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Compost N-mineralization emanated from natural Xerophytic Mediterranean Vegetation debris, soil application and the effects of zeolite

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Keywords: Xerophytic Mediterranean vegetation debris, composting, clinoptilolite, N-mineralization

Reforestation project – Plant raw materials

- The management of plant raw material produced by the maintenance of natural Xerophytic Mediterranean vegetation during a reforestation project is a difficult procedure
  - High lignin content
  - Lack of efficient management plans by the local authorities

Reforestation project – Green wastes nowadays

- Are crumbled by a shredder and applied on soil surface, increasing fire risk during xerothermic seasons.

- Are discharged unexploited to landfill sites, causing:
  - Rapid filling of landfills (almost 65% of the total discharged wastes)
  - Fire risk increase that can be also spread from landfills to residential areas
  - Burden municipalities with fees (transportation, fuels, routes to and from the landfill sites, machinery and vehicles damages)
  - Environmental and social impacts

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Reforestation project – Composting green wastes

- Composting green wastes produced by the maintenance of natural Xerophytic Mediterranean vegetation (lignin-rich plant raw materials) during a reforestation project by using also other agricultural additives (zeolite)
  - Produce a safe and environment friendly product, appropriate for application to forest ecosystems
  - Avoiding soil transportation which is related to possible transport of pathogens, and weed seeds
  - Avoiding the use of chemical fertilizers to natural ecosystems

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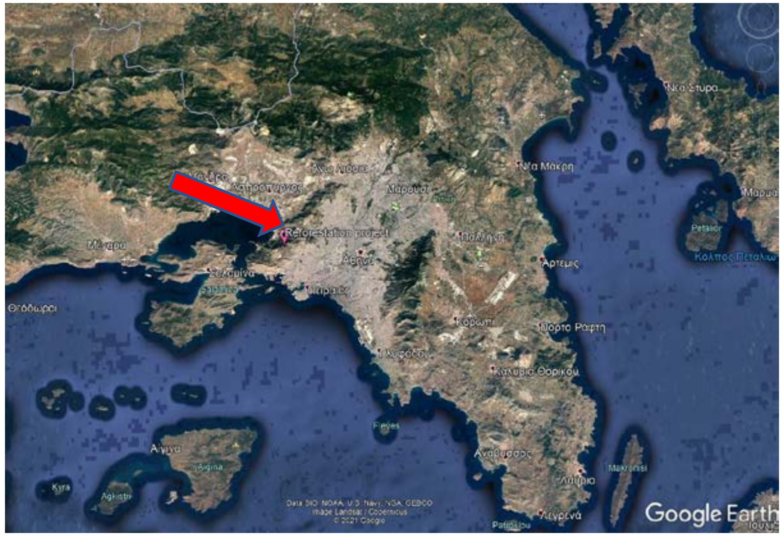
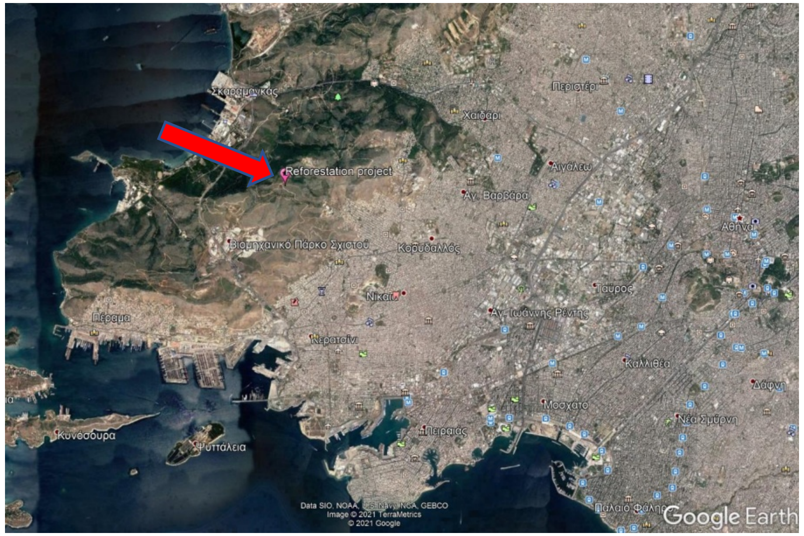
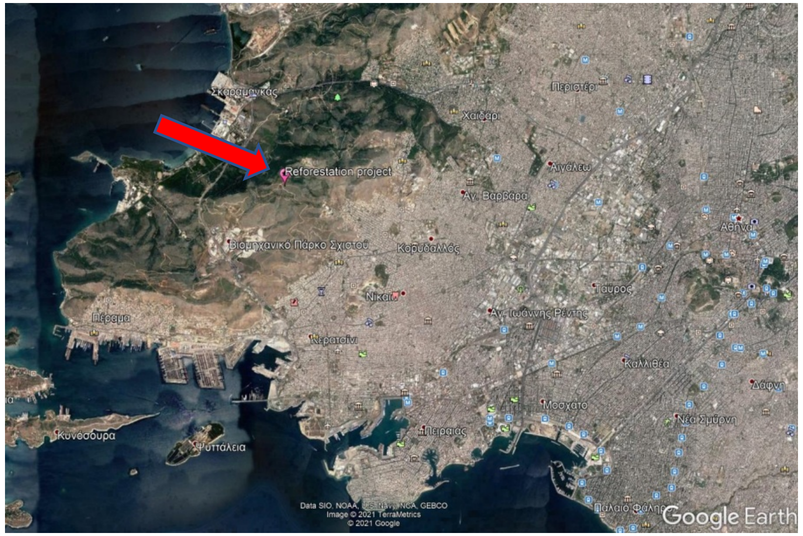
Egaleo mountain – Reforestation project





Egaleo maountain

- Region of Attica, Greece
- 65 hectares reforestation area in Egaleo mountain
- Egaleo mountain is the natural ending of Parnitha mountain at the Saronic golf
- West side of Attica basin.
- General exposition: various
- Altitude: 204-372 m
- Slopes: gentle to moderate, 8-25%
- Semidry bioclimatic level
- Type of Mediterranean Bioclimate: Intensely Thermo-Mediterranean
- Bushy-grassland
- Natural vegetation of Egaleo mountain: Evergreens, hard-leaf zone of Quercetalia ilicis and in the vegetative place of Oleo-ceratonion
- Reforestation area: Secondary growth of brushwood, with main specie the Phlomis fruticosa. Also, secondary growth of bush from evergreens-broadleaves of Oleo-Lentiscetum phyto-social union, with intense degradation.



Green wastes

- Unhealthy or creeping branches of trees and bushes
- Brushwoods.
- Feedstock:
  - 40% conifers (Pinus halepensis, Cupressus sempervirens, Juniperus phoenicea)
  - 30% bushes (Quercus coccifera, Pistacia lentiscus)
  - 20% brushwoods (Phlomis fruticosa e.t.c.)
  - 10% broadleaved trees (Olea europea subsp. oleaster, Ceratonia siliqua, Cercis siliquastrum)
  - Minimal percentage of underbrush vegetation

Composting green wastes

- Crumbled by a shredder
- Composted with urea (H_2NCONH_2) (46-0-0)

Collecting

Crumbling

Moistening / Urea solution

Composting green wastes

- Tank: 500 L
- Water: 250-300 L
- Urea: 12Kg (46-0-0)
- Green wastes in urea solution: 24 h
- C:N and moisture: corrected

Composting green wastes

- Composting phase: 7 months
- Monitoring temperature, moisture and oxygen content
- Temperature: 50-55^{o}C for 30-40 days.

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Laboratory experiment - Treatments

- Nikea: Soil sample from northern Egaleo mountain
- Keratsini: Soil sample from southern Egaleo mountain
- Compost treatments:
  - 5 g (C_5)
  - 10 g (C_{10})
  - 15 g (C_{15})
- Soil (Nikea) - Compost treatments:
  - 15 g soil (N)
  - 15 g soil - 5 g compost (NC_5)
  - 15 g soil - 10 g compost (NC_{10})
  - 15 g soil - 15 g compost (NC_{15})
- Soil (Keratsini) - Compost treatments:
  - 15 g soil (K)
  - 15 g soil - 5 g compost (KC_5)
  - 15 g soil - 10 g compost (KC_{10})
  - 15 g soil - 15 g compost (KC_{15})
- Compost zeolite treatments:
  - 15 g compost - 1 g zeolite ($C_{15}Z_1$)
  - 15 g compost - 2 g zeolite ($C_{15}Z_2$)
  - 15 g compost - 3 g zeolite ($C_{15}Z_3$)

Laboratory experiment

- Zeolite: Clinoptilolite
- All the samples were mixed with 15 g of 20-mesh acid-washed quartz sand
- Compost portion: < 2 mm to obtain a hogenous samples
- Incubation: plastic cylindrical pipes for 119 days according to procedure suggested by Stanford and Smith (1972), for the determination of the mineralizable N
- A thin glass wool pad was placed over the soil to avoid dispersing the soil when solution was poured into the tube

Laboratory experiment

- Leaching mineral N initially present: 100 mL of 0.01 M $CaCl_2$
- Mineralized N: NO_3^-, NH_4^+
- Nutrient solution devoid of N: 25 mL (0.002 M $CaSO_4 \cdot 2H_2O$, 0.002 M $MgSO_4$, 0.002 M $Ca(H_2PO_4)_2 \cdot H_2O$ and 0.0025 M K_2SO_4)
- Excess water was removed under vacuum (60 cm Hg)
- Incubation: 35^oC
- Aerobic system
- After 24 hours: Mineral N was recovered by leaching with 0.01 M $CaCl_2$ and minus-N solution
- Plastic tubes were returned to the incubator with intermittent leachings of mineral N
    - Days 7, 14, 21, 28, 41, 55, 76, 106, 118 for soil, soil-compost samples
    - Days 9, 17, 23, 31, 44, 65, 86, 92, 118 for compost-zeolite samples

Zeolite (Z) properties.

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Analysis results

Nikea (N) and Keratsini (K) soil properties.

Sample	Sand	Silt	Clay	Texture	pH	EC	Organic matter	Total C	Total N	CEC	Calcium carbonate equivalent
	%	%	%			μS cm^{-1}	%	%	mg g^{-1}	cmol Kg^{-1}	%
N	23.4	50.0	26.6	CL	7.67	2380	1.8	1.1	1.20	30.1	27.9
K	27.4	52.0	20.6	SL	7.63	2010	4.7	2.8	3.60	38.4	4.1

Compost (C) properties.

Sample	pH	EC	Organic matter	Total C	Total N	C/N	CEC
		μS cm^{-1}	%	%	%		cmol Kg^{-1}
C	7.90	2945	56.8	33.4	2.17	15.4	109.3

Zeolite (Z) properties.

Sample	Clinoptilolite	Other minerals	pH	Bulk density	Specific density	CEC
	%	%		g mL^{-1}	g mL^{-1}	cmol Kg^{-1}
Z	min 85	max 15	7.50	0.78	2.30	160.3

Summative concentrations of extracted NH_4^+-N and NO_3^--N of 15 g Nikea soil (N) and compost samples (5, 10 and 15 g).

Mineralized N (NO_3^-, NH_4^+)

Summative concentrations of extracted NH_4^+-N and NO_3^--N of compost (5, 10 and 15 g).

Day	C_5		C_{10}		C_{15}	
	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.8	82.0	0.9	223.2	1.4	312.9
14	2.1	104.8	2.6	347.2	3.2	334.1
21	7.4	105.5	10.2	348.3	17.0	337.0
28	9.0	106.3	12.4	349.7	20.2	338.6
41	9.4	106.8	13.1	350.9	22.6	339.4
55	10.1	107.1	14.3	351.1	24.4	339.6
76	10.5	107.2	14.7	354.3	27.3	342.6
106	10.9	109.4	15.3	356.6	27.5	346.3
118	12.7	113.2	18.7	359.5	31.3	349.9

Summative concentrations of extracted NH_4^+-N and NO_3^--N of 15 g Nikea soil (N) and compost samples (5, 10 and 15 g).

Day	N		NC_5		NC_{10}		NC_{15}	
	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.3	0.8	0.3	35.7	0.4	96.9	0.7	177.8
14	1.3	1.4	1.3	40.6	2.1	105.6	2.7	199.9
21	2.2	2.0	3.0	41.4	5.2	106.9	7.9	204.8
28	3.0	2.4	3.9	41.6	14.5	107.1	20.9	205.0
41	3.1	3.1	5.9	42.1	19.2	108.5	26.0	205.7
55	3.7	3.6	9.0	42.6	20.3	108.6	28.1	205.7
76	4.3	6.4	9.7	45.7	21.2	111.8	29.6	209.4
106	4.7	7.8	9.8	46.7	21.3	115.6	29.7	213.3
118	5.5	8.6	11.4	48.0	24.1	116.9	33.3	214.2

Summative concentrations of extracted NH_4^+-N and NO_3^--N of 15 g Nikea soil (N) and compost samples (5, 10 and 15 g).

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Mineralized N (NO_3^-, NH_4^+)

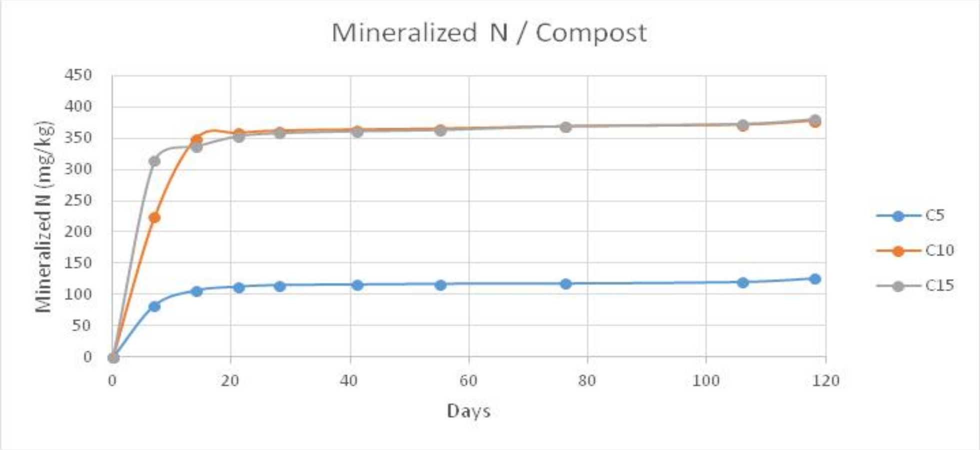
Summative concentrations of extracted NH_4^+-N and NO_3^--N of 15 g Keratsini soil (K) and compost samples (5, 10 and 15 g).

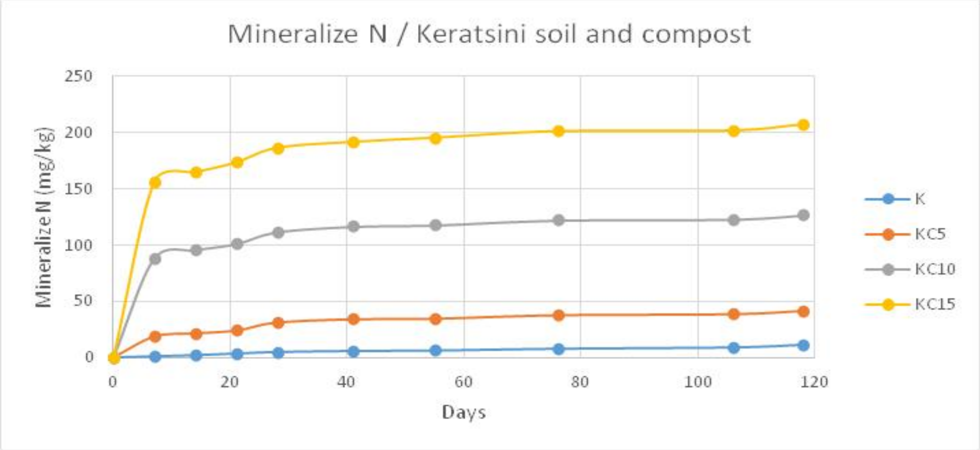
Day	K		KC_5		KC_{10}		KC_{15}	
	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	0.2	0.8	0.3	18.6	0.4	88.0	1.0	155.5
14	0.7	1.3	1.0	20.6	1.3	94.5	2.0	163.0
21	1.7	1.8	2.8	21.4	4.3	96.9	6.4	167.3
28	2.7	2.2	9.8	21.6	14.7	97.1	18.9	167.7
41	2.9	3.0	10.1	24.1	18.5	98.1	23.5	168.4
55	3.2	3.0	10.7	24.1	19.8	98.1	27.3	168.4
76	3.6	4.3	12.5	25.3	22.7	99.5	31.0	170.4
106	3.9	5.2	13.0	25.9	22.8	100.3	31.1	171.1
118	5.6	5.9	14.5	27.2	25.3	101.4	34.8	172.8

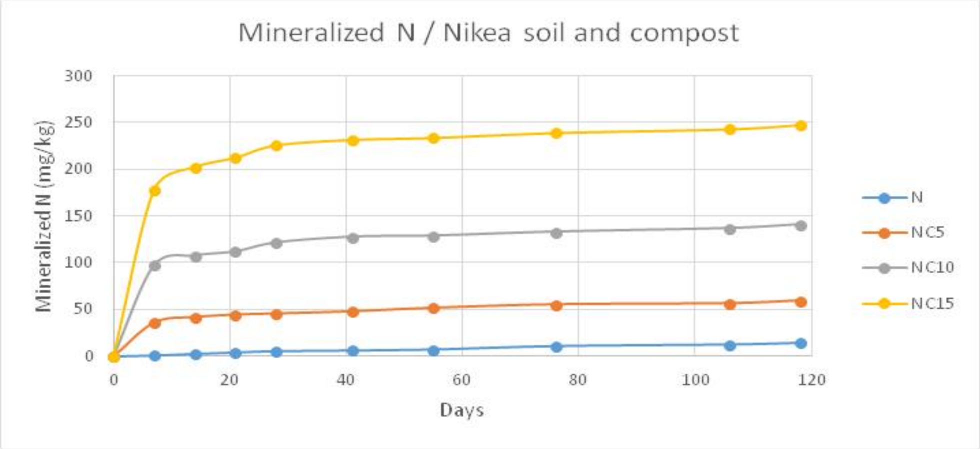
Summative concentrations of extracted NH_4^+-N and NO_3^--N of 15 g compost (C) and zeolite (Z) samples (1, 2 and 3 g).

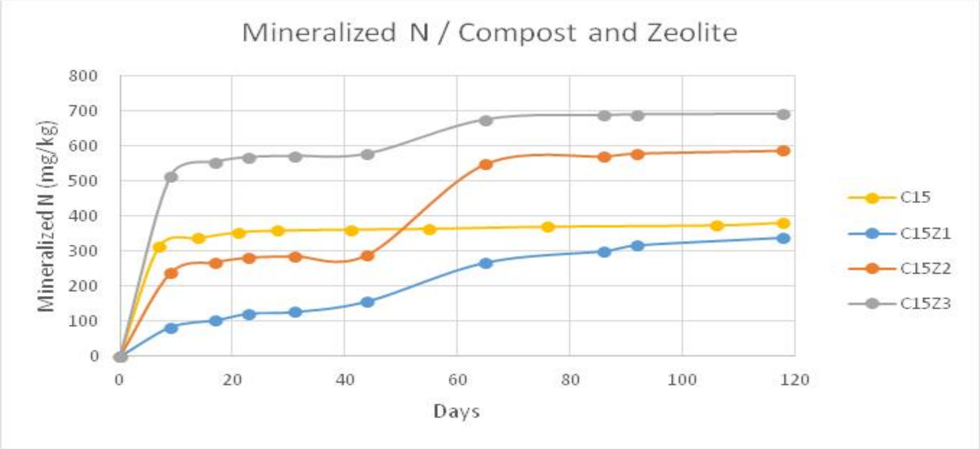
Day	CZ_1		CZ_2		CZ_3	
	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N	NH_4^+-N	NO_3^--N
	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}
0	0.0	0.0	0.0	0.0	0.0	0.0
9	0.5	83.2	1.5	237.2	2.0	512.3
17	4.2	99.2	8.5	260.7	11.2	543.4
23	16.1	106.4	17.6	264.7	21.0	547.1
31	19.8	107.6	19.7	266.4	23.3	548.2
44	21.4	136.2	20.5	270.0	24.5	553.3
65	22.8	245.6	24.4	524.9	26.0	649.5
86	23.9	276.9	25.6	545.6	26.6	660.7
92	24.5	293.1	25.9	553.4	26.8	662.3
118	24.7	314.4	26.1	561.3	26.9	664.3

Mineralized N (total)









Results and discussion 1

- N mineralization of compost generally occurs in two phases, a rapid exponential mineralization phase (the first 15 days), followed by a slow linear mineralization phase (Cambardela et al., 2003). Also nitrogen mineralization of soil-compost mixtures dominate in the early stages of decomposition (the first 30 days).

Results and discussion 2

- The amounts N-mineralized in Nikea soil (N) are higher than Keratsini soil (K), although the soil organic matter content is lower. The same conditions in the soil-compost mixtures were observed during the 118 days of the incubation. Possible the higher concentration of $CaCO_3$ equivalent in Nikea soil enhance biological activities such as mineralization and nitrification (Meiwes, 1995, Demeyer. 2001). According to Jonathan et al (2009) Food waste compost treatments with $CaCO_3$ equivalent showed significantly higher nitrate contents, because the buffering capacity of lime could alleviate the pH reduction during the nitrification. The addition of alkaline materials like lime successfully buffered against the inhibitory low pH conditions during food waste composting and created a suitable environment for the microbial degradation. Addition of alkaline amendments at 1.88% $CaCO_3$ equivalent was adequate to increase the organic decomposition by raising the pH and reach maturity.

Results and discussion 3

- The same amounts of N-mineralized in samples C_{10} and C_{15} (10 g and 15 g of compost, respectively), was observed. The concentrations of NH_4^+-N were higher in the C_{15} samples, while the concentrations of NO_3^--N were almost equal. Cause of the intense microbial activity in C_{15} samples, there were increased requirements of oxygen. Possible anaerobic spots were presented during the incubation that enhance the denitrification.

Results and discussion 4

- Higher amounts of zeolite in compost-zeolite mixtures resulted in higher concentrations of N-mineralized. At the 40th day of the experiment, the zeolite saturated by NH_4^+-N, which were produced by the ammonification process and K^+ of the nutritious solution. According to S.E. Jorgensen (1976), ammonium ions are removed from aqueous solutions by zeolites via exchange with cations or by adsorption in pores of aluminosilicate systems. Ion exchange prevails when concentration of ammonium is equal or lower than the concentration of exchangeable cations of the zeolite, and adsorption begins to predominate with increased ammonium content. Due to high selectivity of zeolites toward potassium ions, potassium is the main competitor for ammonium in removal from aqueous solutions by clinoptilolite (Mumpton, 1999). The NH_4^+ ions which were not participated to the zeolite saturation were transformed to NO_3^- by the nitrification process, and therefore higher amounts of N-mineralized were observed. At the end of the experiment, higher concentrations of N-mineralized at the compost-zeolite mixtures were observed than the pure compost samples.

Conclusions

- A rapid exponential N-mineralization phase is observed for the first 15 days for the compost samples and 30 days for the soil-compost samples, respectively.
- Using zeolite (clinoptilolite) as an agricultural additive in compost increase the mineralized nitrogen which is available to the plants.
- Soil carbonated salts enhance biological activities in compost such as mineralization and nitrification.
- Zeolite (clinoptilolite) reduces nitrogen losses due to denitrification.
- Compost made by debris emanated from natural Xerophytic Mediterranean Vegetation and zeolite could be a suitable substrate for reforestations projects, quarry and mine

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Thank you!

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