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Hydrodynamic and physicochemical properties of two types of substrates under the cedar of the central middle atlas (Morocco)

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Abstract

The cedar of the Atlas settles in Morocco on different types of substrates. However, the quality and nature of the latter have an effect on the reforestation and natural regeneration of the cedar ecosystem. This study investigated the water, physical and chemical characteristics of two substrates (basalt and limestone) representative of cedar soil in the Central Middle Atlas region (Azrou forest - Ait Youssi Amkla forest).

The results showed that substrates tested showed differences for all the properties (water, physical and chemical). These characteristics make it possible to prevent the behavior of each soil vis-à-vis the aeration of the plants root system as well as the availability of water and nutrients.

The basaltic substrate of the Azrou forest has good drainage, good aeration, high water retention capacity, rich organic matter and nutrients compared to the limestone substrate of the Ait Youssi Amkla forest.

Keywords: cedar forest-basaltic soil- calcareous soil - physicochemical properties-Morocco

Introduction

Atlas cedar (*Cedrus atlantica* Manetti ex Endl.) Carrière, 1855) is a forest species that is a natural heritage for Morocco and humanity. It occupies an area of 134,000 ha and is organized into four blocks of unequal importance: the cedars of the Rif occupying nearly 11,000 ha, the central Middle Atlas with the largest area of 78,000 ha, Middle Eastern Atlas with 10,000 ha and High Atlas with an area of 32,000 ha [1].

Natural regeneration and reforestation of cedar trees are related to a number of factors including climatic parameters, vegetation structure and the nature of the substrate. Although Moroccan cedars settle on different types of substrates [2-4], Rif shale and basalt from the central Middle Atlas offer a much more favorable water balance than that observed on substrates. limestone and dolomitic limestones of the Middle Eastern Atlas and the Eastern High Atlas [5]. Numerous studies have shown that the nature of the substrate has a significant effect on the performance of this species. Indeed, Ezzahiri *et al*., 1993 showed that the substrate, the texture and the depth are very important parameters in the renewal of the cedar. They also reported that natural regeneration is very favorable in deep basaltic soils. While on a shallow carbonate substratum, young seedlings cannot overcome the summer cape and dry out quickly. In addition, Aoujdad *et al*., (2015) [6] found that at the Azrou nursery, the growth of seedlings from different cedar sources is significantly different, it is better on the basaltic substrate than calcareous. For its part, Taoufik (2006) [7] showed that the cedar plants grown on basaltic substrate have a higher end shoot elongation compared to other plants on calcareous substrate.

However, few studies deal with the relationship between the characteristics of surface states and the success of reforestation. It is with this in mind that this study aims to evaluate the relationship between the water, physical and chemical parameters of the two representative types of cedar soils in the Central Middle Atlas region.

Material and Method

1. Geographical Situation

The study area (fig. 1) covers two sites located in the middle central Atlas. The first site (33 ° 24 '537' 'N, 5 ° 11' 49 " W, exposure N to NW and Altitude: 1736 m) is part of the Azrou forest which is located on the northern edge and s' extends over an area of 17,806 ha (S1). It is characterized by a contrasting relief with very variable altitudes that can reach 1,800 m. Cedar in this forest is the main species on soils grown on basalt.

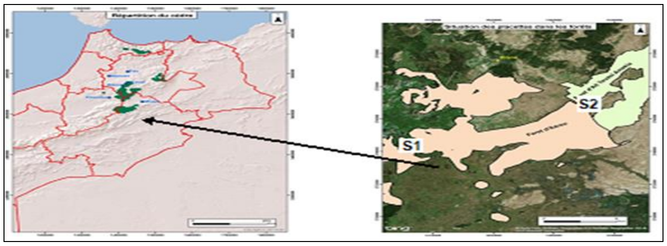

Fig 1: Distribution of cedar in the northern part of Morocco and situation of the two studied sites

The second site (33 ° 27 '23' 'N, 5 ° 02' 10 " W, south-east exposure and Altitude: 1933 m) (S2) is in the forest of Ait Youssi Amkla and extends over an area of 10,451 ha. The land use is represented by cedar and holm oak in association with other species such as *Juniperus sp*, This site is characterized by an altitude that can reach 2,000 m, with soils developed on limestone or dolomite. The climate of the two sites is of Mediterranean type characterized by a cool and wet winter and a dry and hot summer, with an average rainfall of 800 mm per year. The average temperature varies from 3 ° C to 33 ° C for the first site and from 10 ° C to 38 ° C for the second site.

2. Sampling of glacial deposits

In each site, the location of the sample was chosen randomly. From each plot, three samples were taken by auger and then mixed to form a composite sample. This operation was performed on a depth of 0 to 40 cm. For these samples hydrodynamic and physicochemica properties were studied at the pedology laboratory of the Forest Research Center in Rabat. It should be noted that each analysis was performed with three repetitions.

3. Hydrodynamic analyzes of soils

The hydrodynamic characteristics of soils have focused on:

- The humidity elaborated by the following equation:

$$H\% = \frac{100 \text{ x (Weight of the fresh sample - Weight of the dry sample)}}{\text{Weight of the dry sample}}$$

- Soil infiltration was measured in the field by the Muntz method using the double ring infiltometer.
- The hydraulic conductivity (K) was calculated from the infiltration rate curves as a function of time.
- Soil permeability was deduced from saturated hydraulic conductivity data.

4. Physico-chemical analyzes of the soil

The physicochemical characteristics of the soil have interested:

- Soil structure, appreciated in situ according to a classification range [8].
- Particle size, measured by the densimeter method
- Porosity, measured by the standard porosity test [9, 10].

Total porosity (Pt%) = (volume poured / total volume) X 100.
Aeration porosity (Pa%) = (volume recovered / total volume) X 100.
Retention porosity (Pr%) = (Pt%) - (Pa%).

- Apparent density (da) in (g / cm^3), calculated from the following ratio:

$$Da = \frac{\text{Weight of the dry sample}}{\text{Apparent volume}}$$

- pH, measured using a pH meter on two types of solutions namely soil / water at 1 / 2.5 and soil / KCl at 1 / 2.5
- Limestone, determined by Bernard's calcimeter.
- Exchangeable bases (Na^+, Ca^+, Mg^{2+} and K^+) determined by atomic absorption spectrophotometry.
- Cation exchange capacity (CEC), determined by sodium acetate.
- Electrical conductivity (CE).
- Salinity, calculated by the following formula:
- S (g / l) = 0.7 x EC (mmhos / cm).
- Assimilable phosphorus, measured by the method of Olsen.
- Total nitrogen, determined by distillation using the Kheldal Method.
- Organic carbon, measured by the Walkley-Black method
- Organic matter content (M.O), obtained by the formula:

M.O% = C% x 1.72

Results and Discussions

1. Hydrodynamic Characteristics

The results of the hydrodynamic parameters (humidity, water conductivity and permeability table 1) obtained in the basaltic soil are better than those obtained in the calcareous soil. In fact, soil moisture is more important in the basalt than in the limestone. Furthermore, Figure 2 shows the differences in the appearance of infiltration curves of the two types of soil. That of the basaltic soil has shown a very rapid infiltration and a high permeability compared to that of the calcareous soil. These infiltration curves made it possible to deduce the hydraulic conductivity, proportional to the intrinsic permeability of the soil which depends on the porosity of the soil, is of the order of 2.7 for basalt and 2.1 for limestone. All these results converge towards a good drainage at basalt level.

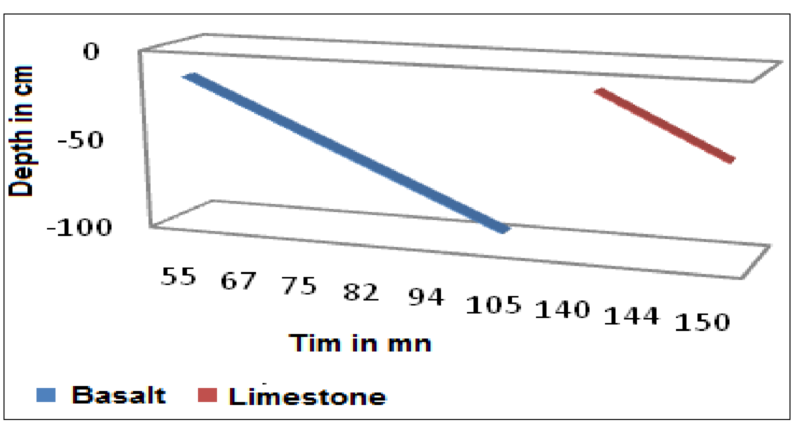

Fig 2: Infiltration in basaltic sol and in limestone soil

Table 1: Hydrodynamic properties of soils

Sol	Humidity	Hydraulic Conductivity	Moderate to fast
Limestone soil	9,22	2,1	Modérée à rapide
Basaltic soil	37,01	2,7	Rapid

2. Physicochemical Properties

The results relating to the physicochemical properties of the soils studied are shown in Table 2.

The particle size analysis of the samples was carried out after decarbonation with hydrochloric acid (N / 70). The level of limestone is 80% for calcareous soil and 12% for basaltic soil. The results of these analyzes (Table 2) show that for the calcareous soil, the silts represent 39%, the clay 15% and the sand 47%, whereas for the basaltic soil the clays present the highest percentage with 57% followed by 24% silt and 19% sands. These results made it possible to highlight a sandy-silty texture for the calcareous and sandy-clay soil for the basaltic soil.

According to in situ assessments, basalt is characterized by a lumpy structure rich in humus while the limestone substrate is granular. The lumpy structure is characterized by a high degree of porosity reflected by the excessive presence of voids filled by air and water [11]. Indeed, according to Figure 3, the total porosity at the basalt soil is of the order of 70% unlike that determined at the level of the calcareous soil which is of the order of 43%. The aeration and retention porosities are important at the level of the basaltic substrate (Pa = 16% and Pr = 55%) whereas for the limestone they are low (Pa = 9% and Pr = 36%).

Table 2: Physical and Chemical properties of both soils

Settings		Limestone soil	Basaltic soil
Granulometry (%)	Clay	15	57
	Fine silt	31	15
	Coarse lime	8	9
	Stringers	39	24
	Fine sand	16	16
	Coarse sand	31	3
	Sands	47	19
Apparent density (g/cm^3)		1,7	1.29
Porosity (%)	Pt	43	70
	Pa	9	16
	Pr	36	55
Total $CaCo_3$ (%)		80	12
C (%)		0.55	5.12
O. M. (%)		0.95	8.8
Total N (%)		0.05	0.48
C/N		11	10.6
P_2O_5 (ppm)		1.11	1.60
pH at 25°C	H_2O	8.40	6,5
	KCL	8.5	6.11
Exchangeable bases (meq/100g)	Na^+	1.46	1.03
	K^+	0.12	0.99
	Ca^{2+}	31	1.37
	Mg^{2+}	1.02	0.1
CEC (meq/100)		1.5	41.0
CE (mS/Cm)		0.25	0.89
Salinity (g/l)		0.175	0.623

It has been shown in Canada in 1986 that there are strong negative correlations between organic matter content and bulk density [12]. The higher the density of soils, the lower the organic matter content [13]. According to Mimouni (1996) [14] and Baize (2000) [15], the lower the bulk density, the more porous the soil. This parameter globally reflects the state of compaction of the soil which explains the high calculated value of the apparent density in the limestone substrate (1, 7) compared to that of the basalt (1, 3) [16].

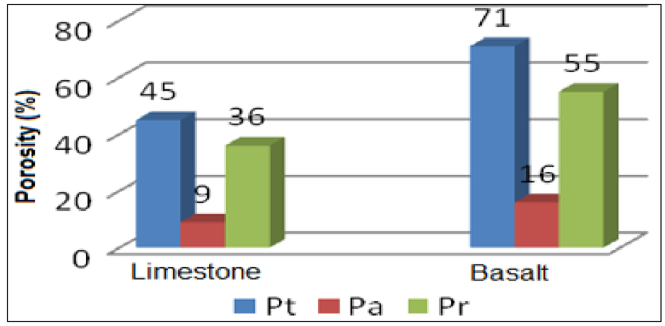

Fig 3: Porosities of calcareous soil and basaltic soil.

The results of the chemical analyzes of the two substrates show a low content of $CaCO^3$ in the basaltic substrate whereas it is of the order of 80% in the calcareous substrate. The presence of limestone gives the soil specific characteristics in terms of physical and chemical behavior and influences its biological activity. Its total absence results in a gradual acidification, more or less rapid according to the pedoclimatic context. Soils containing less than 5% $CaCO^3$ are systematically basic whereas the soil with 50% $CaCO^3$ is highly calcareous [17]. This result is consistent with that found by Chouraichi (2009) [18] who infers that soils with high sand content often have a high to very high total $CaCO^3$ content.

According to Table 2, the pH measurement gave a value of 6.5 in the water and 6.1 in the KCl for the basaltic substrate, whereas it is of the order of 8.4 in the water and 8.5 in KCl for the calcareous substrate. Le Tacon (1978) [19] mentioned that theoretically, at atmospheric pressure and in the presence of an excess of carbonate the pH of the soil solutions is 8.5. A pH close to 7 is more recommended and may be suitable for all species, while increasing the pH reduces the solubility and absorption of aluminum, copper, cobalt, zinc, iron and more particularly manganese [20]. According to Benseghir (1996) [21], the substrate must have a pH between 5 and 8, outside these limits, the plant will face mineral nutrition problems. It also influences the contamination by various fungi as it can cause root burns [22]. Loue, 1986 has demonstrated the influence of pH on assimilation and absorption of trace elements by plants. These elements are more mobile and more available when the pH is lower [23].

The results of the analyzes of the organic matter showed a low organic matter content for the calcareous soil and very strong for the basaltic soil. The presence of organic matter ensures better aeration and warming of the soil [24], significant retention of water [25]. It also allows the release of mineral elements under the action of microorganisms [26]. The higher the organic matter content, the greater the mineralization phenomenon [10, 27]. According to Le Tacon (1978) [19], quantitative and qualitative changes in organic matter, in the presence of limestone, have important consequences on the mineralization of nitrogen. Ammonification is lower in carbonate soil than in decarbonated soil. Also the same author mentioned that when the pH increases the nitrogen transformation decreases. All these elements explain the high nitrogen content (0.48%) for the basaltic substrate which proves to be favorable for the development of the plants and a very low content (0.05%) for the calcareous substrate.

The ratio of carbon (C) to nitrogen (N), long used by foresters, indicates the degree of evolution of organic matter and the degree of resistance to microbial degradation [28, 29]. According to LANO (2008) [17] the more nitrogen there is, the better the decomposition by bacteria. In both substrates this ratio is close to 11% and according to Bonneau (1995) [30] when C / N is less than 25% the nitrogen supply by the trees becomes possible [23].

Calcium (Ca) plays a decisive role in the physical, chemical and biological fertilization of the soil. It is a nutrient for plants and is the cation mainly adsorbed on CEC [17]. Table 2 shows that Ca is the most dominant element in calcareous soil, of the order of 31 meq / 100g and for basaltic soil, 1.37 meq / 100g.. The important content of this element in the calcareous soil is due to the high rate of CaCO3 that this soil contains and which exceeds 80%. For basaltic soil this value can be explained by the presence of organic matter which causes, via the water-soluble organic products, the dissolution of large quantities of Ca [19]. According to Le Tacon (1978) [19], quantitative and qualitative changes in organic matter, in the presence of limestone, have important consequences on the mineralization of nitrogen.

According to the results obtained, the values of assimilable phosphorus, element playing a role of physiological catalyst by promoting the growth of the plant and the development of the roots, are very weak for the two soils.

The content of magnesium (Mg) in nature can be very low, case of basaltic substrate 0.1 meq / 100g). For the calcareous substrate, this element is of the order of 1.02 meq / 100g. This is consistent with the results reported by LANO (2008) [17] stating that soils on limestones may contain very high levels of Mg.

As regards the potassium content (K), it is of the order of 0.99 meq / 100g for the basaltic substrate and for the calcareous substrate it is very low (0.12meq / 100g). This can be explained by the fact that limestone is poor in organic matter [31-33].

The sodium (Na) is a secondary element for plant development. However, its low natural content in soils is sufficient to meet the needs of the plants. On the other hand, an excess of sodium leads to a risk of degradation of the soil structure, which is reflected on the surface by a worsening of the balance and a rise in pH [17]. According to Table 2, the basaltic substrate has an average Na content of 1.03 meq / 100g and the calcareous substrate has a higher value (1.46meq / 100g). Sodium is an element retained with low energy on the CEC. It is therefore easily and rapidly washable by the draining winter rains. A slight excess of sodium is therefore usually only transient.

According to Duchaufour (1977) [34], the cationic exchange capacity (CEC) of the soil allows the reversible storage of certain nutrients for the plant (potassium, magnesium, calcium). The higher the CEC, the more it can retain cations in the soil that can be used to improve its structure and fertility. CEC is a fundamental property that depends on clay content and organic matter [35-36]. According to the results, the CEC at basalt level (41meq / 100g) is better compared to that of limestone (1.5meq / 100g). This result is explained by a high content of organic matter in the basalt (8.8%) compared to the calcareous soil (1%).

In general, the optimum electrical conductivity (EC) at the soil level is between 1.5 and 2.25 mmhos / cm and should not exceed 3 mmhos / cm, depending on the dilution ratio 1/2. An EC less than 1.5 indicates poor soil fertility [37, 38]. According to Serra-Wittling *et al*., (1995) [39] culture substrates should have a low EC (less than 3 mS / cm). Beyond this norm, there could be negative consequences for the germination and emergence of seeds of certain tree species [40]. The EC results of the basaltic and calcareous substrate have values in accordance with the standards of the culture media (0.25 mS / cm for limestone and 0.89 mS / cm for basalt).

EC measurement allows to calculate salinity in soils. The results showed a low salinity level at both substrates; 0.17g / l for limestone and 0.6g / l for basalt. When the salt content is too high, plant growth is affected; water and mineral elements are less absorbed by the root system. This results in burning of the roots and foliage.

The results of this study are consistent with those of Chouraichi (2007 and 2009) [41,18] which demonstrated that cedar dieback in the Middle Atlas zone is related to the soil moisture regime which depends mainly on the equivalent humidity, the apparent density the soil, the substrate on which the soil is formed, the percentage of the fine soil which is a function of the total sand content, the $CaCO^3$ content and the exposure which may be unfavorable.

A single constraint cannot explain the decline of the cedar. The greater the number of unfavorable parameters, the higher the cedar dieback rate.

Conclusion

The quality of the substrate is an important parameter that has a direct influence on the growth of plants and particularly forest. The substrates have very different hydrodynamic, physical and chemical characteristics, the evaluation of which is essential for soil assessment.

For the hydrodynamic properties, the analysis results converge towards a good drainage of the basaltic substrate. On the other hand, the calcareous substrate has a low water conductivity and humidity and medium infiltration and permeability.

Concerning the analysis of the physical characteristics, the basaltic substrate, with a lumpy structure and a sandy-clay texture, has larger porosities and a lower da than the limestone which has a granular structure and a sandy-loamy texture. This gives the basaltic substrate good aeration and a high water retention capacity.

The chemical analyzes show that the basaltic substrate has balanced Na, Ca and K contents. This is justified by a high OM content and an important CEC. On the other hand, the calcareous substrate has high levels of Ca, Mg and Na and a low level of K. The potassium deficiency in the limestone is due to leaching and induces an imbalance between the exchangeable base contents. Basalt contains a low $CaCO^3$ value, while the calcareous substrate has a high $CaCO^3$

content. The latter causes disorders of nitrogen nutrition which causes difficulties in the growth of conifers.

These results show that the characterization of the substrates before planting on the reforestation sites is essential. To better appreciate the soil in the choice of these sites, a study on other parameters such as equivalent humidity, wilting moisture, water availability, relative water content, etc., proves important.

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