LIFE 15/CCA/ES/125

Additional report Name: ABOVE GROUND PARAMETERS MONITORING REPORT

Action D1. Monitoring and project performance indicators

Compiled by: CREAF

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1. Summary

This report presents the results of the second monitoring campaign made during spring-summer 2018. The parameter evaluated is the physiological state of the seedlings that allows to determine survival rates. More than 7000 seedlings have been measured in this campaign, which represent a 30% of the seedlings planted with Cocoon and all the controls. In general seedlings planted with Cocoon have higher survival ratios and better physiological state than controls. However, results vary according to rainfall regime, being better in the most humid regions. Apart of rainfall regime, species type, the quality of the seedling, the planting process and the soil quality seem to play a role on seedlings behavior. Species translocation strategy applied (assisted migration, adaptive restoration) is giving good results (*Quercus ilex subsp. ballota* in El Bruc and *Tetraclinis articulata* in Jijona). Related to the use of assisted migration concept to agricultural uses, olive tree (*cornicabra* var*.)* seems to work well in Catalonia and Alicante (Jijona) trials. Results for survival are similar on seedlings planted in spring and autumn, despite spring's seedlings present a better physiological state (higher percentage of healthy seedlings). Regarding the results from the different Cocoon device versions tested, versions with only one wick and without weeks seem to work better than the current one.

2. Introduction

This report presents the results of the second monitoring campaign made during spring-summer 2018, according to the monitoring protocol, by local partners (Canary Islands by CGC and GESPLAN; Almeria by UA-CAESCG; Valencia (Tous) and Alicante (Jijona) by CSIC-CIDE; Catalonia by CREAF; Italy by BIOPOPLAR and Greece by CERTH). The parameter evaluated is the physiological state of the seedlings that allows determining survival rates. Additionally, height and basal diameter measures have been taken in El Bruc. More than 7000 seedlings have been measured in all the areas in this campaign, which represent a 30% of the seedlings planted with Cocoon and all the controls.

Some important questions, in order to check adaptation to climate change impact like seasonality (comparing spring and autumn plantations results), the use of adaptive species (species adapted to more dry climates) or the species performance with the Cocoon (which species work better) are analyzed. Moreover, the different versions of the Cocoon tested are evaluated regarding seedling vigor.

3. Results and discussion

Tree vigor is a health indicator, also giving insights on survival rates. According to the proposed monitoring protocol vigor has been assessed in all the areas at late spring or beginning of summer 2018, in order to evaluate the seedlings planted during 2016 and 2017. Vigor has been evaluated in a selection of 7.387 seedlings (6.009 Cocoons, 1.378 controls). For each monitored seedling, vigor has been assessed qualitatively by the following semi-quantitative rates:

3: Healthy tree, with more than 75% of green, not wilted leaves. Also, active growing points (apices) may be visible

2: Affected tree, with 25-75% of the leaves being wilted, yellow or brown

1: Severely affected tree with less than 25% of the leaves being green (i.e. the majority wilted, yellow of brown)

0: Presumably dead tree with no or only wilted leaves. Tree seedlings, however, may still recover by resprouting after a rain event

R: Resprouted seedlings

Globally, important differences were found between treatments and controls after summer 2017 that was very dry in all the areas (figure 1). Mortality ratio in Cocoons is close to 30%, and in control group is close to the double (58%). More than half of Cocoons are healthy and growing. Some seedlings classified as dead in spring 2017 resprouted after rains in spring 2018.

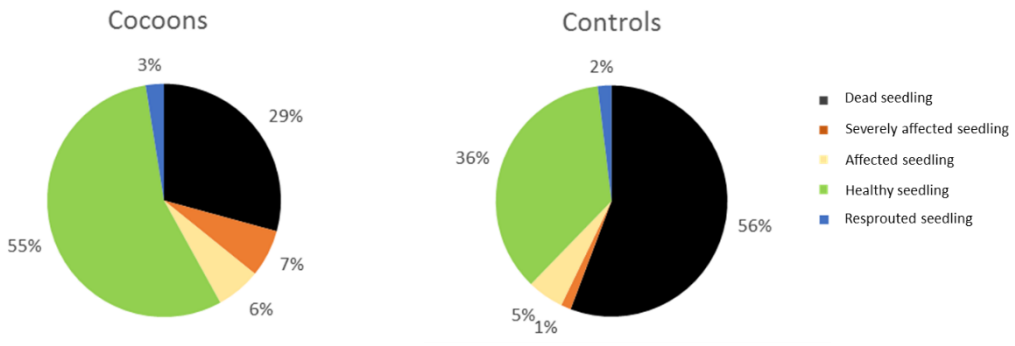

Figure 1. Global distribution of the monitored seedlings planted in The Green Link project, according to their physiological state in May-June 2018.

However, important differences exist between locations, mainly related to the precipitation regime. While plantations in Ptolemais, San Marco or even in Almeria worked well, in Gran Canaria a relatively high mortality ratio has been detected (figure 2). However, competent administration there, in this case the regional government, Cabildo de Gran Canaria, considers that these results are not so bad, mainly compared with previous restoration projects where they had failures ratios close to 100%, which forced them to irrigate the seedlings, with the enormous extra costs that this means. In Tifaracás, control group has higher survival ratio than Cocoon group (figure 3), due that control group has been watered during the first 7 months after planting with 10 litters of water per seedling and watering campaign. This makes this planting method extremely expensive due that water should be transported to planting areas, sometimes and in some places by helicopter.

Figure 2. Distribution of the physiological state of seedlings planted with Cocoon in The Green Link project (7 areas) in May-June 2018 (see color legend in figure 1).

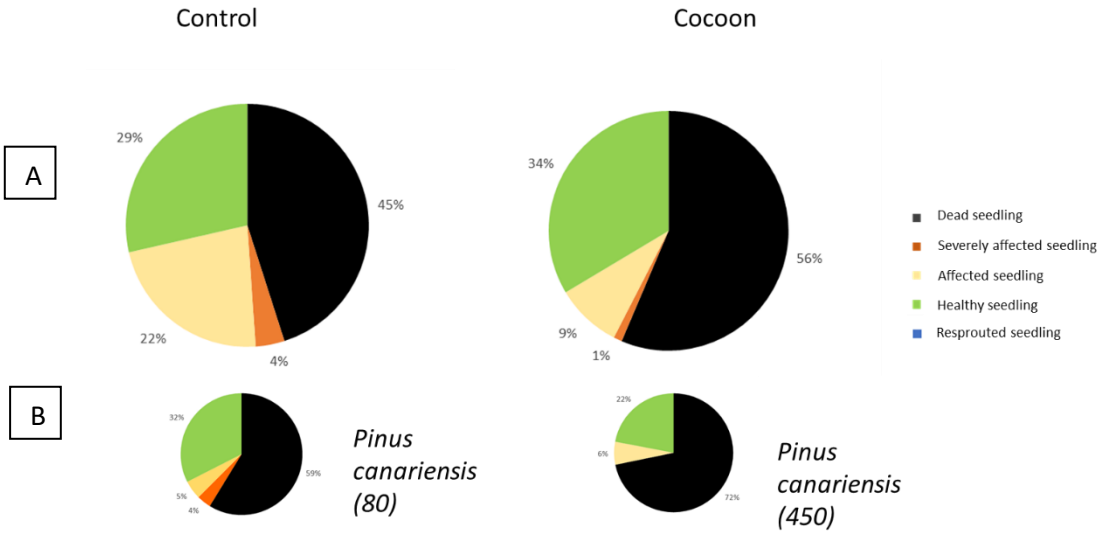

Figure 3. Distribution of the physiological state of monitored seedlings planted in Tifaracás (Gran Canaria), in May-June 2018. A: results for all the planted species, comparing Cocoons vs. Controls; B: results for *Pinus halepensis*, comparing Cocoons vs. Controls (numbers in brackets indicate the quantity of seedlings measured per treatment).

In El Bruc mortality ratio was high compared with other places with similar annual rainfall, despite differences with control group were important (figure 4). This relatively high number of dead seedlings was due mainly to the huge mortality ratio in arbequin olive trees. As it was reported in the Above ground parameters monitored report from November 2017 (see LIFE15 CCA/ES/000125 Midterm Report), arbequin olive tree seedlings planted in El Bruc showed some problems as rotten roots, stem scars, loss of leaves and chlorosis. In contrast, arbequin olive trees planted in Jijona (Alicante), presented very high survival ratio (95%), with the vast majority (90%) of the seedlings planted with Cocoon healthy and growing (figure 5). These olive trees were planted during the first batch, in fall 2016, and some problems related to the plantation technique (insufficient hole depth, overfilling of holes, removal of stones) where reported (see Above ground parameters monitored report on November 2017, and the deliverable Report of lessons learned on July 2017).

Regarding the results in Almería (figure 7) and Ptolemais (figure 8) for all the species, survival ratios for Cocoon vs. controls are similar. However, in Almería these results are highly conditioned for the development of almond trees, which is the main species planted there. The relatively higher survival ratio in controls could be attributed to the fact that controls take better profit of the fertilizing effect of the manure that is being added through sheep pasture. This effect should be transitory because the mycorrhiza added with Cocoons should increase the nutrient uptake. Results from the next monitoring campaign (May 2019) will contribute to elucidate these results. In Ptolemais, the worst physiological state in Cocoons could be explained for the extreme weather conditions during winter 2016-2017 and the

particularities of the area planted in winter (soil characteristics and steeped slope), that presumably cause the death of the seedlings with Cocoon.

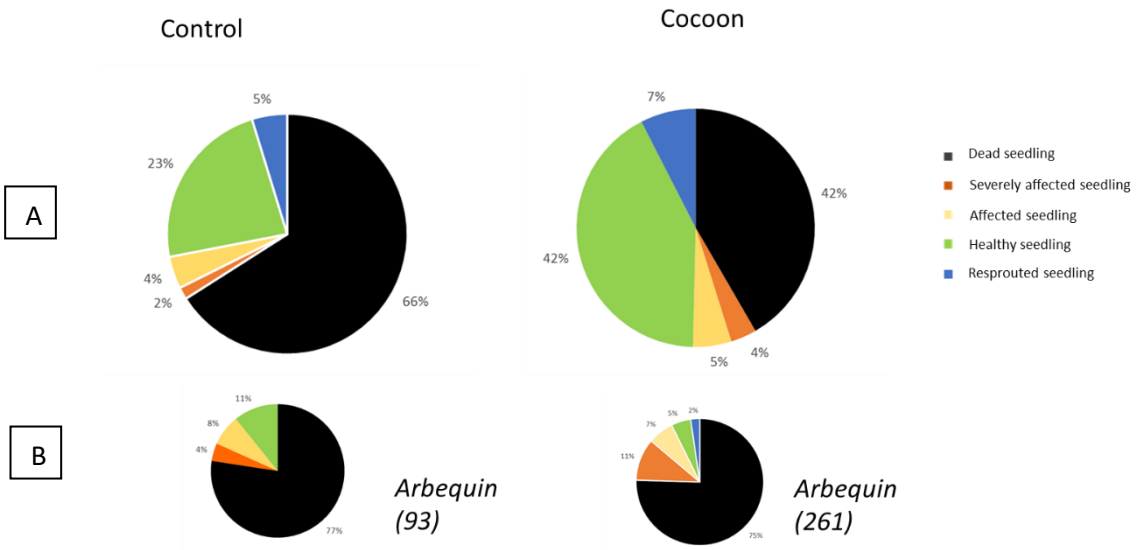

Figure 4. Distribution of the monitored seedlings planted in El Bruc (Catalonia), according to their physiological state, in May-June 2018. A: results for all the planted species, comparing Cocoons vs. Controls; B: results for arbequin olive trees, comparing Cocoons vs. Controls (numbers in brackets indicate the quantity of seedlings measured per treatment).

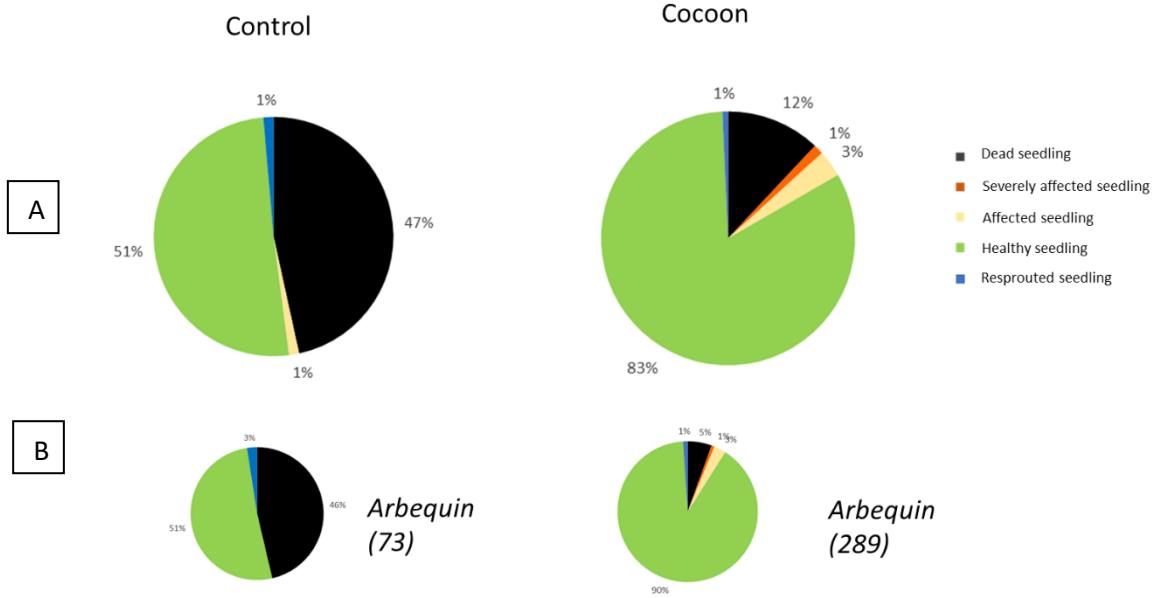

Figure 5. Distribution of the monitored seedlings planted in Jijona (Alicante), according to their physiological state, in May-June 2018. A: results for all the planted species, comparing Cocoons vs. Controls; B: results for arbequin olive

trees, comparing Cocoons vs. Controls (numbers in brackets indicate the quantity of seedlings measured per treatment).

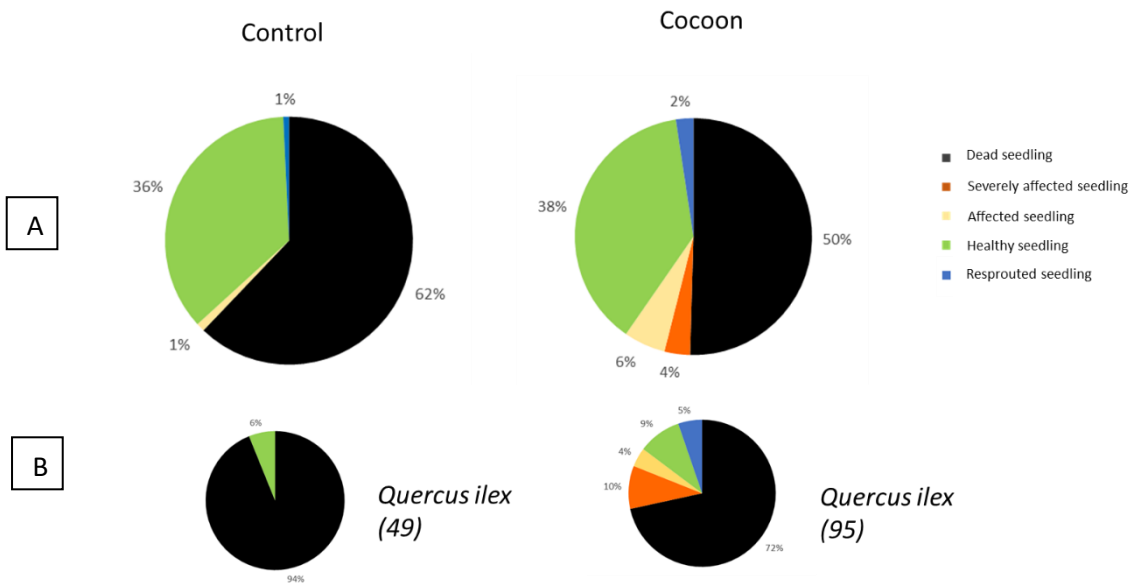

Figure 6. Distribution of the monitored seedlings planted in Tous (Valencia), according to their physiological state, in May-June 2018. A: results for all the planted species, comparing Cocoons vs. Controls; B: results for olm-oak trees, comparing Cocoons vs. Controls (numbers in brackets indicate the quantity of seedlings measured per treatment).

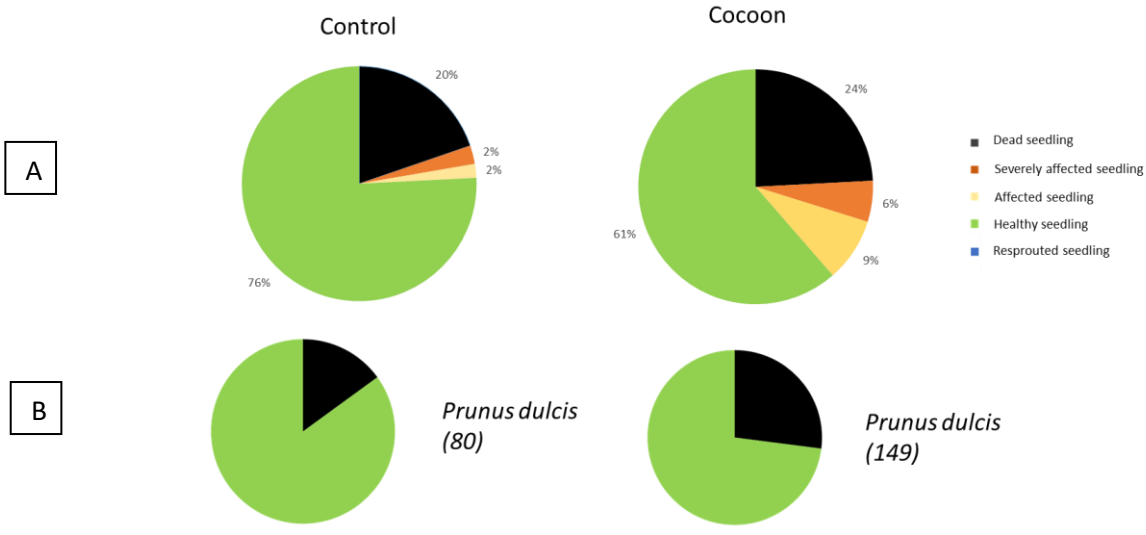

Figure 7. Distribution of the monitored seedlings planted in Almería, according to their physiological state, in May-June 2018. A: results for all the planted species, comparing Cocoons vs. Controls; B: results for olm-oak trees, comparing Cocoons vs. Controls (numbers in brackets indicate the quantity of seedlings measured per treatment).

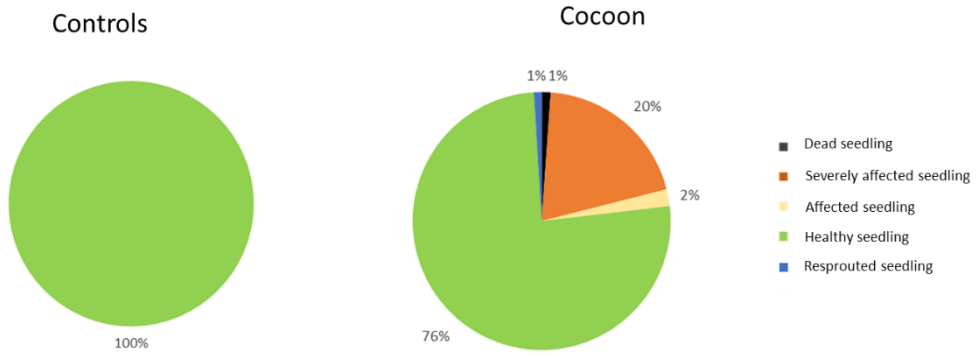

Figure 8. Distribution of the monitored seedlings planted in Ptolemais (Greece), according to their physiological state, in May-June 2018.

Table 1. Survival rates of winter and spring plantations in Ptolemais (Greece) in May 2018.

Spring plantations	
Tree	**Survival (%)**
Cypress 30cm	98.8
Cypress 50cm	98.2
Oak	99
Black locust	100

Winter plantations	
Tree	**Survival (%)**
Cypress 30cm	45.51
Cypress 50cm	11.85
Oak	88
Black locust	96.85

Results in Calabria are the most contrasted between treatments with Cocoon (89% survival ratio) and controls (all death) (figure 9). This could be attributed to the extreme dry conditions in summer 2017 in Calabria and the high vulnerability to drought of some of the species planted (*Populus alba, Populus nigra, Arbutus unedo*). However, some of the controls, especially olive trees, where not included in the monitoring because they disappeared with the severe erosion processes (rills) that occurred in the area after the extreme rainfalls that affected the Calabria region during 2017 and 2018. For this reason, these results should be interpreted with caution, especially those refereed to olive trees.

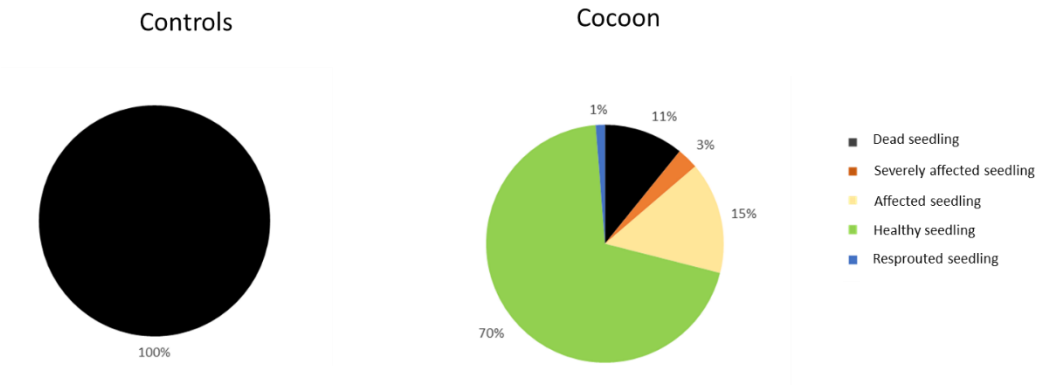

Figure 9. Distribution of the monitored seedlings planted in San Marco Argentano (Italy), according to their physiological state, in May-June 2018.

The effect of rainfall regime on seedling survival could be observed on two species of the Cupressaceae family, which present much contrasted results regarding mortality ratio and physiological state (figure 10). *Juniperus turbinata* planted in Tifaracás, a location with a rainfall less than 200 mm per year and extremely stony and poor soils, present a survival ratio of 44%. Meanwhile, Mediterranean cypress planted with Cocoon in Ptolemais, a location with a rainfall of 570 mm per year, present a survival ratio close to 100%, having 76% of the seedlings healthy and growing. This effect could be seen also, despite not so contrasted, in holm oak seedlings planted in El Bruc and Tous (figure 11).

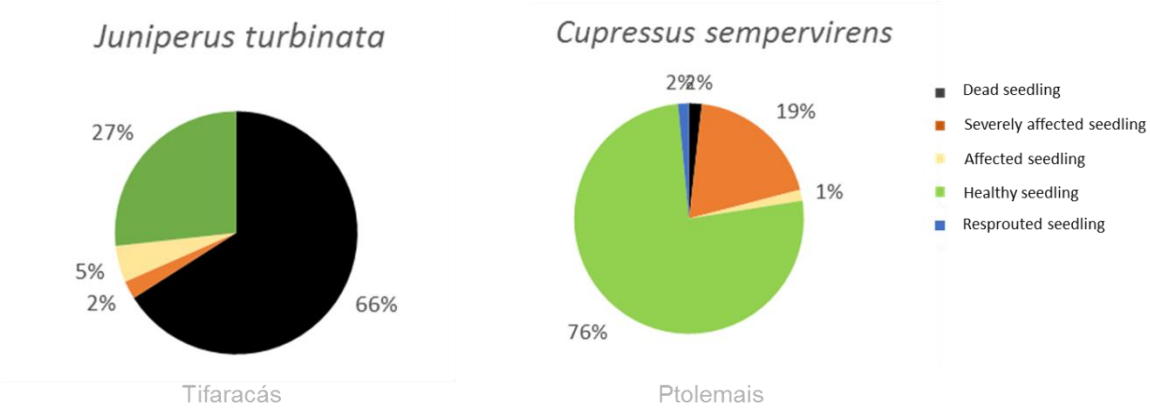

Figure 10. Distribution of the seedlings planted with Cocoon of *Juniperus turbinata* in Tifaracás (Gran Canaria) and *Cupressus sempervirens* in Ptolemais (Greece), according to their physiological state, in May-June 2018.

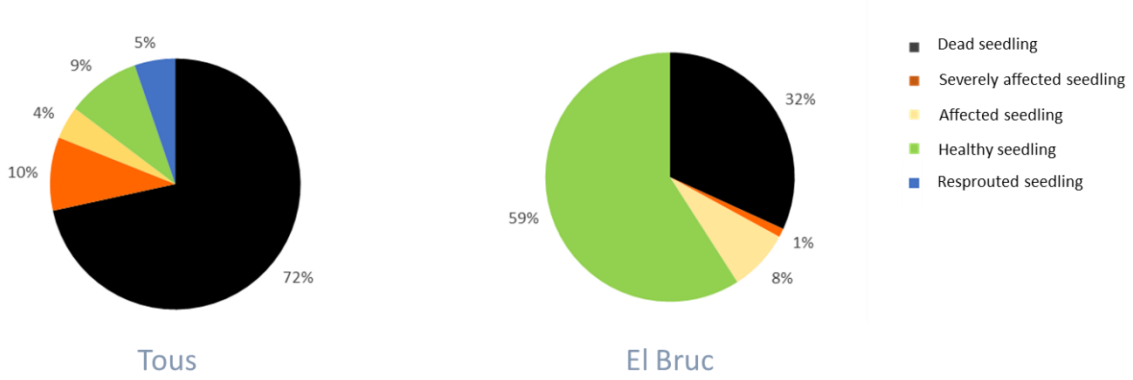

Figure 11. Distribution of the seedlings of *Quercus ilex* planted with Cocoon in Tous and El Bruc, according to their physiological state, in May-June 2018.

Despite of this effect of precipitation, differences between species can be observed in the same location. Despite they are both sensible species, blackthorn and holm oak, present very different results planted in the same place and soil type (figure 12). This holm oak species, *Q. ilex ssp. ballota*, worked very well in El Bruc. Seedlings with Cocoon have grown 16 cm in one year, twice than controls (figure 13). This plantation of holm oak could be considered as an example of adaptive restoration to climate change, because is an autochthonous subspecie from south-Spain and northwest Africa planted at higher latitude, in Catalonia, simulating the displacement that this species could suffer with the climate change (assisted migration). Another species adapted to climate change scenarios in the Mediterranean basin is *Tetraclinis articulata*, which has been planted in Jijona with very good results (figure 14). In the same location, *Arbutus unedo* also worked well, despite being a specie scarcely present in this area, as it is more adapted to humid microenvironments (deep soils, ravines, north faces).

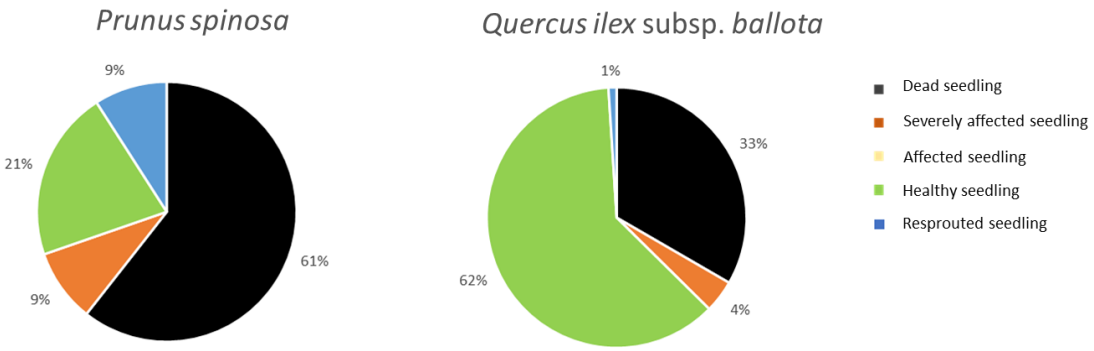

Figure 12. Distribution of the seedlings of *Prunus spinosa* and *Quercus ilex* subsp. *ballota* planted with Cocoon in El Bruc, according to their physiological state, in May-June 2018.

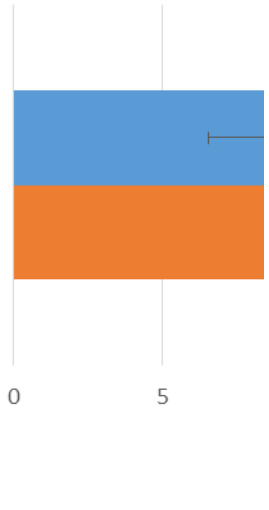

Figure 13. Growth rates of *Quercus ilex* subsp. *ballota* depending on treatment.

Figure 14. *Tetraclinis articulata* (left) and *Arbutus unedo* (right) seedlings planted in Jijona. Date: 08/11/2018.

Related to the assisted migration for agricultural uses, cornicabra olive tree variety was planted in El Bruc and Jijona (see LIFE15 CCA/ES/000125 Midterm Report). Cornicabra is a variety from central and south Spain, more adapted to dry climates than arbequin olive trees or the local vera variety (see figure 15). Vera variety present a high resprouting ratio, due to the characteristics of the seedling and the planting operations (planted on the traditional way, planting directly the resprouts).

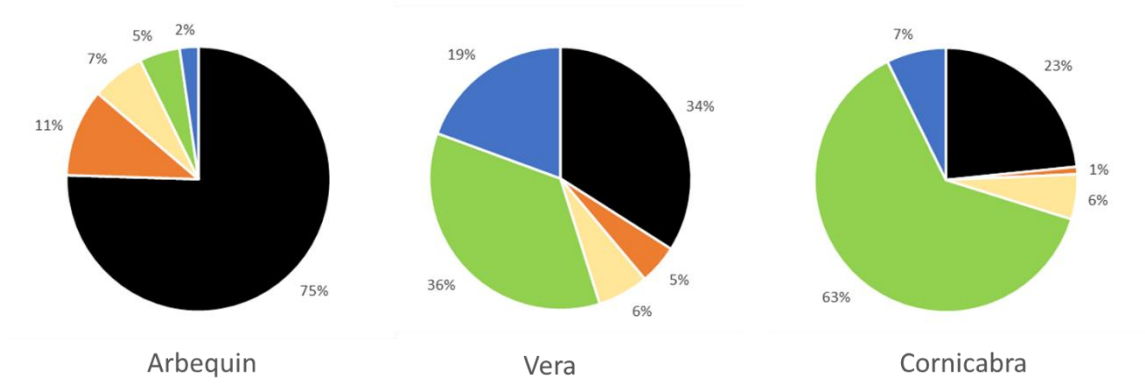

Figure 15. Distribution of the seedlings of the three varieties of olive tree (arbequin, vera and cornicabra) planted with Cocoon in El Bruc, according to their physiological state, in May-June 2018.

Figure 16. Seedling of vera olive tree resprouted after spring 2018 rains. Date: 11/05/2018.

Comparing the results of plantations made with Cocoon in autumn 2016 and spring 2017 we cannot observe important differences, despite seedlings planted in spring were put in just before summer 2017, which was extremely dry in most of the areas (figure 17). In any case, seedlings planted in spring present a better physiological state. This can be attributed at the fact that those planted in spring take better profit of the Cocoon because they have the water of the reservoir available during the hot summer months/summer drought. This is an important result because it means that using Cocoon opens a new plantation window, not affordable with other techniques.

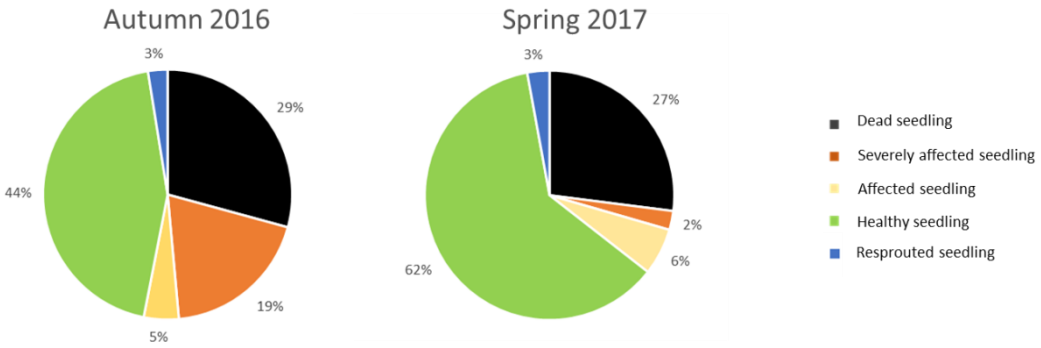

Figure 17. Distribution of the seedlings planted in autumn 2016 and spring 2017 with Cocoon, according to their physiological state, in May-June 2018.

Regarding the results of the different Cocoon versions tested in Tifaracás, those with only one wick and without weeks seem to work better than the current version, despite the number of Cocoons tested, especially for one wick is too small for making conclusions (figure 18). In any case, it seems to indicate that reducing the transmission speed of water could help to improve the performance of the seedlings, probably because humidity levels are maintained higher for more time in the root systems. Regarding wick type, the test made in San Marco does not show remarkable differences between treatments (figure 19).

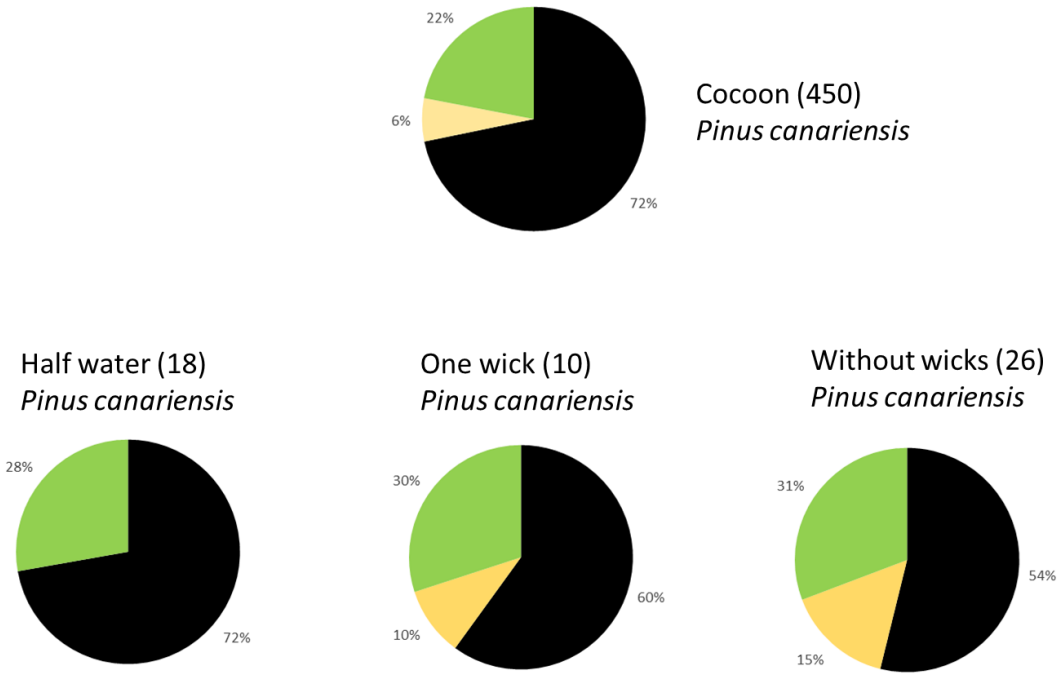

Figure 18. Distribution of the seedlings of *Pinus canariensis* planted with different versions of the Cocoon in Tifaracás (Gran Canaria), according to their physiological state, in May-June 2018. Numbers in brackets indicate the quantity of the seedlings monitored per treatment.

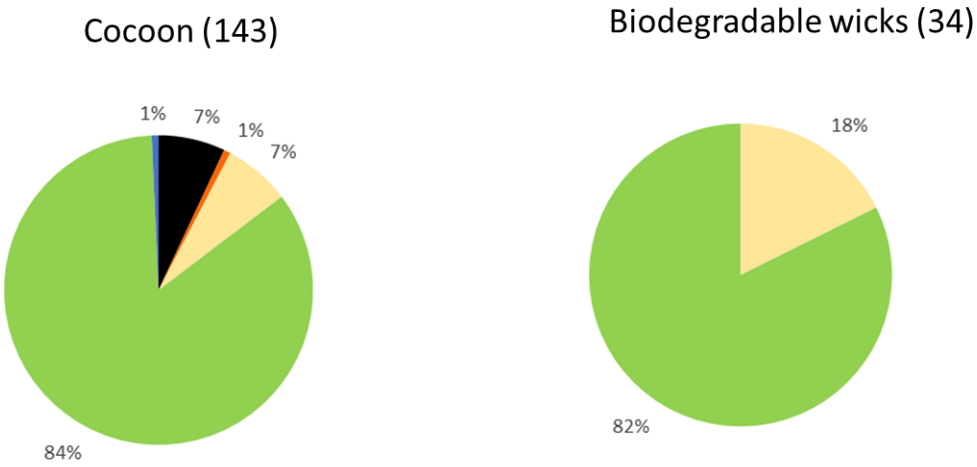

Figure 19. Distribution of the seedlings planted with and without biodegradable wicks in San Marco Argentano (Calabria), according to their physiological state, in May-June 2018.

4. Preliminary conclusions

- For concluding, and despite is too early for making definitive conclusions, in general, seedlings planted with Cocoon have higher survival ratios and better physiological state than controls.

- However, results vary according to the rainfall regime, being better in the most humid regions.

- Apart of rainfall regime, species type, the quality of the seedling, the planting process and the soil quality seem to play a role on seedlings behavior.

- Species translocation strategy applied (assisted migration, adaptive restoration) is giving good results (*Quercus ilex subsp. ballota* in El Bruc and *Tetraclinis articulata* in Jijona).

- Related to the use of assisted migration concept for agricultural uses, cornicabra olive tree seems to work well in Catalonia and Alicante (Jijona) trials.

- Survival results are similar for seedlings planted in spring and autumn, despite seedlings in spring present a better physiological state (higher percentage of healthy seedlings).

- Regarding the results of the different Cocoon versions tested, versions with only one wick and without weeks seem to work better than the current version.