Changes of surface soil characteristics of an inceptisol under 40-year conifer plantation.

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Abstract

The characteristics of the surface soil horizons (forest floor and the 0-5, 5-10cm soil depth), 40 years after conifer plantation, consisting of Pinus ponterosa (Laws), Pseudotsuga menzienzsii (Mird), Thuja plicata (D.Don) and Pinus sylvestris (Arn.) were investigated. The experimental site was located at Cholomon mount in Northern Greece. Gneiss was the parent material and the soils could be classified as Inceptisols. The plantation was consisting of 4 complete randomised blocks 20X20m. From each plot with randomised systematic sampling, 20 samples from the forest floor (Aoo and Ao horizons) and the surface soil (0-5cm and 5-10cm depth) from each forest species were collected with the use of a metallic frame (25X25cm). The same sampling method was conducted in the natural Beech stand next to the plantation as a control.

Results suggested significant differences of the forest floor chemical properties and nutrient concentration in samples obtained. For the soil the results suggested that plant species could affect Ca, Mg, K and Na exchangeable cation concentration and also the concentration of the micronutrients Mn and Fe. Simultaneously the N and organic matter concentration in the mineral soil, were significant different. Significant effect of the plant species on the pH of the surface layers observed.

Keywords: Forest floor, Exotic species, inceptisoils, Forest soil properties, conifer plantation

Introduction

Decreased soil pH, higher leaching and organic matter accumulation, under conifers stand were described eighty years ego, by Rankiaer (Rankiaer from Brandtberg 2000). The soil properties could be change after reforestations of sites were natural broadleaved stands occur. The use of conifers for timber production has an ecological cost in relation with the loss of soil production capacity (Leaf 1979).

The forest species via their nutrient absorption ability, nutrient movement in the forest soil environment, root annual turnover, mycorrhization, root exudates, above ground biomass, litter decomposition, soil microbe activity (Mc Kay and Malkolm, 1988, Hendrics and Bianchi 1995, Angren and Caron 1998, Spears et al 2001, Binkley 1994, Saetre et al 1999), and the ability of the forest species to absorb atmospheric gasses (Hofken and Gravenbort 1982) and throughfall and stemflow chemistry, change soil environment. In addition to this, forest species have a major effect on the quantity and redistribution of the nutrient in the soil horizons (Van Breemen and Finzi 1994, Berendse 1998), because they work as nutrient pump from the lower soil layers to the soil surface (Fisher1990). In particularly conifers could increase the soil acidity in along term basis via the increase of the soil leaching from the soil environment.

Changes are also occurring in the inorganic soil. Increasing acidity, changes in the soil accumulation of N, C and P, and the cation exchange capacity, reduce the soil fertility in

the long term. The situation is even worse when fast growing trees are in poor fertility acid soils, since the nutrient elements remain in the biomass (Innes 1993). In the contrary in neutral or alkaline soils it was reported that accessibility of the nutrient element was increased, when conifers were used (Belton et al 1995, Davis 1995) because of the lower pH resulting to the dilution of the nutrients. The cation concentration in the soil is in relation with differences in the organic matter accumulation and nutrient elements in the biomass (Eriksson and Rosen 1994, Alriksson and Eriksson 1998, Brandberg et al 2000). Therefore, significant changes in the soil properties as a result of conifer plantation should be under serious consideration in forest management programs (Alriksson and Eriksson 1998).
Aim of the studies is to investigate the changes in the top layers of an acidic soil as a result of introduction of exotic species as the dominant forest tree in Taxiarchis site, in Northern Greece, and as a result the ecological cost of such actions.

Material and Methods

Study area.
The research was conducted in Central Macedonia , Chalkidiki, at the Cholomont mount in 870m altitude, with submediteranean climatic type.

Soil conditions.
The soil parent material was gneiss schist and it could be classified as Inceptisols. The soil was acid and it was poor in nutrient elements, low cation exchange capacity, and low base saturation capacity.

Table I: The average soil conditions of the experimental site.

Soil profile	Horizon	Depth (cm)	pH H_2O 1:1	C%	N%	P (Olsen) mg/100gr	Exchangeable cations				Soil Texture
							Ca^{+2}	Mg^{+2}	K^{+}	Na^{+}	
1	A	0-25cm	5.0	1.62	0.096	2.1	4.68	0.432	0.161	0.150	SL
	B_1	25-50	5.1	0.49	0.065	2.2	2.34	0.367	0.133	0.141	SL
	B	50-100	4..8	0.46	0.065	1.5	1.23	0.370	0.199	0.184	SL
	C	100+									
2	A_1	0-15	4.9	1.82	0.130	1.8	3.24	0.502	0.950	0.162	SCL
	A_3	15-41	5.1	1.04	0.146	1.4	3.11	0.390	0.907	0.134	SCL
	B	41-67	4.9	0.62	0.102	1.1	2.95	0.380	0.14	0.162	SL
	C	67+									

Experimental design.
The experimental site was consisting of Pseudotsuga menziensii (Mirb.), Pinus ponterosa (Laws), Thuja plicata (D. Don) and Pinus sylvestris (Arn.) plantations.

Sampling method
For each experimental plot, 20 samples were collected, with the use of a frame of 25X25cm. The forest floor and the surface inorganic soil 0-5cm and 5-10cm were selected separately. Soil samples were also collected from the neighbouring beech stand.

Chemical analysis
The forest floor samples were dried in 84°C for 48h. The dry weigh was measured. The samples were milled in order to make the following analysis: 1. pH with 1:5 organic material water ratio. 2.Organic matter was estimated by loss on ignition at 540°C for 5h, and 2 was the coefficient value used for the C estimation (Nelson and Sommers 1982). 3.

Kjedahl was used for the N evaluation. 4. The K, Ca, Mg, Na, Fe, Mn, Cu, Zn were measured after dry ashing. The ash washed with HCl 1:1 v/v and from the solution the nutrient elements were measured with the use of atomic absorption spectrometry method. 5. The total P measured with a visible light spectrophotometry method.
The soil samples were air-dried and sieved via a fine mesh (<2mm) and the following analysis was made. 1. pH with 1:1 soil water ratio. 2. Organic C measurement by wet oxidation method. 3. Kjedahl was used for the N evaluation.4.The Olsen method was used to evaluate the extractable P.4. The exchangeable cations K, Ca, Mg, were evaluated with the CH_3COONH_4, pH7, 1N solution, were atomic absorption spectrometry method was applied.

Mycorrhizal symbiosis.

Root samples together with small quantities of soil were collected from each sampling spot in mid November, in order to classify the mycorrhizas according to their phenotypic characteristics. The root samples were washed with running tap water and all the soil particles were removed gently. Roots with well-developed ectomycorrhizae symbiosis were classified according to their morphotype, colour, rhizomorphs, branching pattern, with the use of a binocular microscope (Zeiss Stemi 2000) (Agener 1987-1996). Roots were also stained with 0.05% Chlorazol black (Heyman 1970 modified) and examined for other mycorrhizal types.

Results and discussion.

Soil Acidity (pH).

The topsoil layers acidification was higher under the coniferous stand in relation to the natural beech neighbouring stand. The higher acidic conditions for the inorganic soil occurred under the Ps. menziensii and P. ponterosa (Table II). That could be related with organic acids released and the decomposition of the organic matter, and also in the different quantity in Ca of the decomposed organic material. It is notable that pH was lower in Ao than in Aoo. The release of exchangeable Ca^{2+} in relation to the phenolic compounds could explain the differences in the pH in the organic and in the inorganic soil layers (Millik 1997). Soil depth and acidification were correlated. There is a suggestion from Alban et al (1978) that the redistribution of the alkaline compounds, leads to alkalinisation of the surface layers and acidification of the subsurface layers. Similar results were described by the Brandtbeg et al (2000); Binkley and Valentine (1991) and Brand et al. (1986). In contrast were no differences in the topsoil layers between, Picea, Pinus, Betula, and Acer in a 27 year old stand (France et al 1989).

Table II. Acidity (pH) of the topsoil layers.

Species	Aoo	Ao	0-5cm	5-10cm
Pseudotsuga menziensii	4.75	5.11	5.04	4.22
Thuja plicata	4.50	5.06	5.64	5.07
Pinus sylvestris	4.14	4.35	5.17	4.66
Pinus ponterosa	4.04	4.26	4.98	4.64
Fagus moesiaca	5.22	5.26	4.91	4.61

Nitrogen (N)

The differences of N between conifers plantation and the Beech stand were significant in the organic layers, but not in the inorganic soil layers. The Aoo horizon of Pinus ponterosa was with the lower N concentration, while in Ao the lower N was under the Ps. menziensii (Table III). The differences in the chemistry of the organic compounds in the Aoo and the differences in the decomposition processes were responsible for the differences. In Ps. menziensii the decrease of nitrogen from Aoo to Ao layer was 39%. This followed by P. ponterosa, T. plicata and P.sylvestris. The N concentration was higher in the Aoo because new litter material has more N. The N could remain in the Aoo for 1-3 years as it was suggested by Federer (1983) and Boone (1992), Berg and Ekbolm (1983) and Mc Claugherty et al (1985). The organic layers of the exotic plantations were with significant lower N concentration in comparison to the natural beech stands. In the contrast the inorganic layers were with higher N concentration. The first inorganic layer (0-5cm) under the Ps menziensii stand was with the lower N among the other treatments. It is notable that N decrease occurred in the lower inorganic layers 5-10cm, with the highest in P. sylvestris (-50% difference) and the lower in P. ponterosa (-3.3%), while in the beech natural stand the differences were smaller. The differences among the conifers used were because of the differences in the humification of the organic matter, the different rates of organic N mineralisation in the mycorrhizal effect and in the different soil depth, resulting to differences in the fine root system. The density of the fine root system has also significant role in the differences of N concentration in the inorganic layers.

Table III: The soil surface N(%) concentration and the C/N ratio.

Species	Aoo	Ao	0-5cm	5-10cm	C/N			
					Aoo	Ao	0-5cm	5-10cm
Pseudotsuga menziensii	1.40a (0.127)	0.85a (0.21)	0.34a (0.06)	0.18a (0.03)	25.93	19.96	11.11	9.27
Thuja plicata	1.40a (0.16)	1.12b (0.17)	0.56b (0.18)	0.43c (0.10)	30.39	24.82	12.64	9.86
Pinus sylvestris	1.41a (0.18)	1.10b (0.30)	0.44b (0.11)	0.22a (0.05)	30.90	23.19	13.97	12.86
Pinus ponterosa	1.24b (0.12)	1.09b (0.30)	0.30a (0.05)	0.29b (0.09)	37.26	23.81	14.60	8.98
Fagus moesiaca	1.76c (0.13)	1.18b (0.21)	0.28a (0.04)	0.19a (0.03)	23.28	19.17	22.79	12.28

The mean values with the same letter in each column are not significant different form each other ($P<0.05$). Values in brackets are standard deviation.

There was a suggestion that ground vegetation has a significant impact on the differences of the N accumulation (Parfitt et al 1997). These suggestions were in agreement with Dinghton (1995), Brandtberg et al (2000).

The N accumulation is higher under the Ps. menziensii stand and lower in P. ponterosa, while in Ao is higher in P. ponterosa. Data analysis shows significant differences between the conifers and beech stand, with the highest accumulation in Ps. menziensii followed by the T. plicata, P. sylvestris, P. ponterosa, while the N accumulation is much lower in the beech.

The C/N ratio varies between 25.93 and 37.26 in the Aoo while in the Ao between 19.96 and 24.82. The C/N ratio data suggest that there is a delay in the organic matter mineralisation in the Aoo, since a C/N ratio between 20-30 is necessary for the mineralisation of the organic matter (Waring and Sclesinger 1985, Stevenson 1986, Kavvadias et al. 2001).

Phosphorus (P).

The P. ponterosa was with significant less P in the Aoo horizon in relation to the other conifers, while in the Ao the differences occurred at the P. sylvestris and Ps. menziensii showing the lower P. It is noteworthy that the differences between the conifers and the beech natural stand were significant in the organic and in the inorganic soil layers, with wider differences in the topsoil layers. The data analysis shows that conifers could decrease the soil P availability and hold the P in the organic layers.

Table IV: The concentration in the Aoo and Ao horizons and extractable of the topsoil layers.

Species	Aoo mg/g	Ao mg/g	0-5cm mg/100g	5-10cm mg/100g	N/P		C/P	
					Aoo	Ao	Aoo	Ao
Pseudotsuga menziensii	0.65 a (0.09)	0.46 a (0.07)	0.92 a (0.31)	0.81 a (0.22)	21.5	18.5	558	368
Thuja plicata	0.66 a (0.19)	0.68 b (0.07)	1.09 b (0.22)	1.00 a (0.21)	21.2	14	644	408
Pinus sylvestris	0.72 a (0.11)	0.58 c (0.13)	0.72 c (0.10)	0.92 a (0.19)	19.6	22.0	605	439
Pinus ponterosa	0.52 b (0.09)	0.70 b (0.08)	0.80 a (0.17)	0.66 b (0.09)	23.8	15.6	888	370
Fagus moesiaca	1.04 c (0.11)	0.81 d (0.07)	3.78 d (0.32)	3.60 c (0.29)	16.9	14.6	393	282

The mean values with the same letter in each column are not significant different form each other ($P<0.05$). Values in brackets are standard deviation.

The Ps. menziensii and P. sylvestris were with the highest differences between Aoo and Ao horizons, while in the T. plicata were no differences. In contrast the P concentration in Ao is higher in P. ponterosa. Mycorrhizal fungi should be responsible for these differences. In the to soil layers there was a decrease of P concentration between the 0-5 and 5-10cm with the highest in P. ponterosa (-17.5%). In contrast there was an increase in P in the P. sylvestris due to the differences of root depth and to the mycorrhizal symbiosis function. It is also possible that changes in the soil acidity could lead in Al^{3+} increased concentration (Alifragis unpublished data).

The Ps. menziensii was with the highest P accumulation and T. plicata with the lowest. Differences in the humification could explain the differences in P accumulation levels among the different conifer species.

The present data show a decrease of N/P ratio, according to the decomposition rate except from P. sylvestris, were increase occurred, suggesting a lower nutrients release rates. Lee et al (1983) describes similar results.

The C/P ratio under the conifer stands is high suggesting a bad mineralisation conditions in relation to natural beech stand, since good mineralisation conditions occur in C/P ratio between 200-230 (Lousier and Parkinson 1978, Stevenson 1986, Kavadias et al 2001). In addition to this Millik suggests that the increase of phenolic compounds decrease the P anions and that is related with the soil biochemical conditions (Millik 1997).

Calcium (Ca)
The Ca concentration is much lower in the coniferous stand than in the beech natural stand (Table V). The highest Ca values were related with T. plicata and Ps menziensii was with the lowest. There was a decrease in Ca concentration between Aoo and Ao except from P. ponterosa. Differences were also among the different coniferous species in Aoo and in Ao. The differences in the efficiency use of Ca may lead to differences such these in Aoo and Ao. Similar results were also in a similar experimental site located in the central Greece (Alifragis et al 2004). Higher Ca in the needles of Picea abies trees was suggested as the reason for higher concentration of Ca in Aoo horizon (Alriksson and Eriksson 1998). Mycorrhizal fungi could play an essential role in the Ca nutrition since mycorrhizal fungi could reach Ca from appatites $Ca_3(PO_4)_2$ (Wargo et al 2003, Smith and Read 1997, and Blume et al 2002). Plants colonised by ectomycorrhizal fungi could use Ca in a widely and later it could be returned to the soil via the litter fall, and therefore the Aoo and Ao horizons may have more Ca, as Joslin and Wolf (1992) suggesting.
Data analysis indicates a significant difference in the Ca for the 0-5cm layer between the different conifers and also with the natural beech stand. Those differences were much wider under the T. plicata stand. For the 5-10cm layer, there were no significant differences apart from the T. plicata stand.
The increase of Ca^{+2} in the topsoil layers may be a result of the phenolic compounds increase. These compounds may hold Ca^{+2} with no differences in the pH. It was also suggested that the exchangeable Ca^{+2} increase may not be related to the Ca increase in the organic layers, and rather the Ca^{+2} cycle and redistribution are the reasons for the Ca increase (Van Breemen and Finzi 1994, Brendese 1998, Fisher 1990).
The Ca accumulation for the organic horizons shows no differences for the Aoo, while in the Ao P. ponterosa were with the highest and Ps. menziensii were with the lowest. The natural beech stand was with the highest Ca accumulation.

Table V: The Ca concentration in the organic horizons, and exchangeable.

Species	Aoo mg/g	Ao mg/g	0-5cm me/100g	5-10cm me/100g
Pseudotsuga menziensii	4.21a (1.59)	2.88 a (1.95)	14.41 a (5.67)	4.15 a (2.45)
Thuja plicata	11.53 b (1.96)	8.41 b (2.77)	14.77 a (2.71)	8.64 b (3.56)
Pinus sylvestris	8.80 c (1.83)	5.71 c (1.89)	12.08 ab (4.14)	5.43 a (2.77)
Pinus ponterosa	5.85 a (2.16)	7.70 b (3.12)	10.61 b (3.35)	5.96 a (2.41)
Fagus moesiaca	19.43 d (3.13)	11.33d (2.92)	6.66c (1.82)	4.16 a (1.56)

The mean values with the same letter in each column are not significant different form each other ($P<0.05$). Values in brackets are standard deviation.

Magnesium (Mg)
The Mg concentration was higher under the P. ponterosa stand for the Aoo, while in the Ao was the lower (Table VI). The decomposition processes and the increase of the cation exchange capacity could explain those differences. Differences were also between the natural beech stand and the conifers, due to differences in the decomposition rates and

processes. The exchangeable Mg was increased in the coniferous stands in comparison with the beech stand. As for the conifers T. plicata shows more exchangeable Mg.

Table VI: The Mg (mg/g) concentration in the organic horizons, and exchangeable Mg (me/100g).

Species	Aoo mg/g	Ao mg/g	0-5cm me/100g	5-10cm me/100g
Pseudotsuga menziensii	1.62 a (0.41)	3.08 a (0.97)	1.897 ab (0.358)	1.065 a (0.59)
Thuja plicata	1.56 a (0.52)	2.42 a (0.96)	2.193 b (0.551)	1.672 b (0.61)
Pinus sylvestris	1.27 a (0.54)	3.18 a (1.11)	1.727 a (0.340)	1.088 a (0.22)
Pinus ponterosa	3.28 b (1.11)	1.13 b (0.36)	1.704 a (0.360)	1.333 a (0.34)
Fagus moesiaca	1.63 a (0.31)	1.86 c (0.29)	1.23 c (0.192)	0.79 c (0.21)

The mean values with the same letter in each column are not significant different form each other ($P<0.05$). Values in brackets are standard deviation.

The total Mg accumulation for the organic horizons was higher in the Ps menziensii and P. ponterosa and T. plicata was with the minimal. Ps menziensii and P. ponterosa were with higher Mg accumulation from the T. plicata and P. sylvestris. The Ao horizon was with the Ps. menziensii and P. sylvestris in the highest and T. plicata ans P. ponterosa with the minimal. The species effect therefore plays significant role in the Mg accumulation.

Potassium (K)

The K shows the maxima in the P. ponterosa for the Aoo, while in the Ao in P. sylvestris (Table VII). It is worth to mention here the K concentration increases in the Ao horizon in the Ps menziensii and T. plicata in relation to the Aoo. As it was explained for the other nutrient elements the humification and the increase in the cation exchange capacity resulting to K leaching from the Aoo. The natural beech shows higher K values.

Table VII: The K concentration in the organic horizons, and exchangeable K.

Species	Aoo mg/g	Ao mg/g	0-5cm me/100g	5-10cm me/100g	N/K	
					Aoo	**Ao**
Pseudotsuga menziensii	0.73a (0.12)	0.87a (0.19)	0.409ab (0.09)	0.186ab (0.08)	19.1	9.8
Thuja plicata	0.66a (0.09)	0.82a (0.14)	0.459a (0.09)	0.295b (0.09)	21.2	13.6
Pinus sylvestris	0.73a (0.07)	0.72b (0.09)	0.441a (0.12)	0.301b (0.129)	19.3	15.2
Pinus ponterosa	0.96b (0.19)	0.81a (0.28)	0.348b (0.07)	0.259b (0.07)	12.9	13.4
Fagus moesiaca	2.26c (0.52)	1.93c (0.14)	0.57c (0.09)	0.42c (0.11)	18.3	14.5

The mean values with the same letter in each column are not significant different form each other ($P<0.05$). Values in brackets are standard deviation.

The conifer plantations resulting degrease of exchangeable K for the topsoil layers and to the organic layers. The beech was with significant more exchangeable K. The exchangeable K also shows increasing values in soil depth. Brandberg et al (2000) shows that exotic plantations could result in Ca^{+2} and Mg^{+2} while no changes occurred for the K^{+}. Data analysis of the K accumulation values suggests that coniferous plantations could play important role. The K accumulation in the beech stand was similar with the Ps. menziensii while was lower for the other conifers.

The N/K ratio was reduced and it is higher in the T. plicata for the Aoo horizon and lower in the P. ponterosa while is lower for the Ao in Ps. menziensii.

Organic matter

Data analysis shows significant reduction of the C between the two soil layers. Differences in the C occurred between the conifers both Aoo and Ao. Results also show significant differences in the organic matter accumulation between the Aoo and Ao. Ps menziesii was with 3.94 times less organic matter in the Ao while T. plicata was with more organic mater in the Ao. These differences suggesting differences in the decomposition rate. Johansson (1995) suggest that such differences among different species were related with the chemical composition of the litter.

Table VIII: The soil surface C and organic matter accumulation.

Species	**Aoo %**	**Ao %**	**0-5cm %**	**5-10cm %**	Aoo Kg/ha	Ao Kg/ha	Total Kg/ha	Aoo/Ao
Pseudotsuga menziensii	36.31a (4.50)	16.97a (5.21)	3.78a (0.90)	1.67a (0.33)	15053	3813	18866	3.94
Thuja plicata	42.55b (3.22)	27.80b (6.25)	7.08b (1.74)	4.24b (1.34)	6007	6817	12824	0.88
Pinus sylvestris	43.58b (5.00)	25.51b (4.18)	6.15b (1.31)	2.83c (0.71)	7693	7162	14855	1.07
Pinus ponterosa	46.21b (1.45)	25.96b (5.45)	4.38a (1.08)	2.49c (0.45)	12356	8973	21329	1.38
Fagus moesiaca	40.98ab (3.64)	22.63c (4.91)	6.45b (1.22)	2.42 (0.52)	14350	5115	14550	1.84

The mean values with the same letter in each column are not significant different form each other (P<0.05). Values in brackets are standard deviation.

Trace elements

Results show differences in the trace elements among different coniferous species. In the present study we also check the hypothesis that differences in the trace elements concentrations were due to dilution effect.

Data shows that Fe was more in the Ps. menziensii while in Ao Fe accumulation was the maxima. Except from the P. ponterosa were the maxima occurred in the Aoo. The Fe accumulation in the forest floor was Ps menziensii > P. sylvestris > P. ponterosa> T. plicata. Those differences appeared to be related with dilution effect. The Cu, Mn, Zn, values were higher in the Ao. The Cu accumulation follows similar pattern with Fe.

Table IX: The organic horizons Fe, Mn, Cu, Zn concentration (ppm)

Species	Fe		Cu		Mn		Zn	
	Aoo	Ao	Aoo	Ao	Aoo	Ao	Aoo	Ao
Pseudotsuga menziensii	8118a (2541)	18343a (5508)	17.66a (4.2)	19.60a (4.4)	1805a (559)	2203.3a (603)	66.3a (9.7)	88.9a (12.3)
Thuja plicata	6510b (4968)	10291b (7610)	11.93b (2.15)	14.46b (5.2)	681b (489)	788.3b (311)	46.8b (13)	58.9b (18.9)
Pinus sylvestris	4370c (3720)	14908c (4691)	14.26b (2.12)	20.46a (3.5)	743b (359)	1580c (387)	52.5b (14.6)	89.9a (13.5)
Pinus ponterosa	15665d (3880)	3390d (3094)	13.4b (3.85)	9.80c (2.3)	1203c (269)	483.3d (157)	72.1c (12)	44.8b (14)

The mean values with the same letter in each column are not significant different form each other (P<0.05). Values in brackets are standard deviation.

Mycorrhizal colonisation.

All coniferous species were with well-developed mycorrhizal colonisation. Particularly P. ponterosa and P. sylvestris, roots were colonised by Pisolithus sp. In relation to a similar experimental site in central Greece (Alifragis et al 2004), the roots in Tachiarxis were with well-developed mycorrhizal colonisation, covering most of the fine root system, in particular in P. ponterosa. The 30% of the fine T. plicata roots were complete covered by Harting net of Pisolithus sp, while the rest was found only associated with Pisolithus hyphae. Impressive findings suggest also the presence of AMF in association with T. plicata roots, large number of appressoria and also significant number of Glomus spores in areas with no other type of vegetation. It is notable thought that no internal arbuscular mycorrhizal structures were found in examined T. plicata roots.

Conclusions

- The soil acidity was affected by the forest species. Soil acidity of 0-5cm layer was increased. In contrast in P. menziensii the 5-10cm layer was more acidic while in T. plicata was reduce. There was no difference for the other species.

- The N soil concentration was affected. The accumulation was 686.4, 361.5, 439.6, 543.4 and 337.1 Kg/ha for the P. menziensii, T. plicata, P. sylvestris, P. ponterosa and F. moesiaca respectively.

- The P concentration was significant reduced. The ratios N/P and C/P were different due to a different P mineralisation rate. The accumulation of P in the forest floor was 33.5, 10, 22.4, 31.1 and 21.5 kg/ha for the P. menziensii, T. plicata, P. sylvestris, P. ponterosa and F. moesiaca respectively.

- The Ca concentration of the organic layers was significantly reduced. Significant differences occurred between the forest species, with 209, 277, 243, 334 and 357 kg/ha for the P. menziensii, T. plicata, P. sylvestris, P. ponterosa and F. moesiaca respectively.

- P. ponterosa was with significant differences in the Mg concentration in the Aoo layer. The Mg concentration was significant different between the plantation and the natural beech stand for the Ao layer and the 0-5 and 5-10cm. The Mg concentration in the inorganic soil layers was increased. Mg concentration of the forest floor, was related with the forest species. The Mg accumulation was 143.9, 57.1, 99.5, 83.2, 39.87 kg/ha for the P. menziensii, T. plicata, P. sylvestris, P. ponterosa and F. moesiaca respectively.

- Exotic plantations effect the K concentration. There was also a reduction to the exchangeable K^+ . The K concentration of the forest floor was 49.2, 22.6, 26.9, 39.8, and 48.7 kg/ha for the P. menziensii, T. plicata, P. sylvestris, P. ponterosa and F. moesiaca respectively.

- The P. menziensii and P. ponterosa were with more organic matter on the forest floor, the T. plicata was with less while in P. sylvestris were similar with the Beech stand

- The forest species could affect the Fe, Cu, Mn, and Zn micronutrients accumulation in the forest floor.
- The mycorrhizal fungi were different in different coniferous species

References

AlifragisD. Papaioanou A., Orfanoudakis M., and Goulas K. 2004. Could the forest floor characteristics change after the establishment of exotic tree plantations? Procidings of the 10th Panhellenic Soil Science Congress, in Press.

Alban, D.H., Perala, D.A., and Schlaegel, B.E., 1978. Biomass and nutrient distribution in aspen, pine and spruce stands on the same soil type in Minnesota. Can., J. For. Res., 8: 290-299.

Alriksson A., and Eriksson, H.M., 1998. Variations in mineral nutrient and C distribution in the soil and vegetation compartments of five temperate tree species in NE Sweden. For. Ecol. Manage., 108: 261-273.

Angren, D.A., and Caron, J., 1998. Plant induced changes in soil structure : processes and feed backs. Biogeochemistry 42:55-72.

Belton, M.C., O'Connor, K.E., and Robson A.B. 1995. Phosphorus levels in topsoil's under conifer plantations in Canterbury high country grassland New Zealand J.For. Sci., 25: 262-282.

Berendse, F., 1998. Effects of dominant plant species on soil during succession in nutrient poor ecosystems. Biogeochemistry 42: 73-88.

Berg, B., and Ekbolm, G. 1983. Nitrogen immobilization in decomposition needle litter at variable carbon: nitrogen ratios. Ecology 64: 63-67.

Binkley, D., 1994. The influence of tree species on forest soils: processes and patterns. In "Proceedings of the Trees and Soil Workshop. Lincoln University Lincoln University Press. Cantesbury, pp 1-33.

Binkley, D., and Valentine D., 1991. Fifty-year biochemical effects of green ash, white pine and Norway's spruce in a replicated experiment. For. Ecol. Manage. 40:13-24.

Boone, R.D. 1992. Influence of sampling date and substrate on nitrogen mineralization: comparison of laboratory – incubation and buried-bag methods for two Massachusetts forest soil. Can.J.For.Res.22:1895-1900.

Blume, J.D., Klaue, A., Nezat, C.A., Driscoll, C.T., Johnson, C.E., Siccama, T.G., Eagar, C., Fahey, T.J., and Likens, G.E. 2002. Mycorrhizal weathering of apatite as an important calcium source in base-poor forest ecosystems-Nature 417:729-731.

Brand, D.G., Kehoe, P., and Connors, M., 1986. Coniferous afforestation leads to soil acidification in central Ontario. Can. J. For. Res., 16: 1386-1391.

Brandtberg P.O., Lundkvist H., Bengtsson J.,2000. Changes in forest-floor chemistry caused by a birch admixture in Norway spruce stands. For. Ecol. Manage., 130: 253-264.

Davis M.R. 1995. Influence of radiata pine seedling on chemical properties of some New Zealand mountain soils. Plant Soil , 176: 255-262

Dighton, J. 1995. Nutrient cycling in different terrestrial ecosystems in relation to fungi. Can. J. Bot., 73: 1349-1360.

Eriksson, H.M. Rosen K. 1994. Nutrient distribution in a Swedish tree species experiment. Plant and Soil. 164: 51-59.

Federer, C.A. 1983. Nitrogen mineralization and nitrification: depth variation in four New England forest soils. Soil Sci. Soc. Am. J. 47: 1008-1014.

Fisher, R.F., 1990. Amelioration of soil by trees. In "Sustained Productivity of Forest Soil" . Gessel S.P., Lacate, D.S., Weetman, G.F., Powers, R.F. (Eds). University of British Columbia Press. Vancouver pp 290-300.

France, E.A., Binkley D., and Valantine D., 1989. Soil chemistry changes after 27 years under four tree species in southern Ontario. Can. J. For. Res. 19: 1648-1650.

Hendrics, C.M.A., Bianchi, F.J.J.A., 1995. Root density and root biomass in pure and mixed forest stands in Douglas-fir and beech. Neth. J.Agric. Sci. 43: 321-331.

Hofken, K.D., Gravenhorst G., 1982. Deposition of Atmospheric Pollutants. Georgi H.-W., Pankrath (Eds), Reidel, Dordrecht, pp 191-194.

Innes, J.I. 1993. Forest Health: Its Assessment and Status. CAB International, Walling ford, U.K. 677pp.

Johansson, M.B., 1995. The chemical composition of needle and leaf litter from Scots pine. Norway spruce and white birch in Scandinavian forest. Forestry 68 (1).

Joslin, J.D., and Wolfe, M.H., 1992. Red spruce soil solution chemistry and root distribution across a cloud water deposition gradient. Can. J. For. Res. 22: 893-904

Kavvadias V., Alifragis D., Tsiontsis A., Brofas G., and Stamatelos G., 2001. Litterfall, litter accumulation and litter decomposition rates in four forest ecosystems in northern Greecec. For. Ecol. Manage. 144:113-127.

Leaf, A., 1979. Proceeding of Symposium on Impact of Intensive Harvesting on Forest Nutrient cycling. State University of New York, Syracuse N.Y. 421 pp.

Lee, R.S. Pritchett, W.L., Smith, W.H. 1983. Forest floor characteristics under longleaf pine on two spot sols. For. Ecol. Manage. 5: 193-205

Lousier, J.D., Parkinson, D., 1978. Chemical element dynamics in decomposing leaf litter. Can. J. Bot. 56: 27-95-2812.

Millik I., A.M., 1997. Effect of phenolic compounds on selected soil properties. For. Ecol. Manage 92: 11-18.

Mc Claugherty, C.A. Pastor, J., Aber J.D., and Melillo J.M. 1985. Forest litter decomposition in relation to soil nitrogen dynamics and litter quality. Ecology 66: 266-275.

Mc Kay, H.M., and Malcolm, D.C. 1988. A composition of fine root component of a pure and mixed coniferous stand. Can. J. For. Res. , 18: 1416-1426.

Nelson D.W., and Sommers, L.E. ,1982. Total carbon, organic carbon, and organic matter. In Page A.L.(Ed.).Method of Soil Analysis. Amer. Soc. of Agronomy and Soil Sci. Soc. of America. Madison.

Parfitt, R.L. Percival R.L., Dhlgreen R.A., and Hill L.F., 1997. Soil and solution chemistry under pasture and radiata pine in New Zealand. Plant Soil 191: 279-290.

Perala D.A., and Alban, D.H., 1982. Rates of forest floor decomposition and nutrient turnover in aspen pine, and spruce stands on two soils. U.S. For. Serv. Res. Pap. NC-277, 5pp.

Saetre, R., Brandtber, R.P., Lund Kvist, H., and Benftsson J., 1999. Soil organisms and carbon, nitrogen, and phosphorus mineralisation in Norway spruce and mixed Norway spruce – Birch stands. Biol. Fertil. Soil 28: 382-388.

Smith S.E. and Read D. 1997. Mycorrhizal Symbiosis 2nd Edition. Academic Press pp. 131.

Spears J.D.H., Lajtha K., Caldwel B.A., Pennington S.B., and Vanderbilt K. 2001. Species effects of ceanothus velutinus versus Pseudotsuga menziensii, Douglas – fir, on soil phosphorus and nitrogen properties in the Oregon cascades. For. Ecol. Manage., 149: 205-216.

Stevenson, F.J., 1986. Cycles of soil:Carbon Nitrogen, Phosphorus, Sulfur, Micronutrients. Wiley. New York. 380pp.

Van Breemen, N. and Finzi A.C., 1998. Plant – soil interaction: ecological aspects and evolutionary implications. Biogeochemistry 42: 1-19.

Waring, R.H., Schlesinger W.H., 1985. Nutrient cycling throught forests. In Forest Ecosystems, Concepts and Management. Academic Press. Orlando, F.L., pp 121:156.