Chemical Characterization of *Acacia cyanophylla* Compost as Growth Substrate

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Abstract: To evaluate the quality of *Acacia cyanophylla*-based compost and to study the possibilities of improving its chemical proprieties, raw and screened *Acacia cyanophylla* compost according to different techniques were incorporated with rabbit manures compost in various proportions. Growth substrates obtained were subjected to chemical analysis (pH, Electrical Conductivity, Salinity, Organic Matter, Total Organic Carbon, Total Nitrogen, C/N ratio and potassium and phosphorus contents). Results obtained showed variations in chemical parameters depending on the type of screening methods (simple or double) and the nature of the mixture considered. Even if significant differences were observed for diverse substrates, recorded values were in the standards of acceptance, only for potassium and phosphorus contents, were it is necessary to optimize the incorporation of rabbit manures compost to adjust the level in those minerals in *Acacia cyanophylla* compost.

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Key words: *Acacia cyanophylla* compost, screening, mixture, growth substrate, chemical characterization.

1. Introduction

In order to modernize forest nursery sector, Tunisia was oriented towards the inclusion of new production technologies and nursery management. The optimization of forest seedlings cultivation techniques (irrigation, fertilization, pesticide treatments...) can't alone ensure seedlings quality production if the physicochemical properties of growth media aren't satisfactory (Guehl et al. 1989; Landis et al. 1990; Alsanius et al. 2004; M'Sadak et al. 2012). Peat is the most commonly used material as a plant substrate, although for reasons of cost and sustainability, alternative materials are being investigated (Hernández-Apaloaza et al. 2005), including waste material such as pine bark, various biosolids, ash derived from coal combustion, etc. (Stewart et al. 1998; Abad et al. 2002; Hernández-Apaloaza et al. 2005; Chen and Li, 2006). Several research studies have shown the importance of using forest biomasses compost, especially *Acacia cyanophylla* compost, for the conception of suitable growth medium for the production and growth of forest seedlings; those composts have shown promising results. That's why; compost of Acacia was the subject of several research projects in Tunisia. Substrates containing composted bio-solids and yard debris had superior performance, but not all their physic-chemical properties are within the suggested optimum range (Fitzpatrick and Verkade, 1991). Material destined for use as a plant substrate must possess a series of physical (low apparent density, high porosity, good distribution of air and water) and chemical properties (appropriate pH, high cation exchange capacity, sufficient provision of nutrients, low salinity, absence of elements and phototoxic compounds), among other properties (Abad et al. 1993). In this regard, the present study intends to evaluate the chemical characteristics of crude and screened *Acacia cyanophylla*-based compost and in mixture with rabbit manures compost. The final objective is the development of a suitable growth substrate for the production of forest seedlings in containers.

2. Materials and Methods

2.1. Preparation of Substrates Being Tested

The compost used in the present study was manufactured from fresh woody materials (branches, and leaves) of *Acacia cyanophylla*. Windrow piles, 1.5 m high by 10 m long, were constructed using shredded materials. Forced aeration was used for the first eight weeks (bio-oxidative phase), followed by a six-month maturation period during which the piles were turned periodically to maintain adequate O_2 levels. During the maturation phase, the pile was turned every 15 days in order to improve both the O_2 level inside the pile and the homogeneity of the material. Ammonium nitrate was added to windows to ensure Carbon-Nitrogen (C/N) nutritional balance. Pile moisture was controlled weekly by adding enough water to obtain moisture content of not less than 50%. For its optimum use as growth substrate in forest nursery, the end product was passed through different size screening meshes (Table 1). Taking into account *Acacia cyanophylla* compost characteristics, it was mixed with rabbit manures compost, at different ratio, in order to prepare suitable growth media for forest nursery. (Table 2) shows the volumetric formulations of the different media used in this study.

Table 1. Screening techniques and meshes used for the preparation of screened compost

Screening Technique	Meshes used (mm)	Screened compost
Simple Screening (SS)	6 mm	SS1
	8 mm	SS2
	12 mm	SS3
Double Screening Technique (DS)	(8) and (12) mm	DS1
	(12) and (8) mm	DS2

Table 2. Growing media used in the study

Media	Formulation
RACC	RACC (100%)
RMC	RMC (100%)
M1	RACC (75%) + RMC (25%)
M2	SS3 (75%) + RMC (25%)

RACC: Raw *Acacia cyanophylla* compost
RMC: Rabbit manures compost
SS3: 12 mm screening mesh *Acacia cyanophylla*-based compost
% Volume in brackets.

2.2. Chemical Characterization of Substrates

Raw *Acacia cyanophylla* compost, rabbit manures compost, simple and double screened *Acacia cyanophylla* compost by diverse screening meshes and different substrates mixtures were chemically analyzed according to the following parameters: pH, Electrical Conductivity (EC), salinity (S), Organic Matter (OM), Total Organic Carbon (TOC), Nitrogen (N), Carbone-Nitrogen ratio (C/N), phosphorus (P) and potassium (K) contents.

2.3. pH

pH measurement was carried out according to international standard (ISO, 1994). pH was analyzed in a 1:5 (v/v) water extract. Dried substrate sample (20 g) was diluted in 5 times its volume (1/5) of water (100 ml distilled water). Suspension was put to stirring for 5 minutes then left to settling for at least two hours. The pH reading was done through a pH meter.

2.4. Electrical Conductivity and Salinity

Electrical conductivity (EC) is the measure of soluble ions concentration in order to assess the salinity of the substrate (Tiquia, 2010). It was determined by conductometer and is expressed in (ms/cm) or (mmhos/cm^3). EC was analyzed in a 1:5 (v/v) water extract (ISO, 1994). Salinity (S), expressed in g L^{-1}, was estimated from the electrical conductivity (EC) using the following equation: S = 0.7 x EC.

2.5. Organic Matter and Total Organic Carbon

The determination of OM rate at each substrate involves the following two steps:

20 g of each substrate sample was put in the oven for 24 hours at 70°C. 3 g of previously dried substrate sample was put for 2 hours in 900°C oven for at least 6 hours in a muffle. Dry residue was determined after calcinations. The OM content was determined according to the following equation:

OM (%) = [(M1-M2)/M1] x 100

M1: Weight before sample calcinations (mg);
M2: Weight after sample calcinations (mg).

Total Organic Carbon (TOC) is calculated according to the following equation:

TOC (%) = [OM (%) / 1.8] x 100.

2.6. Nitrogen and C/N Ratio

Nitrogen (N) was determined according to Kjeldahl method (Goyal et al. 2005). 200 mg of the substrate and 5 ml of sulfuric acid (H_2SO_4) was put in a flask (mineralization phase). After 30 min, 200 mg of selenium catalyst was added to the suspension and passed in the digester heating for 1 hour until an appearance of yellow color (digestion phase). After cooling, 30 ml of distilled water was added to the flask; 30 ml of sodium hydroxide was added to alkalinize the medium (distillation phase). Nitrogen content on each substrate was displayed directly on a sheet computer.

2.7. Phosphorus

The estimation of phosphorus (P) was carried out by atomic absorption spectrometry using the vitrovanadomolybdate reagent. Phosphoric acid (H_2PO_4) gives a yellow phosphor-molybdic complex, which its optical density was measured by a spectrophotometer at 430 nm. After the calcinations of substrate samples in the oven, cinders were added to distilled water. In a volumetric flask of 25 ml, 10 ml of cinders solution already prepared was put in the flask; 5 ml of nitrovanadomolybdique reagent and 10 ml of distilled water were added to the flask. After one hour, suspension was passed at photo-colorimeter. P_2O_5 content was determined using the following formula: P_2O_5 (%) = 2.29 x P (%).

2.8. Potassium

The determination of potassium content was carried out using a flame photometer. 1 g of each substrate sample was put in a porcelain dish and placed in oven for two successive calcinations process (first calcinations at 220° C for 2 hours and a second calcination at 550° C for 6 hours). After cooling, 2 ml of hydrochloric acid (HCl) was added in each capsule. Sample substrates were heated in a sand bath until the total evaporation of HCl. 5 ml of HCl (N/10) and 95 ml of distilled water were added in volumetric flasks of 100 ml. Samples were passed through photometer after passing the appropriate calibration solutions to potassium mineral (K^+). The K_2O content was determined according to the following formula: K2O (%) = 1.2 x K (%).

2.9. Experimental Design

The chemical characterization of all substrates was carried out according to a randomized block design, with four replications for each chemical treatment. All results reported in the text are the means of determinations made on four replicates. RACC was considered as control substrate and the different media (Table 1 and 2) as treatments.

2.10. Statistical Analyses

Chemical parameters of substrates were evaluated with analysis of variance (ANOVA) and Duncan multiple range test ($p < 0.05$) using the SPSS (13.0) System. Differences were considered significant at the 5% level (means followed by different letters).

3. Results

3.1. pH

Table 3 reports pH results of different growth substrates tested. pH of different substrate samples are within the optimum range (pH is close to neutral) which is appropriate to the assimilation of nutrients. It should be noted that there is a significant difference in pH between the tested substrates. The pH of the RACC was smaller than RMC. Substrate resulting from simple screening with 6 mm mesh has the lowest pH, while the substrate resulting from double screening using successively 12 mm and 8 mm meshes has the highest pH, in comparison with others screened composts, however, this pH remains lower than of Raw *Acacia cyanophylla* compost and Rabbit manures compost. Accordingly, screening significantly lowers pH of substrates; it's the same case for mixtures.

Table 3. pH of different substrates

Samples	Formulation	pH
[**1**] Raw *Acacia cyanophylla* compost	RACC	6.7^{c}
[**2**] Rabbit manures compost	RMC	7.7^{a}
[**3**] Substrate resulting from simple screening with 6 mm mesh	SS1	6.0^{g}
[**4**] Substrate resulting from simple screening with 8 mm mesh	SS2	6.1^{fg}
[**5**] Substrate resulting from simple screening with 12 mm mesh	SS3	6.3^{de}
[**6**] Substrate resulting from double screening consecutively with 8 mm and 12 mm meshes.	DS1	6.2^{ef}
[**7**] Substrate resulting from double screening consecutively with 12 mm and 8 mm meshes.	DS2	6.4^{d}
[**8**] Mixture: 75% RACC + 25% RMC	M1	6.9^{b}
[**9**] Mixture : 75% SS3 + 25% RMC	M2	6.6^{c}

(*) Means followed by the same letter are not significantly different at 5% level according to Duncan test.

3.2. Electrical Conductivity and Salinity

Table 4 shows the results for the electrical conductivity (mmhos/cm^3) and salinity (g L^{-1}) of different tested growth substrates.

Table 4. Electrical Conductivity (EC) and Salinity (S)

Samples	EC (mmhos cm^{-3})	Salinity (g L^{-1})
RACC	1.70^{bc}	1.19^{bc}
RMC	1.50^{efg}	1.05^{efg}
SS1	1.65^{c}	1.15^{c}
SS2	1.50^{efg}	1.05^{efg}
SS3	1.40^{g}	0.98^{g}
DS1	1.80^{ab}	1.29^{ab}
DS2	1.20^{h}	0.84^{h}
M1	1.64^{cd}	1.05^{cd}
M2	1.77^{ab}	1.24^{ab}

Electrical conductivity and salinity, which their values affect considerably plant growth, are within the acceptable standards for all substrates. However, when particles size decreases (simple or double screening), values of electrical conductivity and salinity decreases significantly. Unlike pH, salinity of the substrate resulting from double screening using consecutively 12 mm and 8 mm meshes is significantly higher than salinity of substrate resulting from double screening via 8 mm and 12 mm meshes consecutively. It is the same for mixtures.

3.3. Organic Matter and Total Organic Carbon

Table 5 below reports the results observed in the rate of Organic Matter and Total Organic Carbon of different growth substrates. Results show that the rate of organic matter in different growth substrates is influenced by particle size obtained from simple or double screening. When particles size increases, organic matter content increases and inversely. The organic matter content is significantly lower in substrates resulting from a double screening using consecutively 12 mm and 8 mm meshes than from substrates resulting from double screening using repeatedly 8 mm and 12 mm meshes. Organic matter is significantly higher in substrates resulting from simple screening with 12 mm mesh and double screening using consecutively 8 mm and 12 mm meshes. From these findings, we suggest that screening operation leads to a loss in organic matters of substrates. The loss in OM was also noted in studied mixtures.

Table 5. Organic Matter (OM) and Total Organic Carbone (TOC)

Samples	OM (%)	TOC (%)
RACC	64.3^{c}	35.7^{c}
RMC	67.2^{a}	37.3^{a}
SS1	60.6^{h}	33.6^{h}
SS2	61.4^{g}	34.1^{g}
SS3	63.0^{f}	25.0^{f}
DS1	63.8^{e}	35.4^{e}
DS2	53.6^{i}	29.7^{i}
M1	65.0^{b}	36.1^{b}
M2	64.0^{d}	35.5^{d}

(*) Means followed by the same letter are not significantly different at 5% level according to Duncan test.

3.4. Nitrogen and C/N Ratio

Table 6 below reports results of Nitrogen content (N) and C/N ratio of different growth substrates tested. There were significant differences in terms of nitrogen contents and C/N ratio. The lowest nitrogen content was recorded in RACC while the highest rate was noted in rabbit manures compost. Concerning simple screened compost, the more the mesh used in screening is smaller, the more the rate of Nitrogen is lower. Screened compost resulting from double screening using consecutively 8 mm and 12 mm meshes has lower N content than screened compost resulting from double screening using repeatedly 8 mm and 12 mm meshes. M2 mixture (75% SS3 + 25% RMC) has better N content than M1 mixture (75% RACC + 25% RMC). Concerning C/N ratio, the highest value corresponds to the RACC, whereas the lowest was recorded in simple screened compost using 6 mm mesh.

Table 6. Nitrates content (N) and C/N ratio

Samples	N (%)	C/N
RACC	1.23^{g}	29.0^{a}
RMC	1.81^{a}	20.6^{g}
SS1	1.76^{b}	19.1^{h}
SS2	1.46^{d}	23.3^{e}
SS3	1.45^{d}	24.1^{d}
DS1	1.31^{f}	27.0^{b}
DS2	1.37^{e}	21.7^{f}
M1	1.37^{e}	26.3^{c}
M2	1.54^{c}	22.9^{e}

(*) Means followed by the same letter are not significantly different at 5% level according to Duncan test.

3.5. Phosphorus

Table 7 below illustrates results concerning the percentages of phosphorus (P) and phosphoric acid (P_2O_5) of different growth substrates tested. This table shows that RACC has the lowest phosphorus contents; however, rabbit manures compost has the highest P_2O_5 content. This observation justifies the need to mix between the two types of composts to correct the value of phosphorus. This value was also influenced by the particle size, the more the size of particle increase and the more the phosphorus content increases significantly. M2 mixture (75% SS3 + 25% RMC) has the highest level of P and P_2O_5.

Table 7. P and P_2O_5 contents

Samples	P (%)	P_2O_5 (%)
RACC	0.03^{h}	0.07^{h}
RMC	0.45^{a}	1.03^{a}
SS1	0.04^{g}	0.09^{g}
SS2	0.06^{f}	0.14^{f}
SS3	0.08^{e}	0.18^{e}
DS1	0.10^{d}	0.23^{d}
DS2	0.09^{d}	0.20^{d}
M1	0.13^{c}	0.30^{c}
M2	0.17^{b}	0.4^{b}

(*) Means followed by the same letter are not significantly different at 5% level according to Duncan test.

3.6. Potassium

Table 8 shows recorded results concerning potassium (K) and potassium oxide (K_2O) of different growth substrates tested. RACC has the lowest K_2O content; however, RMC has the highest potassium content. These results are similar with those found in phosphorus; that's why; it is evident to make mixture between *Acacia cyanophylla* compost and rabbit manures compost to correct potassium content in the final substrate. Similarly, results found relating to screened compost are also consistent with those observed for phosphorus.

Table 8. K et K_2O contents

Samples	K (%)	K_2O (%)
RACC	0.41^{e}	0.07^{e}
RMC	1.08^{a}	1.03^{a}
SS1	0.46^{d}	0.09^{d}
SS2	0.53^{c}	0.14^{c}
SS3	0.36^{f}	0.18^{f}
DS1	0.32^{g}	0.23^{g}
DS2	0.39^{e}	0.20^{e}
M1	0.60^{b}	0.30^{b}
M2	0.54^{c}	0.40^{c}

(*) Means followed by the same letter are not significantly different at 5% level according to Duncan test.

4. Discussion

According to the results obtained, it is clear that the chemical behavior of different tested substrates was influenced by the nature and size of substrate used and ratio and nature of the mixture. The pH values of the different substrates were in the optimum range of neutrality and this irrespective of the screening procedure or the nature of the mixture. However, Landis et al. (1989); Lamhamedi (2000) showed that the relatively neutral pH of mature *Acacia cyanophylla*-based compost, combined with the poor quality of irrigation water could negatively affect the nutrient availability in the root plants. Indeed, irrigation water in nurseries are generally loaded with bicarbonate and carbonate, the gradual accumulation of those mineral in growth substrate cause an increase in pH, which has a direct effect on nutrient availability, even if they are present in the nutrient solution. This effect on nutrient availability can be explained by the appearance of marked symptoms of micronutrient deficiency particularly in woody and deciduous plant (Lamhamedi, 2000; Gogorcena et al. 2001). At a pH of 7.5, the absorption of iron by the plant becomes very limited and for a pH above 8.5, growth medium becomes alkaline and the assimilation of Cu, Zn, Mn, Fe and N decreases gradually (Amand et al. 2008). Sanchez-Monedero et al. (2004) showed that the increase in EC inhibits water imbibitions and reduces seeds germination. A high EC can delay the development of transplanted seedlings (Kratky and Mishima, 1981; Herrera et al. 2008). According to Soumare et al. (2002), growing media should have a low EC less than 3 mS/cm. Beyond this limit, the negative impact could occur during seeds germination and emergence of certain tree species. The EC may be an indicator of nutrients availability in the culture medium. Plants developed better roots in substrate containing few nutrients (Comtois et al. 2004). A high value of EC represents a large amount of ions in solution, making it more difficult to absorb water and nutrients by plant. The non-availability of nitrogen for plants in growth substrate is one of the most important factors inducing crop loss (Gruda et al. 2000). According to Lemaire et al. (1989), growth medium with low C/N ratio are not suitable, as they evolve over time through mineralization process, this lead to substrate subsidence, changes in porosity related to dry matter losses and clogging by fine particles. Competition for oxygen between microorganisms appears especially as the porosity decreases. According to Mustin (1987), mature compost should have a C/N ratio between 8 and 15. These data was not in agreement with our results, which involve that the tested substrates are not yet ripe. It should be suggested that other factors were responsible for high values of C/N ratios. It is also evident to make mixture between rabbit manures compost, which is rich in minerals ions, and *Acacia cyanophylla* compost, which has low mineral elements contents, by respecting a good balance between the different elements. Indeed, according to Bouhaouach et al. (2009), an excess of K can interfere with the absorption of Ca and Mg, due to the antagonism between Ca and K. Calcium makes soil environment favorable to microorganisms, which are agents of organic matter decomposition.

5. Conclusions

This study allowed characterizing the chemical behavior of a number of growth substrates based of *Acacia cyanophylla* compost, riddled or in mixture with rabbit manures compost, intended for the production of aboveground forest plants. The main results are reported below. *Acacia cyanophylla* compost is not a suitable substrate for forest seedling growth because of its poor ions contents, which justifies its screening or mixing with rabbit manures compost to improve its nutritive proprieties. The best mixture ratio is 75% simple screened with 12 mm mesh *Acacia* compost and 25% rabbit manures compost.

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