Quality improvement of cacti and succulents with alternative substrates

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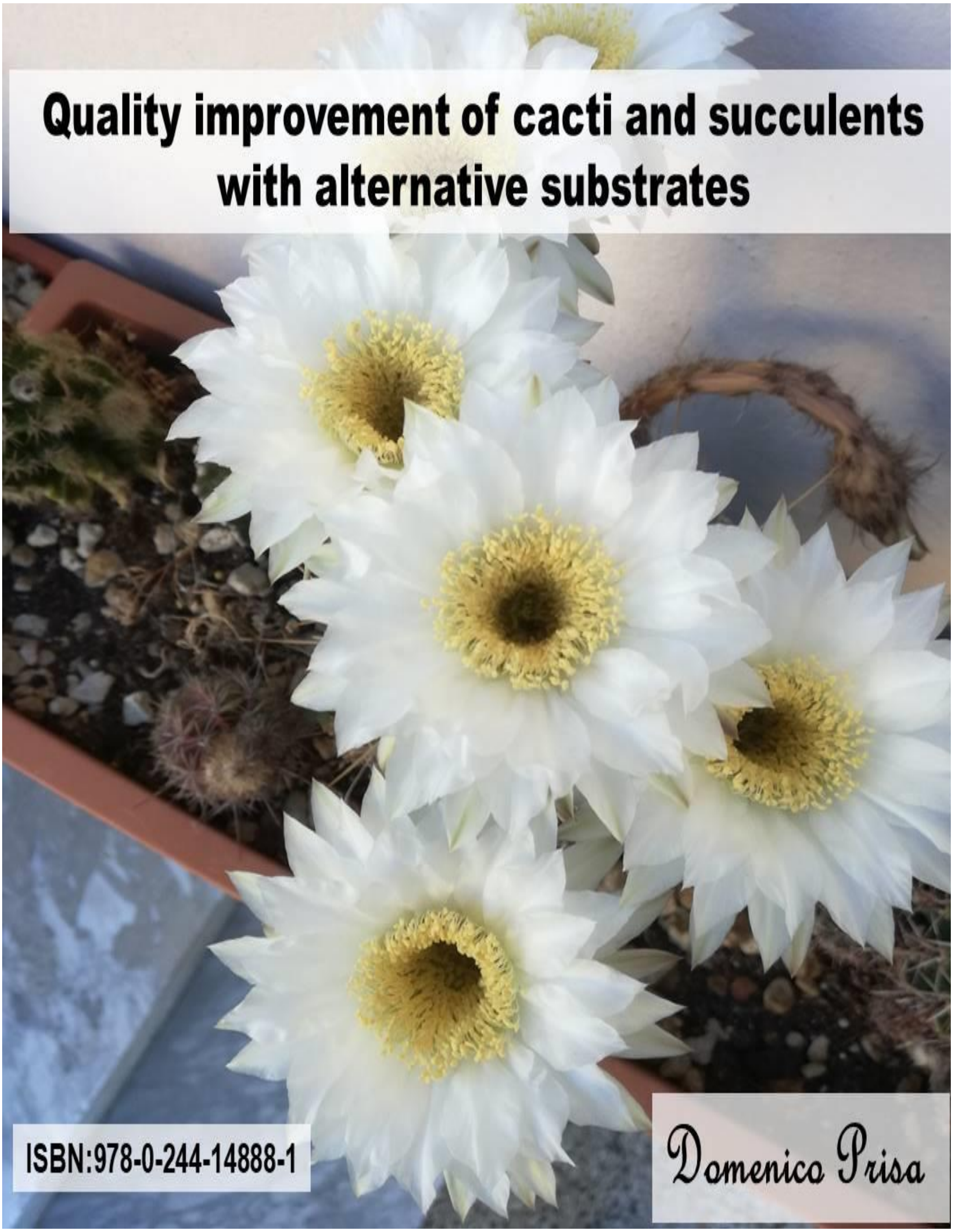
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Propagation substrates

The soil performs fundamental functions for the support of the root system. It consists of degraded rocks, water, air, organic substances and is formed as a result of chemical, physical and biological actions. In the soil can take place both the germination of the seeds, but also the formation of new plants through agamic methods, such as cuttings, or the buds, the division of the tufts, rhizomes, tubers. In the soil there are exchanges and reactions between the elements and there are nutrients that the roots can only use if dissolved in water.

Soil weaving

- coarse sand: 2 to 0.2 mm
- fine sand: 0,2 to 0,02 mm
- silt: from 0,02 to 0,002
- clay: less than 0,002 mm

The term structure refers to the spatial arrangement of particles and their aggregation.

Propagating substrate means "any material or combination of materials used to provide support, moisture, ventilation and nutrients during the plant propagation process". At present, a propagation substrate in modern nurseries must have: lightness, manageability, uniformity, absence of pathogens, or of seeds of weeds and other contaminants.

Many propagation substrates are characterized by the mixture of various components, each of which is able to determine particular properties. Only two components can be used to give a substrate the right properties, which simplifies preparation. Among the most used organic materials are peat, coconut fibre, bark, wood by-products, compost. Inorganic materials include sand, perlite, vermiculite, polystyrene, rock wool and zeolites.

The characteristics of a propagation substrate (Iapichino, 2012)

Provide a propagation substrate

For the propagation of seeds and cuttings, the substrate must give the plants the possibility of anchoring and support, until transplanting into pots. The apparent specific gravity or apparent density of a substrate represents the solid component, expressed as its dry weight per unit of apparent volume (g/cm-3). A good substrate should have an apparent specific gravity of 0.50 (g/cm-3), be stable and maintain its characteristics in the period between the beginning of the propagation phase and the production of the new plant. Normally it consists of a 30% solid part and the remaining 70% of empty spaces (total porosity).

Porosity

In order to germinate the seeds or to allow the radical development, it is advisable that in the substratum there is a good aeration. It is therefore appropriate that carbon dioxide, which is harmful both to seed plants and to young cuttings, should be able to spread rapidly. The empty spaces of a substrate (total porosity) represent the volume of the substrate that can potentially be filled by air or water. Therefore a good propagation substrate should have a total porosity of 65-70%. Reference should also be made to free porosity (macroporosity), defined as the percentage by volume of a substrate corresponding to the empty spaces after gravitational water drainage. This type of porosity should range between 15 and 30%.

Water retention capacity

The percentage volume of water remaining within the substrate at full gravitational water drainage represents the water retention capacity. It is related to the total volume of pores so small (≤ 8-10 µm) that they exceed the force of gravity, and corresponds to the microporosity of the substrate. Its value should be between 25 and 35%, but it can reach higher levels especially in peat. The smaller the size of the micropores, the greater the amount of water retained. The water retention capacity influences the frequency of irrigation.

Cation exchange capacity (CSC)

Indicates the ability of a substrate to retain positively charged ions. Peat, coconut fibre, vermiculite and bark have a negative electrical charge and therefore retain cations that can be released to the solution circulating inside the substrate and then absorbed by the plant's root system. The greater the exchange capacity, the greater the number of nutrients in the form of cations that the substrate can retain. Capacity expressed in thousand-equivalents per 100 g of substrate (meq/100g). It is very important because most of the nutrients are in the form of cations (NH4, K, Ca, Mg, Zi, Cu, Mn, Fe).

Ph

It is the degree of measurement that expresses the degree of acidity or alkalinity of a solution. It is defined as the measurement of the concentration of hydrogen ions in the nutrient solution of the substrate. It's expressed on a scale from 1 to 14. The pH 7 value represents neutrality; a value above 7 indicates a basic pH and a value below 7 an acid pH. It is well known that succulent plants usually like a neutral (7) or slightly acidic (6-6,5) pH, except for the epiphytes, which want it a little more acid, and others, on the contrary, which like it more alkaline.

Six simple optical comparison colorimetric kits can be used for measurement. Pour a tablespoon of soil into 30 ml of demineralised water, mix and leave to rest for 24 hours, then filter through a funnel in the hole of which bibular paper or a sock has been inserted. 5 ml of liquid is taken and poured into the graduated tube included in the test and colorimetric comparisons are made. Otherwise you can buy a professional piaccametro that provides more accurate and easier to make measurements.

Fertilizers

They are able to supply mineral elements to the ground, you can find natural (organic) and chemical elements in various titles and forms: liquids, powder, grains, etc.. In a good substrate of propagation and cultivation must be present: nitrogen, phosphorus, potassium, calcium, sulfur, magnesium, iron essential for the life of plants. During the germination phases, the seeds already contain sufficient nutrient reserves to fulfil the first phases, so it is not necessary to provide nutrients. Fertilizers are required as soon as the cotyledons are visible. It is usually possible to use a ternary fertiliser (N-P-K) (20-10-20) at a dose of 50 mg/L. This dose can be increased up to 100-150 mg/L in the following steps. The measurement of the electrical conductivity of the substrate allows you to monitor the salinity of the solution circulating at the root level and check for any imbalances. The values must be between 0,5 and 1,2 dS/m at sowing and germination and between 0,9 and 2,5 dS/m at the stage when the seedling is well rooted.

Nitrogen is a growth regulator necessary for protein synthesis and the formation of living matter. It is present in organic matter and humus, and is transported by phloem and xylem. It provides for the construction of the structure of plant tissues together with the hydrogen and oxygen of water and photosynthetic carbon. Some microorganisms are able to transform organic nitrogen into ammoniacal and therefore nitric, which is the form in which plants can most easily assimilate it (80-90%). No plant is able to fix atmospheric nitrogen without entering into symbiosis with bacteria of the genus Frankia. Fleshy plants require little nitrogen, otherwise they will become susceptible to disease.

Phosphorus is the constituent of nucleic acids (Dna-Rna), and adenosine triphosphate (ATP), it is present in chromosomes and its organic compounds are fundamental in energy processes. It stimulates apical and radical meristems, contributes to the maintenance of good health, strengthens the defences against diseases and adversities, promotes flowering and seed formation, transforms raw sap into processed. Bone meal and guano are, among the natural fertilizers, those with the highest content of phosphorus.

Potassium is fundamental in the osmotic process of the cells, present in the cytoplasm and in the vacuoles, it determines the internal hydraulic pressure, strengthens the plants, forms the sugar reserve, gives colour to the flowers, regulates the transpiration. A deficiency in it makes the plant look withered. Potassium sulphate with a titre of 50-52 is used.

Sulphur and calcium are generally sufficient in field soil, but not always in prepared soils. The first is sulphur amino acids, and is responsible for protein synthesis; the second is a component of cell membranes and pectins, activates enzymes, neutralizes organic acids, slows down tissue aging, strengthens the plant against parasite attacks, supervises water turnover, lymph transport and root development.

Magnesium is a component of chlorophyll, it facilitates the transfer of phosphorus, it is an activator of biochemical reactions, it enters into the synthesis of starch and sugars.

Iron is used for the development of chloroplasts for the synthesis of chlorophyll, regulates photosynthesis and cell respiration, and enters into the constitution of various enzymes. The intake takes place in chelated form (EDTA, DTPA, EDDHA). A lack of this causes ferric chlorosis, which gives the plant a yellowish colour.

Among the trace elements that must be present, but in minimal quantities:

- boron: sugar transport and meristematic development
- manganese: photosynthesis and enzymatic activation
- copper: enzymatic activation and protein synthesis
- zinc: enzymatic activation, synthesis of proteins and hormones
- chlorine: photosynthesis

Microelements are fundamental to cell enzyme systems, act as cofactors and can be absorbed by the leaves. The nutrient solution is mainly taken by means of the roots by osmosis and by active absorption. It does not fertilize during the rest of the plant, nor after transplanting. The ratio of the main elements nitrogen, phosphorus and potassium should be 1-2-4 or 1-3-5, i.e. little nitrogen, much phosphorus, much potassium. For fertilising you can use the method of watering or mixed with the soil. (Cecarini, 2011)

Substrate disinfection

The practice of substrate disinfection is essential for the use of old soil, or for the use of delicate sowings. The aim is to eliminate any unwanted seeds, cryptogamic spores, eggs and insect larvae. Some executable methodologies are as follows:

- water the substrate well with boiling water
- use the oven at 100°C for at least 30 minutes, or the microwave oven at full power for the same time
- use 40% formaldehyde to be diluted in water at the time of use in a ratio of 1:50 (Cecarini, 2011).

Components used in substrates (organic materials) (Iapichino, 2012)

Peat

It is extracted from deposits of partially decomposed debris and accumulated in cold, marshy and humid environments in Canada, northern Europe, Russia. The plant species that lead to the formation of the peat belong to the genera Sphagnum, Caryx, Fragmites and Hypnum. The substrate is marketed in plastic bales of various volumes. One problem with the use of this substrate is dehydration. Mixtures with a high proportion of peat (more than 60-70%) shrink when their water content is too low. The excessive use of peat, being a non-renewable material, has caused a great deal of environmental criticism in recent years, especially in Europe, and consequently a trend towards the search for alternative substrates.

Coconut fibre

It is a vegetable material obtained from the shelling of coconuts and which has characteristics similar to those of sphagnum peat. During processing, smaller fibre fractions are removed, compacted for 2-3 years and then dehydrated. Coconut fibre absorbs water much more easily than sphagnum peat. It has excellent water retention, ventilation and good cation exchange capacity (40-60 meq/100g). It has good stability over time, as it slowly decomposes and excellent resistance to compaction.

Bark

By-product of woodworking. Pine bark and pine compost have long been used for pot crops and their use has been extended to the preparation of propagation substrates. The most used conifers are Picea abies, Pinus pinaster, Pinus sylvestris, Pinus nigra maritima, Sequioa, Cedrus, Abies. The bark is an excellent substitute for peat, but has a lower capacity for water retention.

Compost

It is the result of the decomposition and humification of various organic materials by various microorganisms, mainly bacteria, fungi and actinomycetes. For the composting process to take place in the best possible way, the moisture content inside the mass must be 50-65% and temperatures of 45-55°C must be reached.

Components used in substrates (inorganic materials) (Iapichino, 2012)

Vermiculite

Hydrated magnesium, aluminium and iron silicate which, when subjected to heat treatment at 760°C, expands to form a porous structure in parallel sheets (total porosity 94-96%). It retains up to five times its weight of water thanks to its thin-flap structure, but has little resistance to compression. Vermiculite is characterized by high buffering power and high values of cation exchange capacity.

Perlite

It is an aluminium silicate of volcanic origin. The water in the granules evaporates to form closed-cell aggregates. White, sterile material, marketed in particles of various particle sizes, with an irregular shape. It retains water only on the surface and in the spaces between the aggregates and has a water retention capacity of 15-35%. It has a low cation exchange capacity and its prolonged use causes a change in colour from white to yellow.

Sand

It is the heaviest of all the substrates (1400/1600 Kg/m3) and comes from the decomposition of various types of rocks. Silica sand with particles between 0.02 and 2.0 mm in size is generally used for plant propagation. It contains few or no nutrients; the one of marine origin has a high content of sodium chloride so it must be washed.

Polystyrene

It is sometimes used as a substitute for perlite as the granules increase the porosity and drainage of a substrate. Light material that does not deteriorate over time at neutral pH.

Pumice

Aluminium silicate of volcanic origin, pumice improves the drainage and ventilation of substrates. It is marketed in various particle sizes and has a tendency to deteriorate due to the disintegration of the particles. Contains small amounts of sodium, potassium, calcium, magnesium, iron and has a neutral pH.

Expanded clay

It is obtained by treating the clay at 700°C. It increases the drainage and aeration of the substrate and is used with organic materials in a percentage of 10-35% for the preparation of mixtures for pots.

Rock wool

It is obtained through the fusion at 1500-2000°C of aluminium, calcium, magnesium and carbon coke silicates. Produced in various shapes and sizes such as blocks, blocks and cubes, it is able to absorb considerable quantities of water while maintaining good porosity and aeration of the root system.

Zeolitites and zeolites

Zeolites are a family of minerals consisting of 52 species, which can be chemically defined as "*alumino-silicate hydrates of alkaline and/or alkaline-earthy elements* (essentially, Na, K, Ca)" and, structurally, belonging to the roof-silicates such as silica minerals, feldspars and feldspatoids.

By virtue of their crystallochemistry, zeolites have the following chemical-physical characteristics:

- high and selective cation exchange capacity (CSC) for low ion potential cations (NH4, K, Pb, Ba, Cs, Sr)
- reversible dewatering
- selective molecular adsorption
- catalytic behavior.

In addition to beautiful macro- and microscopic crystals of "hydrothermal" genesis formed within fractures and cavities of effusive magmatic rocks (especially basalts) of which they form a subordinate part (5 -10%), zeolites occur in submicroscopic crystals (1-20 μm) evenly distributed within pyroclastic rocks (tuffs, ignimbrites) of which they are diagenized (20- 40%) or preponderant (50-70%).

In substitution of the generic and improper terms ("natural zeolites", "sedimentary zeolites", "rocks rich in zeolite", "tuffs rich in zeolite") normally used in literature, the name "**zeolite"** has been introduced in order to define in a scientifically correct way the diagenised pyroclastic rocks with a prevalent (> **50%)** zeolite content and subordinate amounts of other silicate phases (quartz, cristobalite, feldspar, plagioclase, pyroxen, mica) and volcanic glass. The most common zeolithic species in the "zeolites" are: **clinoptilolite** (Figure 1**)** present in variable quantities (40-60%) in diagenized "acid" tuffs spread in many European countries (Slovenia, Czechoslovakia, Hungary, Romania, Bulgaria, Greece) and extra-European countries (Turkey, Iran, Russia, USA, Cuba, Japan, China, Australia); **chabasite** (Figure 2) and **phillipsite** (Figure 3) present in variable quantities (30-70%) especially in Italian alkaline-potassium "basic" ignimbrites (Figure 4).

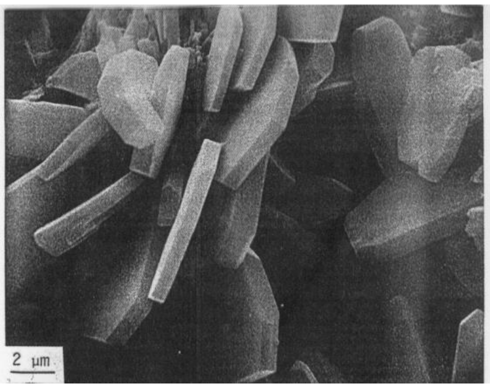


Figure 1.- SEM *photo of clinoptilolite lamellar crystals of Greek zeolitis.*

Figure 2.- SEM *photo of pseudocubic chabasite crystals of the "Red Tuff with black pumices" (Latium-Tuscany).*

Figure 3.- *SEM photo of prismatic phillipsite crystals from the "Yellow Neapolitan Tuff".*

The "zeolites", due to their content in zeolite, possess:

a) high (1.4 -2.1 meq/g) **and selective cation exchange capacity**

(b) reversible dehydration

(c) structural cryptoporosity

and, by their lithological nature (micro and macro tissue porosity, lithoid consistency), present:

(a) water retention

(b) mechanical strength

(c) permeability

(d) low density

The zeolithic properties (cation exchange capacity, reversible dehydration, structural porosity) depend on the type and concentration (%) of zeolite present in the rock

The other properties (water retention, mechanical resistance, permeability, density) depend on the nature (tuff, tufite, ignimbrite) and the diagenetic process (hydrological system "open", "closed", "geoautoclave") suffered by the volcanic rock.

Since chabasite and phillipsite are zeolithic species with CSC of 3.3 - 3.4 meq/g and are found in ignimbrites with micro and macroporous texture while clinoptilolite is a zeolithic species with CSC of 2.2 - 2.3 meq/g and is found in compact tuffs, the chabasite and phillipsite zeolites widespread in Italy show higher CSC and water retention values and lower density values than those of the clinoptilolite zeolites widespread abroad.

Use of zeolites in Agriculture and Floriculture- In agronomic field s.l., zeolites, classifiable as such only if the zeolite content of the rock to which they belong is higher than 50% on the basis of X-ray analysis using only the Rietveld-RIR methodology (attached to the Decree of the Ministry of Agriculture, Food and Forestry of 27 January 2014 n. 1377 supplement n.12).), were included among the **soil conditioners** by Decree of the Ministry of Agricultural, Food and Forestry Policies of 3 March 2015 and in Organic Farming by Decree of 17 January 2017 published Official Gazette of the Italian Republic of 3 March 2017 General Series n.52.

The use of zeolites both in the natural state and enriched in NH4 (through cation exchange or "exhausted" product of wastewater purification processes) as a corrective of soils and substrates involves: increase in **water retention**, **cation exchange capacity** (CSC), **permeability** and degree of **aeration** of soils, **solubilization of** tricalcium phosphates, **neutralization of** excess acidity and reduction of the assimilation by crops of harmful elements (Pb, Cd) and radiogenic (Cs, Sr), weak but significant reduction in the intensity of the **temperature range** of the soil, significant reduction in the **salinity of** water for irrigation use

The optimal quantity of zeolites to be applied as a correction varies with the type of soil: 1 - 2 Kg/m2 in soils with a predominantly sandy component; 2 - 4 Kg/m2 in soils with a predominantly clayey-loamy component. It can be used in soils with the addition of 20% in volume of substrate, this ensures better supply of water and nutrients, reduction of water and temperature stress, reduction of compaction and improvement of aeration of the substrate, promotes the development of bacteria symbionts (Passaglia and Prisa, 2018; Prisa and Burchi 2015a,b; Prisa 2017a,b; Prisa, 2018; Prisa and Castronuovo, 2018).

Substrates for cactus cultivation

General formula

- 4 parts of universal soil
- 1 part humus
- 3 parts of pumice
- 2 parts chabasite zeolite (grain size 3-6 mm)

Alternative formula

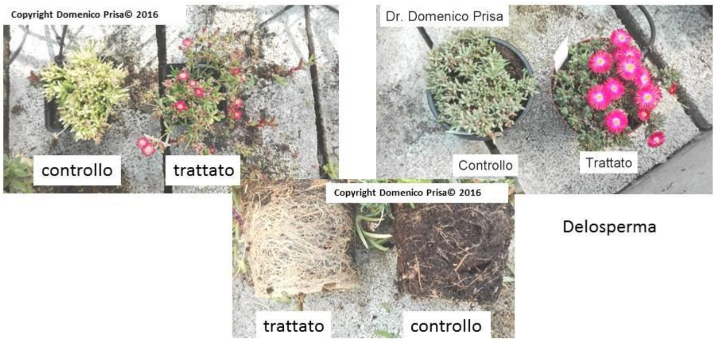
- 2 parts of universal soil
- 2 parts humus
- 2 parts of pumice
- 2 parts of lapillus
- 2 parts chabasite zeolite (grain size 3-6 mm)

You can add 0.5% spirulina, 0.5% bone meal, 0.5% pelleted manure or bat guano

Cactus and succulent experiments with zeolite-based substrates

Experimentation on delosperma

Addition to the substrate of cultivation of 20% by volume of zeolite to 3-6 mm chabasite (chabasite thesis)



Tesi	Peso fresco vegetativo (g)	Peso fresco radicale (g)	Numero di fiori (n°)
Controllo	35.33 b	25.66 b	45.61 b
Chabasite	48.45 a	38.36 a	78.13 a

Experimentation on sedum

Addition to the cultivation substrate of 10% by volume of zeolite to 3-6 mm chabasite (chabasite thesis)

Tesi	Peso fresco vegetativo (g)	Peso fresco radicale (g)
Controllo	22.10 b	18.71 b
Chabasite	31.00 a	25.32 a

Cactus seeding experiment

Addition to the substrate of cultivation of a 10% in volume of zeolite to chabasite 0-3 mm (chabasite thesis)

Echinopsis	% di germinazione	TMG (tempo medio di germinazione)
Controllo: torba + vermiculite.	67	32
Controllo: torba+ perlite	70	35
Controllo: torba + sabbia	74	34
Trattato: Torba+ chabasite	88	26

Experimentation with aloe vera and arborescens

Addition to the substrate of cultivation of a 10-20% by volume of zeolite to chabasite 3-6 mm (thesis 1 chabasite 10%, thesis 2 chabasite 20%)

Micronaturale: Aloe Vera e Aloe arborescens

Trattamento Aloe Vera	Fruttosio (mg (g DW)$^{-1}$	Glucosio (mg (g DW)$^{-1}$	Prolina (mg (g DW)$^{-1}$	Aloina (mg (g DW)$^{-1}$
CTRL	80.95 c	30.26 b	0.75 c	152.89 c
T1	91.18 b	32.48 ab	0.87 b	164.37 b
T2	93.52 a	34.40 a	1.17 a	172.95 a

Trattamento Aloe Vera	Numero di foglie/pianta (n°)	Numero di germogli/pianta (n°)	Peso fresco della foglia (g)	Peso fresco del gel (g)	Peso fresco delle radici (g)
CTRL	21.92 c	2.86 c	402.55 c	220.22 c	452.26 c
T1	23.50 b	3.41 b	438.15 b	277.44 b	491.81 b
T2	25.52 a	4.47 a	514.30 a	308.22 a	564.43 a

Trattamento Aloe Arborescens	Numero di foglie/pianta (n°)	Numero di germogli/pianta (n°)	Peso fresco della foglia (g)	Peso fresco del gel (g)	Peso fresco delle radici (g)
CTRL	23.37 c	3.42 c	468.06 c	247.67 c	502.55 b
T1	24.18 b	3.95 b	499.89 b	293.38 b	591.81 a
T2	26.46 a	5.11 a	575.55 a	369.12 a	626.40 a

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