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Regenerative approaches for building climate change resilience into EU agricultural regions prone to desertification

LIFE-ArgOassis

Work Package 2

Preparatory Actions and Implementation Plan to Combat Desertification and Adapt to Climate Change

Deliverable D2.1

Nursing and planting protocols & Soil sustainability

Lead Beneficiary: KES RESEARCH CENTRE (KESRC)

Contributing Partners: MINISTRY OF AGRICULTURE, RURAL DEVELOPMENT AND ENVIRONMENT OF CYPRUS (MARE) - AGRICULTURAL RESEARCH INSTITUTE (ARI) & DEPARTMENT OF FORESTS (DF)

Contents

D2.1 (A) Sustainable Soil Management Practices

For cereals

i) Weed management after of spring harvest

Weeds after the spring harvest of cereals do not appear every year in Cyprus. A necessary condition is that there is enough soil moisture available to weeds and that harvesting has been made early within spring so that there is enough time for weeds to grow before summer time.

Cutting cereals early in the season is performed when producers predict that the spring months (March – April – May) will be dry and is not expected to produce significant seed yield. In this case they prefer to cut for hay, which is more profitable. Also, in years when there is a high demand for hay and favourable prices, a greater number of grain producers select the above option. In Cyprus, the current need to develop goat and sheep farming for halloumi cheese production has increased the demand for green fodder supply and has contributed towards more frequent cutting for hay regardless of weather conditions.

If there is sufficient moisture in the soil, the new vegetation that may appear in the spring consists of a second growth cycle of the cereal seeded in the field or can consist of wild species. Such cases appear in **Figures 1-4.**

Figure 1 Secondary cereal vegetation grown in spring one month after hay cutting

Figure 2 Sparse vegetation grown after hay cutting and spring tillage

Figure 3 Secondary wild vegetation growing in spring one month after hay cutting

Figure 4 Secondary cereal vegetation growing in spring almost two months after cutting for hay

LIFE-AgrOassis will "exploit" this vegetation to create ground cover. We will promote its surface cutting with a stem cutter and the deposition of the cut aboveground biomass on the soil surface to create a dry mulching layer (**Figures 5, 8 and 9**). This method is much more cost efficient compared to the application of tillage.

Figure 5 Use of an mulcher as an option to address secondary vegetation and ground cover establishment. The "knives" of the mulcher (right).

Our aim in Cyprus is to abolish or at least significantly limit the spring or summer tillage which is a common practice (**Figure 7**). The ground cover from dry mulching will limit water loss and limit extreme soil temperatures experienced during the summer months. It also reduces energy consumption, production costs and CO_2 emissions.

The growth of the wild vegetation will be monitored and cutting will be done before the seeds ripen to limit weed infestation in the following years.

ii) Management of autumn wild vegetation

This above practice (cutting with a mulcher; **Figure 5** or a rotary stem cutter/slasher/ stubble cutter; **Figure 9**) will also be repeated for managing the appearance of any wild vegetation before sowing in autumn.

But while the lack of soil moisture does not allow weeds to re-emerge in the summer after cutting with a stubble cutter, cutting in the fall carries the risk of leaving surviving roots that could lead to faster weed growth after seeding. Due to a competitive advantage, this would reduce cereal production or oblige producers to use greater amounts of herbicides. For this reason and due to the fact that suitable no-till seeders are often not available, a light soil surface treatment (e.g. with a disc harrow) is recommended in the last week before sowing.

Figure 6 The use of a disc harrow is recommended to manage autumn secondary growth through light soil treatment in week before sowing. This method also breaks up the summer mulching layer and allows the new seed to germinate without the need for plowing.

Weed plant communities differ from field to field and from year to year in the same field. Data on the time and conditions of their appearance, their composition, speed and growth characteristics and especially the time period during which they create a mature seed stock will be recorded. The gathering of these records combined with the observations from the producers in relation to weeds will assist in more effective weed management removing the need for tillage (**Figure 7**) and promoting mulching as a sustainable soil management practice (**Figure 8**).

Figure 7 Spring tillage will expose the bare soil to sun heat stress as well as rain and wind erosion. This option is not promoted by LIFE-AgrOassis. It increases energy consumption, production costs and CO_2 emissions.

Figure 8 Soil protection in cereal cultivation from sun heat stress as well as rain and wind erosion through a ground cover mulch formed by primary and secondary vegetation cutting promoted by LIFE-AgrOassis.

For tree plantations/orchards

The approach towards weed management applied for cereals will also be applied to orchards. Here the adoption of no tillage can be total. The cutting of the weeds growing between the trees and the creation of ground cover with their cut weed biomass will be promoted to limit evaporation from the soil due to the extreme temperatures of summer and also to increase the water available for transpiration by the trees.

Figure 9 Surface cutting of wild vegetation to create a summer ground cover mulch in a young carob plantation and in an olive plantation using a rotary chain cutter (left) in contrast to the unsustainable practice of tillage before summer time (right) (photo of olive ground cover mulch, D. Trakkidis).

The above practice will permit the achievement of two additional goals:

i) To reduce the risk of fire spreading to the crown of trees, since standing weed stems more easily transfer fire flames to tree foliage

ii) To avoid the disturbance of surface tree roots which occurs with tillage. Surface roots contribute greatly to plant nutrition regardless of how deep the tap roots penetrate.

iii) Energy consumption and production costs are significantly reduced.

D2.1 (B) Resilient Hedgerow Installation in Burnt and/or Degraded Agricultural Land (Final Planting Scheme)

The Forest Department in collaboration and under the guidance of the KES Research Center (KESRC) have worked with the aim of producing seedlings resistant to water stress in the nursery with reduced care requirements in arid environments.

In this context:

A) The available plants for production have been updated and the production plan has been formulated.

B) The instructions for the preparation of the plants in the nursery have been defined as well as the production schedules for the first planting season starting in November 2023,

C) The production problems that need to be solved have been identified, while the available methodologies/solution technologies have been explored.

Update of available plants and production plan

Following meetings between the involved partners, the productive capacity of the Department of Forestry's nurseries was examined for the 24 plant species proposed in the project (WP2 T.2.2.2). The availability of seedlings is determined by the amount of seed production of the previous year, derived from wild plants of Cyprus which are utilized by the Forestry Department. This method depends on the weather conditions and the biological cycle of the plants, and is followed to guarantee that the genetic potential of the new seedlings will be indigenous. After checking the available seed stocks, it was discovered that the existing possibility of producing propagating material exists for 17 plant species for which the production of seedlings has already started. One more plant is under consideration. The 18 (17+1*) species of plants to be exploited were divided into three groups according to their biotype:

1. **Tree species:** *Pistacia atlantica, Ceratonia siliqua, Olea europaea* var. *sylvestris, Prunus dulcis, Cupressus sempervirens.*
2. **Shrub species:** *Pistacia terebinthus, Pistacia lentiscus, Crataegus azarolus, Laurus nobilis, Arbutus andrachne, Quercus coccifera* subsp. *calliprinos, *Ziziphus lotus, Bosea cypria.*

3. **Herbaceous plants:** *Thymbra capitata, Asparagus stipularis, Rosmarinus officinalis, Capparis spinosa* var. *canescens, Origanum majorana.*

Most of the selected plant species have a deep root system and as species adapted to drought, they can be used to improve the environment in desert and semi-desert areas with severe water shortages and areas that have been severely damaged by fires.

Then, to formulate the production plan, the plants were classified into two groups according to their bioclimatic requirements. The first group included the plants that prevail in the Thermo-Mediterranean belt (zone) of vegetation and the second those that prevail in the Meso-Mediterranean belt (zone) of vegetation. Based on the areas in which planting is expected to take place in Cyprus, the proportion of plants was determined to be 70% to 30% between the two respective zones. Also, plants were separated according to whether their root system will be prepared in tubes (11,000 plants) or not (7,000 plants). For the production quantities of each type of plant per year an estimate of the expected demand from the farmers in fruit and bee attracting plants has been made, based on the discussion held with them by KESRC during the project's information meetings. Also, the productive potential of the Department of Forestry's nurseries as well as the ecological establishment requirements of certain species were taken into account (Tables 1 & 2).

The preparation work was finalized for the three years of production in the nursery and for a total number of 18,000 seedlings produced (6,000 tree species and 12,000 shrubs and herbs) using 4,000 **root growth tubes**. The production of 3,000 deep-rooted plants (1,280 trees + 1,720 shrubs) will take place during its 1st year using the tubes and will be supplemented with 1,350 plants (shrubs and herbs) without tubes (total 4,350 plants) to cover a length of hedgerows of about 6 km. Another 1,000 tubes will be constructed the same year and will be used the 2nd year. In the 2nd year the 4,350 plants will be installed and the preparation of 4,000 plants in tubes (2,290 trees + 1,710 shrubs) as well as 2,070 shrub-herb plants without tubes (total 6,070) will take place. In the 3rd year, the above plants will be installed. Furthermore, the preparation of 4,000 tube plants (2,430 trees + 1,570 shrubs) together with 3,580 non-tube shrub-herb plants (total 7,580) will be finalized; to be planted in the 4th year of the project. In the 3rd and 4th year approximately 12 km of hedgerows will be created per year. Note that after the end of each planting phase the tubes will be reused for the production of the next year's deep-rooted seedlings (Tables 3 & 4).

Table 1 The 1st year nursery production plan for 3000 plants in tubes to create 6km of hedgerows.

Plant life form	Bioclimatic Zone	Tube Numbers	Plant species	Distribution based on expected farmer interest	
				%	Number of Plants
Trees	ThermoMED	700	*Pistacia atlantica*	0.1	70
			Ceratonia siliqua	0.6	420
			Olea europaea var. *sylvestris*	0.2	140
			Cupressus sempervirens	0.1	70
			SUM	1	700
	MesoMED	300			
			Prunus dulcis	0.15	45
			Pistacia atlantica	0.1	30
			Ceratonia siliqua	0.5	150
			Olea europaea var. *sylvestris*	0.2	60
			Cupressus sempervirens	0.05	15
			SUM	1	300
Total		**1000**			**1000**
Shrubs	ThermoMED	1400			
			Pistacia terebinthus	0.1	140
			Pistacia lentiscus	0.2	280
			Crataegus azarolus	0.3	420
			Ziziphus lotus	0.2	280
			Capparis spinosa var. *canescens*	0.2	280
			SUM	1	1400
	MesoMED	600			
			Pistacia terebinthus	0.2	120
			Pistacia lentiscus	0.15	90
			Crataegus azarolus	0.25	150
			Laurus nobilis	0.1	60
			Arbutus andrachne	0.1	60
			Quercus coccifera subsp. *calliprinos*	0.05	30
			Bosea cypria	0.05	30
			Capparis spinosa var. *canescens*	0.1	60
			SUM	1	600
Total		**2000**			**2000**

Table 2 The 2nd and 3rd year production plan in the nursery for 4000 plants/year in tubes to create 12km of hedgerows per year.

Plant life form	Bioclimatic Zone	Tube Numbers	Plant type	Distribution based on expected farmer interest	
				%	Number of Plants
Trees	ThermoMED	1750	*Pistacia atlantica*	0.1	175
			Ceratonia siliqua,	0.6	1050
			Olea europaea var. *sylvestris*	0.2	350
			Cupressus sempervirens	0.1	175
			SUM	1	1750
	MesoMED	750			
			Prunus dulcis	0.14	105
			Pistacia atlantica	0.1	75
			Ceratonia siliqua	0.5	375
			Olea europaea var. *sylvestris*	0.2	150
			Cupressus sempervirens	0.06	45
			SUM	1	750
Total		**2500**			**2500**
Shrubs	ThermoMED	1050			
			Pistacia terebinthus	0.1	105
			Pistacia lentiscus	0.2	210
			Crataegus azarolus	0.3	315
			Ziziphus lotus	0.2	210
			Capparis spinosa var. *canescens*	0.2	210
			SUM	1	1050
	MesoMED	450			
			Pistacia terebinthus	0.16	72
			Pistacia lentiscus	0.14	63
			Crataegus azarolus	0.3	135
			Laurus nobilis	0.1	45
			Arbutus andrachne	0.1	45
			Quercus coccifera subsp. *calliprinos*	0.06	27
			Bosea cypria	0.04	18
			Capparis spinosa var. *canescens*	0.1	45
			SUM	1	450
Total		**1500**			**1500**

Table 3 The planting scheme per year of nursery production for tube plants.

Plant life form	Species in tubes	TOTAL	Year1	Year2	Year3
Trees	*Ceratonia siliqua*	**3420**	850	1215	1355
	Olea europaea var. *sylvestris*	**1200**	200	500	500
	Pistacia atlantica	**600**	100	250	250
	Cupressus sempervirens	**525**	85	220	220
	Prunus dulcis	**255**	45	105	105
Shrubs	*Crataegus azarolus*	**1470**	570	450	450
	Pistacia lentiscus	**916**	370	273	273
	Capparis spinosa var. *canescens*	**850**	340	255	255
	**Ziziphus lotus*	**700**	0	420	280
	Pistacia terebinthus	**614**	260	177	177
	Arbutus andrachne	**150**	60	45	45
	Laurus nobilis	**150**	60	45	45
	Bosea cypria	**66**	30	18	18
	Quercus coccifera subsp. *calliprin*	**84**	30	27	27
Total		**11000**	**3000**	**4000**	**4000**

* Production capacity confirmation pending

Table 4*:* The planting scheme per year of nursery production for tubeless plants.

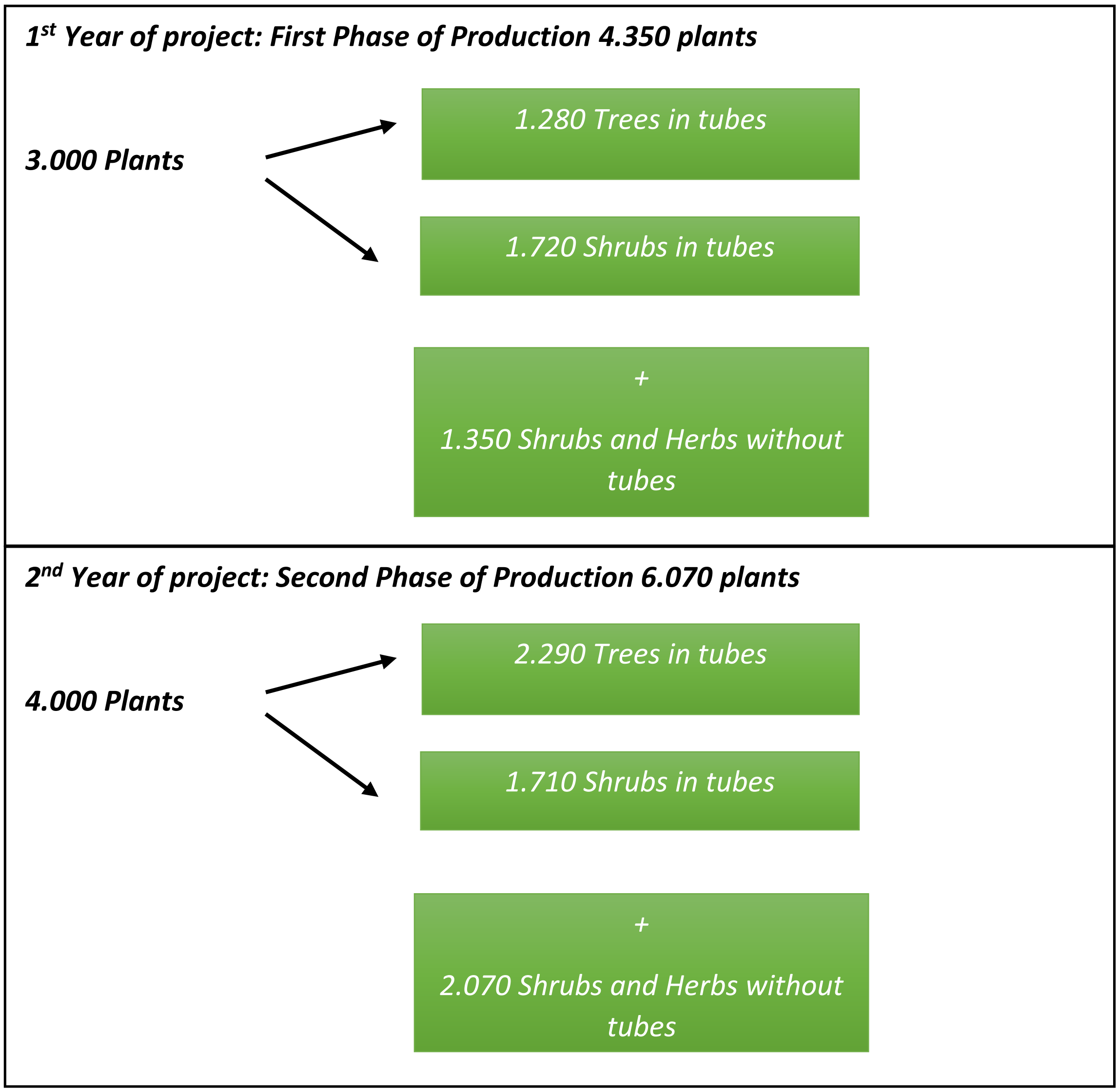
Plant life form	Species without tubes	TOTAL	Year1	Year2	Year3
Shrubs+ Herbs	*Thymbra capitata*	**2800**	150	1325	1325
	Origanum majorana	**1750**	359	695	696
	Asparagus stipularis	**1750**	141	50	1559
	Rosmarinus officinalis	**700**	700	0	0
Total		**7000**	**1350**	**2070**	**3580**

The plant production plan is depicted in Diagram 1.

Total number of produced tree:

18,000 Plants = 6,000 Trees + 12,000 Shrubs

1 Year of project: Construction of 4,000 root growth tubes



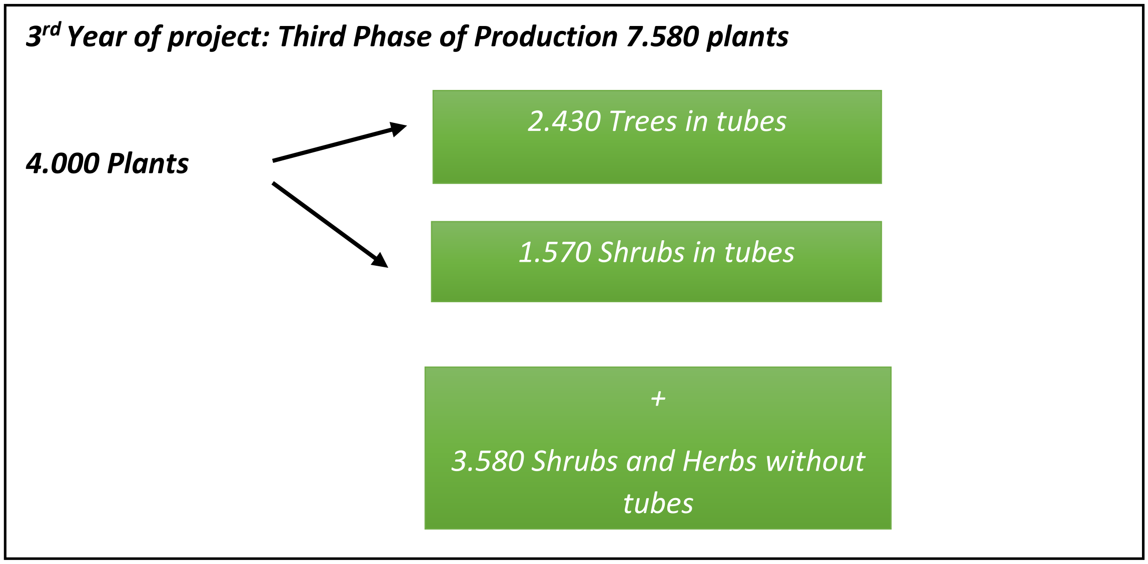


Diagram 1 Total production plan in the nursery for 3 years.

Finally, for production control purposes and under the supervision of KESRC each production year will include 50 additional plants in tubes and 50 in classic bags which will not end up in the field (see Section Bc iii).

Guidelines for preparing deep rooted plants in the nursery

To permit deep root training, 60cm deep tubes will be used for the growth of the seedlings, compared to the classic pots-bags. Training will last 90 days according to the protocol below. The aim is to develop a longer root system in tubes than in pots as well as greater productivity of the shoot and root in the tube than in the pot. Seedlings will already be adapted from the nursery to drought conditions with the aim of saving on irrigation water, while permitting successful establishment in barren and arid lands.

Installation of seedlings in root growth tubes

The partners have finalized the plan for the construction of the planting tubes and the installation of the seedlings inside them. Seedlings, once exceeding 5 cm in height will be transplanted into 1.4 liter pots in preparation for their establishment in tubes at the appropriate time (see below). The PVC tubes with dimensions (60 cm X 10 cm) will have a volume of 5 liters in topsoil plus soil improvement materials. They will consist of two hemispherical sections assembled together with removable tape and will have a waterproof removable cover of two layers of plastic bag for protection that will surround their lower section (**Figure 10**). KESRC at the request of the Forest Department also considered alternative plans for the construction of the tubes which will not be pursued, either for reasons of cost or functionality.

The plants will be irrigated under a special protocol in all plant containers in order to gradually bring them to water stress conditions. Moreover, a suitable location has been found within the Athalassa Forest Nursery of the Department of Forestry for the installation of the root growth tubes. The space has sufficient exposure to the sun to exert heat stress of the plants.

For production control purposes 50 plants per year will also be established in the classic 5-liter bag-pot and compared with a corresponding number of control plants in a tube.

i) Preparation steps for deep-rooted species

- At the bottom of the tube, 20g of Attapulgite are placed for each plant. The bottom must be prepared to be watertight (**Figure 10**).
- Potting soil is added up to just below the root level of the seedling.
- 20g of the beneficial microbe complex (Micosat-F-Olivo) is added under the root of the seedling before the seedling is placed. After the seedling is placed within the tube its roots should be in contact with the complex
- The top part of the seedling soil should be at least 5 cm below the top edge of the tube.

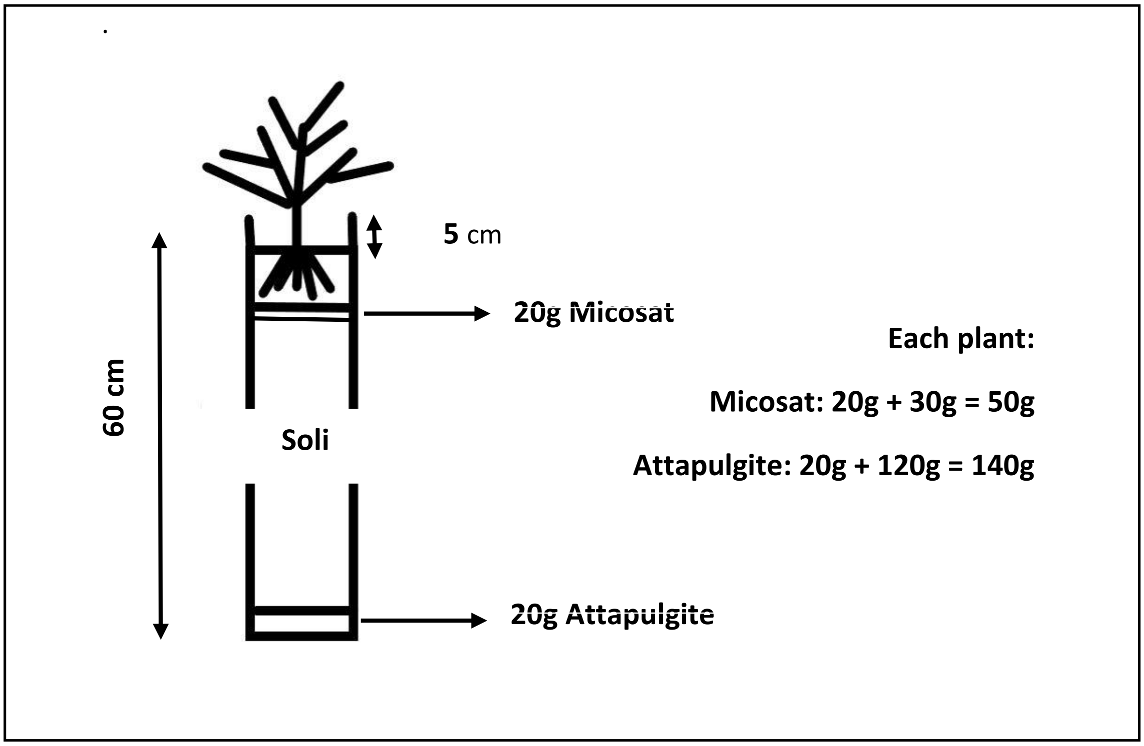


Figure 10 Schematic for instating the seedlings within the root growth tubes (top) and prepared tubes from the Forestry Department (left). The platform to maintain the tubes during production will be used for easy loading of tubes on trucks using a forklift (right).

The Forest Department with the support of KESRC has completed the pricing of the root growth tube system. The Forestry Department is in the construction stage of the tubes (**Figure 10**). KESRC has completed the order and received the delivery for Attapulgite and Micosat-F-Olivo from the supplier.

ii) Watering protocol for tube plants

The Forest Department undertakes the watering of the plants in the nursery by drip method as per the protocol below formulated in collaboration with KESRC.

- **For system installation in March:** for 4 weeks plants in all root growth tubes are irrigated weekly (every 7 days) with an amount of 0.5 liters of water, in the next 2 weeks all plants are irrigated weekly (every 7 days) with 0.25 liters of water, while they do not receive any irrigation for the next 2 weeks. In the following months the plants receive 0.5 liters of water per month until the month of October.
- **For system installation in June - July:** for 4 weeks the plants in all plant pots are irrigated weekly (every 7 days) with an amount of 1 liter of water, in the next 2 weeks all plants are irrigated weekly (every 7 days) with 0.5 liters of water, while they do not receive any irrigation for the next 2 weeks. In the following months the plants receive 0.5 liters of water per month until the month of October.

Note that in all cases the systems must be exposed to direct sunlight.

iii) Quality control of tube planting systems

For quality control of the systems KESRC will undertake the monitoring of specific control plants. In the control plants, soil moisture will be measured with a moisture sensor at a depth of 5 cm from the top and at the bottom of the plant container. These measurements will indicate the top and bottom moisture retention in the substrate and the rate of moisture loss.

The speed of plant growth will be determined by recording the changes in various plant characteristics such as the dimensions and weight of specific plant organs. For this purpose, measurements will be made for the height and width of the plants with a measuring tape and for the weight of the plants with a scale.

In particular, after 8 weeks from the start of the installation, the length (metric tape) and weight (scale) of the above-ground and underground part of the plant will be measured as well as a check for any diseases in the 50 control tube plants. Corresponding measurements will be made on 50 additional plants that will grow in the usual planting bags of the same volume of soil and under the same watering conditions, near the plants with the tubes.

For the measurements, the uprooting of the plants will be performed with special care, so as not to cut off part of the root system. After above ground/underground measurements, the 2 parts of the plant will be dried until they reach a constant weight. Shoot/root fresh and dry weight ratios will also be calculated.

Production problems and solutions

1. It was decided that the best time for root growth tubes to receive plants should be after the start of the dry season (e.g. June 2023). In this way, extensive rainfall is avoided that could lead to a possible excesses of the amount of optimum water inside the containers, as would be the case during the wet climatic season. It also ensures sufficient solar radiation to thermally stress the tubes by allowing water in the surface soil layers within the tube to evaporate. The above practice is critical in reducing upper root system growth and permits root growth deeper into the tube where moisture is protected from solar evaporation.
2. Adherence to the irrigation protocol was found to require specialized drip control systems that would need to be installed in the Forest Department's new irrigation system. The Department of Forestry has proceeded to consult with suppliers and has ensured the appropriate system.
3. The Forestry Department is considering ways to solve the lack of propagating material for two plant species *Ziziphus lotus* and *Thymbra (Thymus) capitata*. For *Z. lotus* it was decided to transfer its production to the second year's planting phase giving time to solve the problem (Table 3.) For *T. capitata* its production numbers during the first phase were significantly reduced and the goal of producing a large number of plants was carried over to subsequent phases (Table 4). In the event that the problem cannot be resolved within the deadlines set for the production phases, the partners agreed to replace it with other ecologically equivalent species available to cover the needs of the 1st year of plantings. The problem will be reviewed during the second production phase.

D2.1 (C) Sustainable Production of Compost and its Application

Compost production

Composting consists of the controlled decomposition of biodegradable materials, which is mainly aerobic and allows the development of temperatures suitable for thermophilic bacteria as a result of biologically generated heat. During the composting process, all parts of a batch should exhibit one of the following temperature–time profiles:

— 70 °C or higher for at least 3 days,
— 65 °C or higher for at least 5 days,
— 60 °C or higher for at least 7 days or
— 55 °C or higher for at least 14 days.

During composting, the material will be mechanically mixed regularly to ensure proper aeration throughout the volume of material. Also, there will be a system of self-checking and record keeping.

The production of compost should be in accordance with the conditions and operation of the composting units described in the special Annex of the new legislation on fertilizers (the legislation is in the final stage of legislative review) and in which the following procedures are described:

1) Separation of biodegradable waste before it is received by the unit, the type of which is determined by a relevant Table. The waste is separated at the place of production and must not be kept mixed with other waste during the waste collection phase.

2) Receipt of biodegradable waste at the composting unit. The waste is received by the plant's storage area, where re-separation and shredding may take place.

The new legislation includes requirements for the composting plant that have relate to protecting the environment. The compost producer must ensure a functional and efficient composting process. LIFE-AgrOassis will fully comply with the above requirements. Proper machinery will be used for distribution on compost within the fields (**Figure 11**).

Criteria for selecting fields for compost incorporation

LIFE-AgrOassis will use the following criteria for selecting the field in which a quantity of compost will be incorporated:

1) the quality of the soil (its particular physico-chemical characteristics, the problems of fertility, water relations, pollution, erosion, etc.),

2) the quality of the compost (degree of stability, nutrient release potential) and

3) the distance of the field from the compost production unit which determines the transport cost and the carbon footprint of the application,

4) the possible discrepancy between availability (the date of mature compost production) and the time of application (depends on sowing or planting date).

Figure 11 Compost distribution in a field.