000
		P_2O_5	-0.278	0.051	-5.481	0.000
	3	Constant	59.757	14.443	4.137	0.002
		Slope	1.062	0.216	4.928	0.000
		P_2O_5	-0.234	0.048	-4.905	0.000
		Ca	0.928	0.404	2.295	0.042
Aydos-1	1	Constant	78.061	10.868	7.182	0.000
		Clay	1.813	0.426	4.253	0.001
Guren	1	Constant	3.629	398.568	6.282	0.000
		Sand	-39214.286	6358.864	-6.167	0.000
	2	Constant	2317.243	354.236	6.542	0.000
		Sand	-36463.600	5630.456	-6.476	0.000
		P_2O_5	0.945	0.408	2.314	0.039

In this study area, a positive correlation was determined ($p< 0.05$) between available phosphorus amount and seedling height growth. Although, P_2O_5 amounts of soils calculated in regression analysis, it might be ignored due to measuring sampling height growths in only two sample plots. On the other hand, regression equations are stated below for the sample areas where height growth measurements were taken.

$SH= 98.681 + 4.31$ Sand ($R^2=0.87$)
$SH= 102.097 + 0.270$ Sand $+ 0.212\ P_2O_5$ ($R^2=0.97$)

Although not including in multiple regression equation, available water amounts of soils in Guren site explain height growth as 67% and equation is given below;

$SH= 96.878 + 1.042$ AWC ($R^2=0.67$)

CONCLUSIONS

Douglas fir is a fast growing tree species and has been planted widely outside of its natural distribution areas. In our country, plantation studies started with this species in 1972. Particularly, encouraging results were obtained in the studies conducted on Marmara, West and East Black Sea regions.

In this study, four different Douglas fir stands located in the Cide-Kastamonu Forest Enterprise which are regenerated naturally in 1990 and 1991 are studied. However, on these sites, due to low number of seedlings, recession on height growth and morphological characteristics of the seedlings were considered the reasons of the failures. Hence, relationships between some site environment factors and sampling development are studied.

The plantation sites of Sehdag, Aydos-1, Aydos-2 and Guren have heavy soil texture comparing the soil texture in the natural distribution areas of Douglas fir. In the study areas, soil pH played important roles such as, no seedlings observed on the soils which have high pH, sampling height growth retarded, negative and significant relationships found between pH and seedling height growth. It might be concluded from this point of view that soil pH have significant effect on Douglas fir seedling growth and development. Therefore, the plantation sites which are subject to afforestation practices with Douglas fir species should have proper soil pH values and soil textures.

According to the statistical analyses, positive or negative correlations were determined between sampling height growth and some soil properties. Of these, some soil variables affected sampling height growth individually or in multiple-way. These correlations and regression equations are valid for the site environments of the study areas.

Results of this study indicate that site environment should be done prior to afforestation studies especially for exotic tree species and these studies should be done on suitable growing sites for the species needs. In other words, detailed site environment and inventory should be prepared and all data regarding the species' provenance and site necessities should be gathered before regeneration and/or afforestation studies.

In order to be successful in afforestation and regeneration studies, it might not be sufficient to determine the plantation type and time and suitable tree species for appropriate site environments. On the other hand, processes during the whole life of the stands, particularly cultivation studies in the first few years after planting require control by qualified personnel.

Although Douglas fir seedlings present in the sites of Sehdag, Aydos-1, Aydos-2 and Guren, they did not show good height growth developments (Especially in Guren study site the conditions are really worse). Unfortunately, searching the areas which have pH values close to the natural distribution areas of the species could not saved the success of the afforestation studies in these areas. Because, failures in the regeneration sites are not only depended on the soil pH, but also highly depended on the site environments such as altitude, slope, steepness, other soil properties and natural tree species distribution of the site.

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