AgriInnovation Program Stream B

2017-18 Annual Performance Report

Precision irrigation in nursery using wireless tensiometers

Name of Recipient: Canadian Ornamental Horticulture Alliance	
Project Title: Canadian Ornamental Horticulture Research and Innovation Cluster	
Project Number: AIP-CL20	Period Covered by Report: 2017-04-01 to 2018-03-31
Activity #: COHA 02 Name of Activity: Precision irrigation in nursery using wireless tensiometers	Principal Investigator: Charles Goulet, Université Laval

1. Performance Measures. See Annex A for an explanation of each measure.

Innovation Items	**Results Achieved**	Provide a description (2-3 paragraphs) for each item produced and describe its importance to the target group or sector. Explain any variance between results achieved and targets. Use plain language.
# of new/improved practices	1	Irrigation is one of the most important factors for nursery profitability, influencing both plant quality and production costs. Nursery production requires a significant supply of water, especially for container production (often more than 200,000 L/ha per day). Unfortunately, traditional irrigation management results in a significant loss of water in part because some of the water never reaches the plant and in part because of overwatering due to a wrong evaluation of the plant needs. To insure a better management of the resource and reduce the impact on the environment, it is essential to move toward precision irrigation. In this project we have evaluated a new generation of wireless tensiometer that measures the water available to the plant and allows precise irrigation control. We have established the best clustering practices based on the water needs of diverse species. We have also evaluated the best irrigation strategies in a commercial setting and demonstrated that we can reduce water use while maintaining an optimal growth. Overall, we propose improved practices for water management in plant nurseries. These results have the potential to help growers across the country and we expect a quick adoption by the industry.

Information Items	**Results**	**Provide the complete citation for each item. Please see**

	Achieved	Annex A for examples.
# of information events	2	1. Goulet, C. *Precision irrigation in nursery using wireless tensiometers*, COHA Webinars, 2018/02/14. 2. Goulet, C. *Irrigation de précision en pépinière avec tensiomètres sans fil*, Salon de la FIHOQ, 2017/11/16.
		Provide the # of attendees
# of individuals attending information events	55	1. 15 attendees ~ 40 attendees
		Provide the # of attendees who intended to adopt new information or technology
# of individuals attending information event who intend to adopt new innovation	13	1. 3 attendees (based on discussion after the talk) 10 attendees (based on discussion after the talk)
		2.
		2.

2. Executive Summary

Key Highlights -

Water management is one of the most important issues in nursery plant production. Providing enough water to the plants is essential to maintain an optimal growth and has a direct impact on both plant appearance and the duration of the production cycle. Nonetheless, deciding when to irrigate is often challenging and overwatering can be detrimental both for the environment and for the production costs.

Nursery plant production requires a large volume of water (up to 200,000 liters/ha/day) and optimization can therefore have a significant effect on the volume needed every year. To optimize water use and help in the decision making, we evaluate a new generation wireless tensiometer that measures the water available to the plant and allows precise irrigation control.

Using a web interface, we were able to monitor changes in water availability to the plants in real time. This allowed precise control and an accurate assessment of the best irrigation threshold for different species. Based on these results, we compared four irrigation strategies in a commercial nursery; using notably wireless tensiometers with or without capillary mats. Water use and plant growth were measured to determine the impact of each of the strategies, providing useful information for the evaluation of the wireless tensiometers. In parallel, we tried to find the best clustering practices for a wide range of species by combining them to reference species monitored with wireless tensiometers. One challenge in a nursery is the wide diversity of species that are grown together. Each has different water needs and it would be too expensive and/or complicated to monitor them individually with tensiometers. By knowing what species cluster best together, we hope to set guidelines towards more efficient water use in plant nurseries.

Success Story

One of the most interesting results of the project first year was the great diversity measured between the species in the optimal irrigation threshold. Among the five perennials and five shrubs tested, some grew the best when the soil was irrigated while it was still moist, whereas others didn't suffer at all from a dryer irrigation threshold. This indicates that some species can maintain an optimal growth with less water and therefore reduce water use in a nursery production. Another interesting finding was the difference in the total volume of water used between the species regardless of their optimal threshold. For example, the *Hosta* used around seven times less water than the *Astilbe* despite growing the best at the same irrigation threshold. This difference, which can be explained in part by their contrasted growth rate, illustrated the need to create clusters based on their overall water needs during a season. To give more information to the growers on that matter, we have tested different clustering of species in the second and third year of the project. It was interesting to see that most species are able to grow well with several of the reference species. For example, the *Potentilla* gave similar results when clustered with 7 out of the 10 reference species. This also means that they can sometimes give similar results with far less water, providing opportunities for the growers to reduce water use.

In the second part of the project, we were also able to test the wireless tensiometers in a commercial setting. The wireless tensiometers provided reliable data, likely facilitating the decision process of growers who will use it. The main advantage of wireless tensiometers is the possibility to access the information from wherever you are (either by using the web interface or by receiving alarms on your cell phone). This allowed more flexibility in the nursery operations and also prevent an oversight. After a few changes between the second and third year, we were able to reduce water use in the commercial setting by almost half without reducing the plant growth. This was achieved by combining wireless tensiometers with capillary mats. These results illustrate how we can reduce water use by optimizing water management in plant nurseries.

3. Objectives/Outcomes (technical language is acceptable for this section)

Irrigation is one of the most important factors for nursery profitability, influencing both quality and production costs. Nursery production requires a significant supply of water, especially for container production. Despite the importance of irrigation, nursery water management appears to mostly depend on the personal judgment of growers rather than measurements. Almost three producers out of four base decisions to irrigate on visual appearance or pot weight. Not enough water can retard plant growth and reduce quality, while overwatering can be highly detrimental to the environment and can cause, at least for some species, severe growth disorders. It also raises production costs by increasing the expenses related to water treatment, irrigation system maintenance, pumping and/or acquisition cost, and irrigation labour.

By delivering the right amount of water at the right time to the right plant, precision irrigation offers a way to optimize water management. In this project, we have evaluated how wireless tensiometers can be used to implement precision irrigation in a nursery production. Wireless tensiometers measure the water available to the plant and send the information by cell signals, allowing a real-time monitoring and a precise irrigation. More specifically, the objectives of the project included:

- To determine, using wireless tensiometers, the irrigation thresholds (soil water potential) of container grown plants to optimize growth and water use.
- To establish the best clustering practices for a wide range of plant species based on their water needs.
- To compare standard watering in a commercial nursery to an automatic irrigation controlled by tensiometers with or without capillary mats.

The deliverable associated to the project were:

2015 –2016:

- Identification of the irrigation threshold of 10 reference nursery plant species with tensiometers.

2016 –2017:

- Identification of the best clustering practices for a set of nursery plant species with the 10 reference plant species and their irrigation threshold.
- Evaluation of water use and plant growth with 4 different irrigation strategies based on precision irrigation in a commercial nursery.

2017 – 2018:

- Identification of the best clustering practices for a set of nursery plant species with the 10 reference plant species and their irrigation threshold. (not the same group of species as 2016).
- Evaluation of water use and plant growth with 4 different irrigation strategies based on precision irrigation in a commercial nursery, in combination with the clustering of 2 species.

Setting irrigation thresholds

During the first year of the project, we have evaluated the optimal irrigation threshold for ten reference species (Table 1), selected for their popularity and wide range of water needs. Four irrigation thresholds were selected, ranging from abundant water available to the plant (-3 kPa) to very little water available (-12 kPa). The plants were grown in 2 gallons pots at the nursery of Université Laval from June to September under a high tunnel to control the irrigation. Water meters were used to measure the volume of water associated with each treatment. Plant growth parameters were monitored throughout the growing season and biomass yield (dry weight) was measured at the end of the season. The experiment for each reference species was conducted as follow: 4 treatments (soil tension threshold), 12 biological replicates, for a total of 480 plants.

After an analysis of the results, each species was assigned an irrigation threshold based on the driest treatment which allowed an optimal growth. There were major differences in the total volume of water used by the species regardless of their optimal threshold. For example, the *Hosta* used around seven times less water than the *Astilbe* despite growing the best at the same irrigation threshold. This difference, which can be explained in part by their contrasted growth rate, illustrated the need of creating clusters based on their overall water needs during a season.

Hydrangea paniculata 'Phantom', Evaluation of different watering threshold.

Sedum spectabile 'Autumn fire', Evaluation of different watering threshold, watermeters, irrigation lines with microsprinklers. Wireless tensiometer station with a tensiometer probe. Experimental setup of 2015.

Table 1. Optimal threshold for the ten reference species used for the project and total water use for each species at their optimal threshold in 2015.

Species	**Optimal water threshold**	**Water use (L/plant)**
Perennials		
Sedum spectabile 'Autumn Fire'	-3 kPa	35,7
Echinacea purpurea 'White Swan'	-6 kPa	43,1
Astilbe arendsii 'Diamant'	-6 kPa	77,2
Hosta 'Golden Tiara'	-6 kPa	11,1
Hemerocallis 'Stella de Oro'	-12 kPa	26,7
Shrubs		
Thuja occidentalis 'Nigra'	-3 kPa	29,6
Spiraea japonica 'Gold Mound'	-6 kPa	39,2
Euonymus alatus 'Compactus'	-9 kPa	11,8

Physocarpus opulifolius 'Diabolo'	-9 kPa	72,2
Hydrangea paniculata 'Phantom'*	-9 kPa	66,8

*The cultivar Phantom was not available in 2016 and 2017 and was replaced by Mega Mindy.

It is important to point out that the amount of water used during a season can change from years to years. For example, the summer of 2016 was warmer and sunnier than 2015 (the effect is accentuated by the tunnel) and plants grew more (and used more water). It can also change drastically depending of the size and quality of the plug used. For example, the *Astilbe* we had in 2015 were really vigorous from the start, while the quality of the plants from 2016 was not as good. The result was a decrease in the amount of water used (while it increased for all the other species). Therefore, before clustering species or cultivars together, it is important to assess the vigor of the plants.

Comparing different irrigation strategies

Based on the results of 2015, we have evaluated in 2016 and 2017 the efficiency of wireless tensiometers in a commercial setting. We have compared four irrigation strategies; standard irrigation by the grower, irrigation by the grower with a capillary mat, automatic irrigation based on wireless tensiometers, and automatic irrigation based on wireless tensiometers in combination with a capillary mat. Water use and plant growth were measured to assess the impact of each of the strategies. In 2016, *Physocarpus opulifolius* 'Diabolo' was used as a reference species for the experiment. Automatic irrigation with wireless tensiometers (either with sprinklers or with capillary mat) resulted in plants with the same size and quality as the one irrigated by the experienced grower. It didn't however allow reducing the amount of water used. The main reason is that while the grower was avoiding watering just before rain was forecasted or when the wind was really high and could blow the drops of the sprinklers, the automation didn't allow such finesse in the decision process. More complete automation systems with weather stations do exist (from Hortau and other companies), but were not tested in our experiment. Those would likely decrease the water used in a completely automated system and we are planning to explore these options in future projects. Regardless, the wireless tensiometers provided reliable data all summer, likely facilitating the decision process of growers who will use it. The main advantage of wireless tensiometers is the possibility to access the information from wherever you are (either by using the web interface or by receiving alarms on your cell phone). This allows more flexibility in the nursery operations and also prevents an oversight.

Evaluation of different irrigation strategies using capillary mats, sprinklers and wireless tensiometers.

Based on the results of 2016, some changes were made to the setup of 2017. The four irrigation strategies were; standard irrigation by the grower (using sprinklers), irrigation by the grower with a capillary mat, irrigation based on wireless tensiometers (using sprinklers), and irrigation based on wireless tensiometers in combination with a capillary mat. Instead of using completely automatic irrigation, we have decided to go toward a hybrid approach where the ultimate decision to irrigate was taken by the team. The data was received from the tensiometers and the irrigation was started only when the weather conditions were good. In other words, the irrigation by sprinklers was delayed if it was too windy or if the rain was coming. Since capillary mats are not affected by the wind, it didn't affect much the irrigation schedule of the treatment of capillary mats with tensiometers. However, the irrigation with tensiometers and sprinklers was often affected since the wind was strong on the site and the size of the droplets was small. The sprinkler irrigation based on the soil tension, was therefore often done in the morning or at night. Another change that was made in 2017 was the ground preparation for the capillary mats. In 2016, the slope of the ground was a little too high and it didn't allow the capillary mats to be as efficient. To remove the effect of the slope, the ground was reworked in the spring of 2017.

The experiment of 2017 was done with *Spiraea japonica* 'Gold Mound' and *Potentilla fruticosa 'Goldstar'.* The irrigation was controlled only based on the soil tension of the reference species. The *Potentilla* was clustered with the *Spiraea* based on the clustering results of 2016 which indicated that the two species have similar water needs. For the *Spiraea*, irrigation with wireless tensiometers (either with sprinklers or with capillary mat) resulted in plants with the same size and quality as the one irrigated by the experienced grower (Figure 1A). However, the amount of water used with capillary mats and tensiometers was a lot less than with the three other irrigation strategies. In fact, the amount of water was reduced by almost half (2.50 m^3/bed for capillary mats and tensiometers vs 4.64 m^3/bed for sprinklers and tensiometers) without reducing the plant quality (Figure 1B).

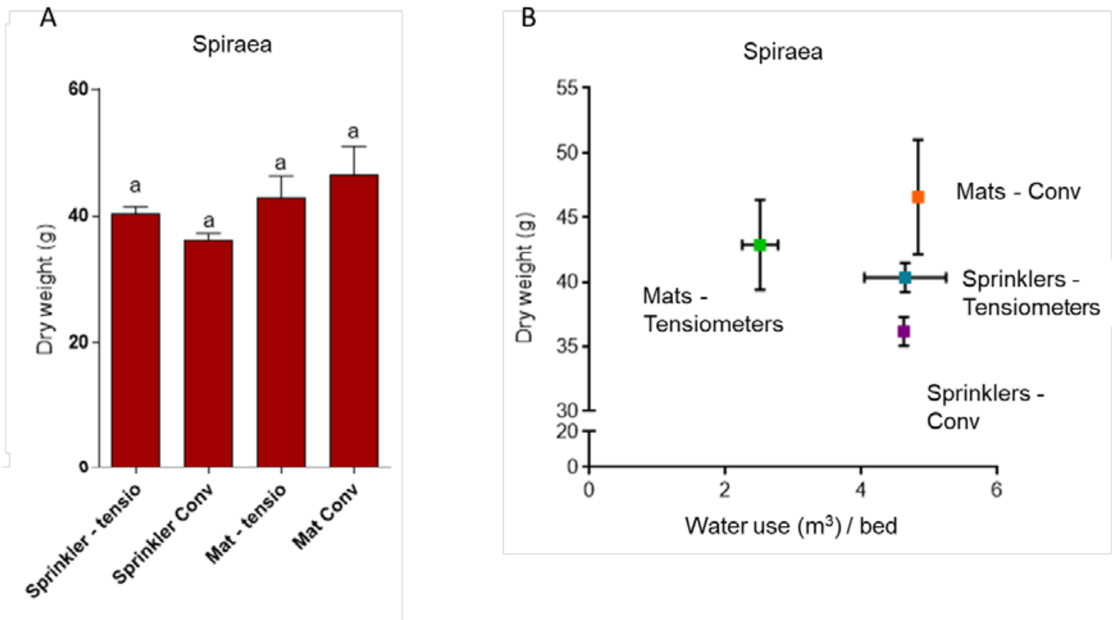


Figure 1. Effect of irrigation strategies on the growth of *Spiraea japonica* 'Gold Mound' in a commercial setting. A) Dry weight of the plants submitted to irrigation based on wireless tensiometers (using sprinklers), standard irrigation by the grower (using sprinklers), irrigation based on wireless tensiometers in combination with a capillary mat, and irrigation by the grower with a capillary mat. B) Water use associated with the four irrigation strategies. ±SEM.

Since the irrigation of the *Potentilla* was done based on the needs of the *Spiraea*, the same strong reduction in water consumption was observed with the Potentilla (Figure 2B). In contrast to the *Spiraea*, the *Potentilla* had slight differences in the dry weight of the plants under each treatment (Figure 2B). Both treatments with capillary mats had higher biomass at the end of the season. This is particularly interesting considering that the capillary mats with the tensiometers had the lowest water consumption of all the treatments. For the plants irrigated by sprinklers, the use of tensiometers resulted in a higher biomass than when the plants were irrigated by the experienced grower. This means that the precision of the tensiometers can allow an optimization of the plants growth while reducing or maintaining the amount of water used. The results of the *Potentilla* also illustrate the advantages of species clustering based on water needs, especially when new technologies like wireless tensiometers and capillary mats are used.

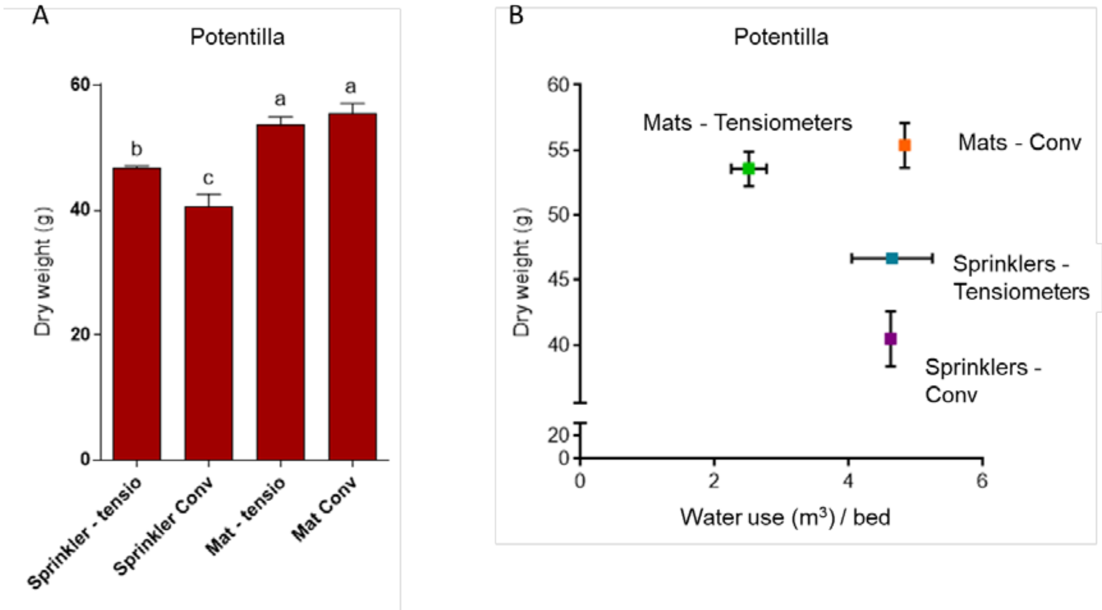


Figure 2. Effect of irrigation strategies on the growth of *Potentilla fruticosa 'Goldstar'* in a commercial setting. A) Dry weight of the plants submitted to irrigation based on wireless tensiometers (using sprinklers), standard irrigation by the grower (using sprinklers), irrigation based on wireless tensiometers in combination with a capillary mat, and irrigation by the grower with a capillary mat. B) Water use associated with the four irrigation strategies. ±SEM.

Highlights from the clustering experiment

The second goal of this project was to find the best clustering practices for a wide range of species by combining them to ten reference species monitored with wireless tensiometers. Each year we have tested 29 new species in combination with the 10 reference species at their optimal threshold. The experiments for this section of the project were made at the Laval University nursery.

As expected from the result of 2015, the reference species needed contrasting water supplies. This means that, for example, the *Weigela* associated with the *Euonymus* received only 15 per cent of the water than the *Weigela* associated with the *Physocarpus*. This wide range allowed to establish for each species what association allows an optimal growth. It was interesting to see that most species are able to grow well with several of the reference species. For example, the *Potentilla* gave similar results when clustered with 7 out of the 10 reference species. This also means that they can sometimes give similar results with far less water. In the setting of our experiment, the clustering *Potentilla* with *Hemerocallis* resulted in the same growth as clustering with *Physocarpus* while reducing the water use by 70 per cent. For other species like *Cornus*, only the clustering with the most water demanding species gave good results. A list of the species used in 2016 and 2017 with the best clustering for each can be found in table 2 and 3.

Table 2. Clustering experiment of 2016.

*Species for which the identification of the best clustering was complicated because of plant mortality. Clustering experiments with *Aquilegia canadensis* 'Little Lanterns' and *Prunus cistena* were also discarded because of diseases.

Clustering experiment.

Table 3. Clustering experiment of 2017.

	Euonymus	Hosta	Thuja	Hemerocallis	Spiraea	Echinacea	Hydrangea	Sedum	Physocarpus	Astilbe
Achillea millefolium	Grey	Grey	Grey	Grey	Blue	Dark blue	Grey	Blue	Blue	Blue
Aconitum napellus	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Alchemilla mollis	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Dark blue	Blue	Blue
Amelanchier canadensis	Blue	Blue	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue	Blue
Aster lateriflorus	Grey	Grey	Grey	Blue	Blue	Dark blue	Blue	Blue	Blue	Blue
Baptisia australis	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue
Buddleia davidii 'Black Knight'	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Blue	Blue	Dark blue
Caragana arborecens	Grey	Blue	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue	Blue
Chaenomeles x superba 'Crimson Gold'	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Chelone glabra	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue	Blue	Blue
Dianthus 'Kahori'	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Festuca glauca 'Elijah Blue'	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue	Blue
Geranium sanguineum	Grey	Grey	Grey	Dark blue	Blue	Blue	Blue	Blue	Blue	Blue
Heuchera micrantha 'Palace Purple'	Grey	Blue	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue	Blue
Ilex verticillata	Grey	Grey	Grey	Blue	Blue	Dark blue	Blue	Blue	Blue	Blue
Iris sibirica 'Ruffled Velvet'	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue
Lavandula angustifolia 'Hidcote Superior'	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Liatris spicata 'Floristan Blanc'	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Dark blue	Blue	Blue
Ligularia przewalskii*	Grey	Grey	Grey	Grey	Grey	Grey	Grey	Blue	Grey	Dark blue
Lonicera x xylosteoides 'Clavey's dwarf'	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Philadelphus virginalis	Grey	Grey	Grey	Blue	Blue	Blue	Dark blue	Blue	Blue	Blue
Rhododendron 'Mandarin Lights'	Blue	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue	Blue	Grey
Rhus typhina	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Rubus odoratus	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue
Scabiosa columbaria 'Blue note'	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue
Sorbaria sorbifolia	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue
Spirea x arguta	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Spirea x vanhouttei 'Rennaissance'	Grey	Grey	Grey	Blue	Dark blue	Blue	Blue	Blue	Blue	Blue
Viburnum dentatum 'Autumn Jazz'	Grey	Grey	Grey	Blue	Blue	Blue	Blue	Dark blue	Blue	Blue

Grey: not suggested, Blue: possible clustering, Dark blue: suggested clustering for optimal growth and water use.

*Species for which the identification of the best clustering was complicated because of plant mortality.

Relation between the water use and the gain in biomass can be illustrated in Figure 3. If the water is not sufficient enough, the plant simply dies. This situation happened for a few species (example: *Potentilla*) when associated with Euonymus which doesn't need a lot of water to thrive. Passed that threshold; plants gain biomass as water increase until they reach a plateau where more water won't translate into biomass gain. If too much water is applied, the biomass will start to decrease. To reduce water use while maintaining the optimal growth, it is important to target the beginning of the plateau. Results from the clustering experiment illustrate well how it can be done by associating plants together. In Figure 4 we can see that we didn't reach the plateau yet with *Cornus* (we would need a reference species that needs more water), while we did we *Hydrangea macrophylla* and *Potentilla*.

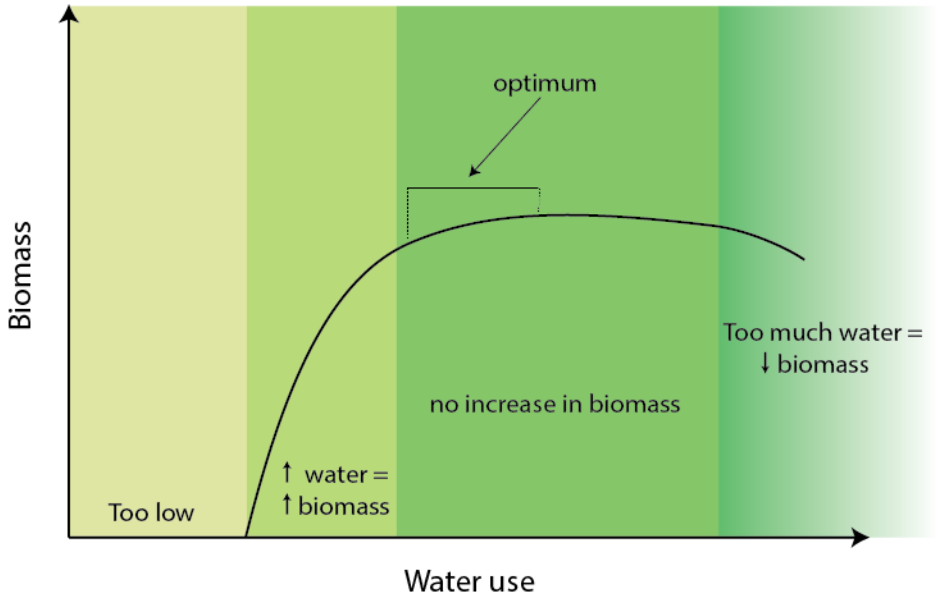
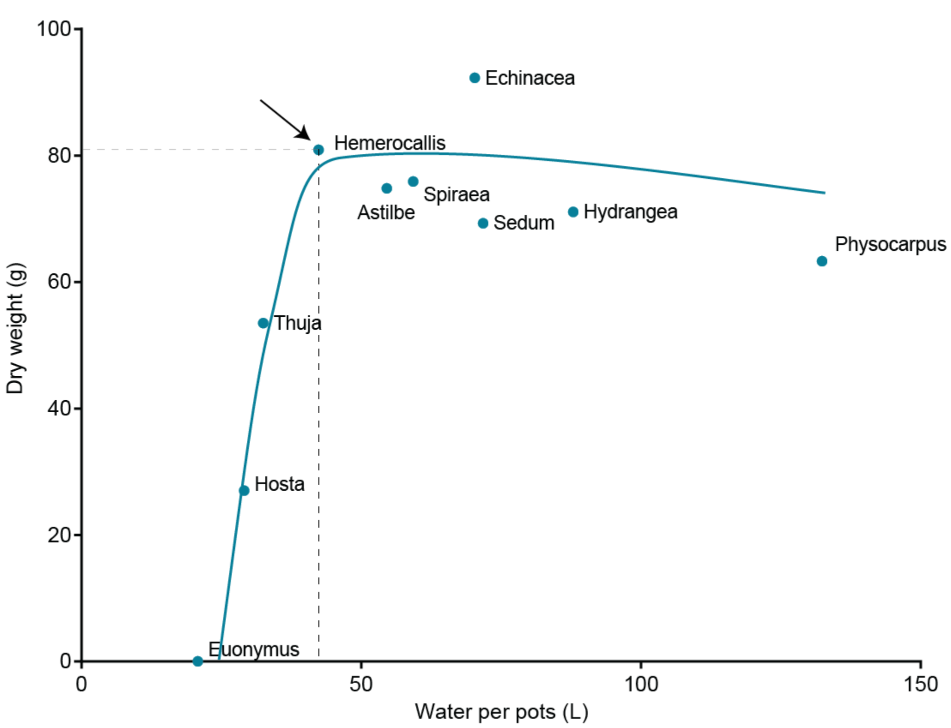
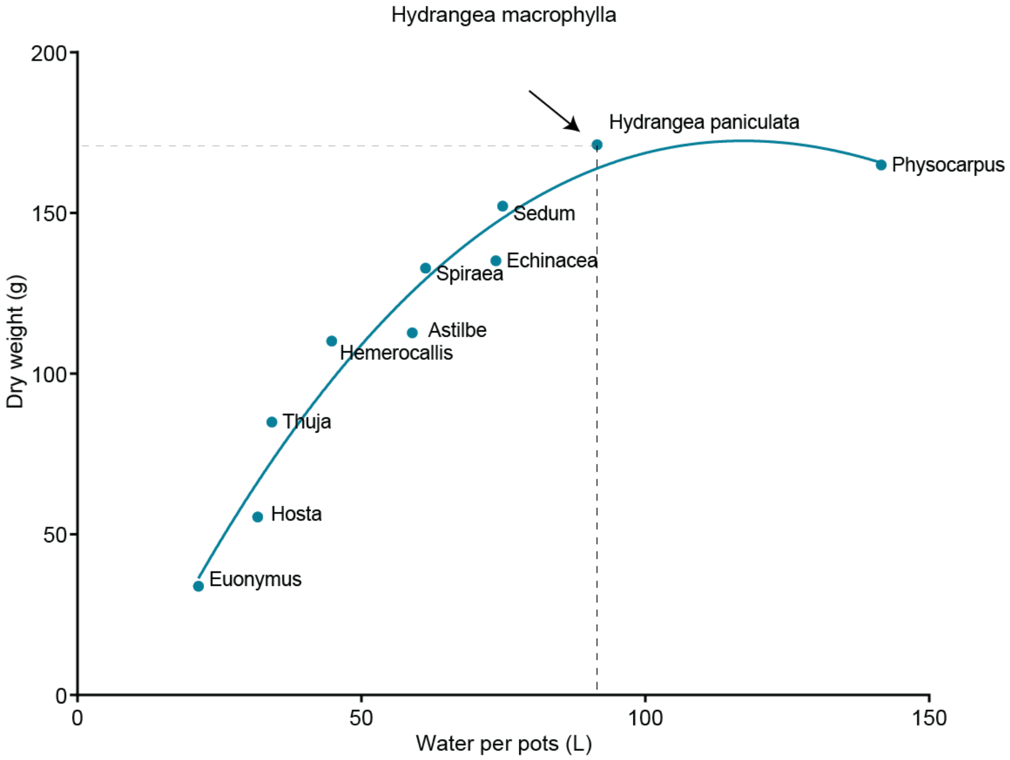


Figure 3. Relation between water use and biomass in a nursery setting.





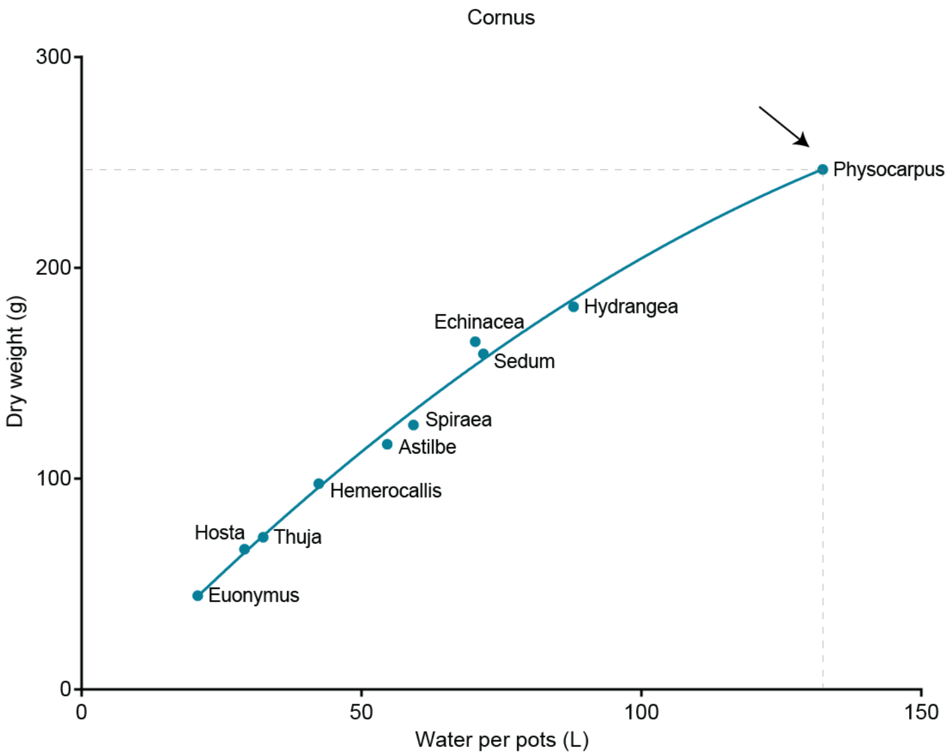
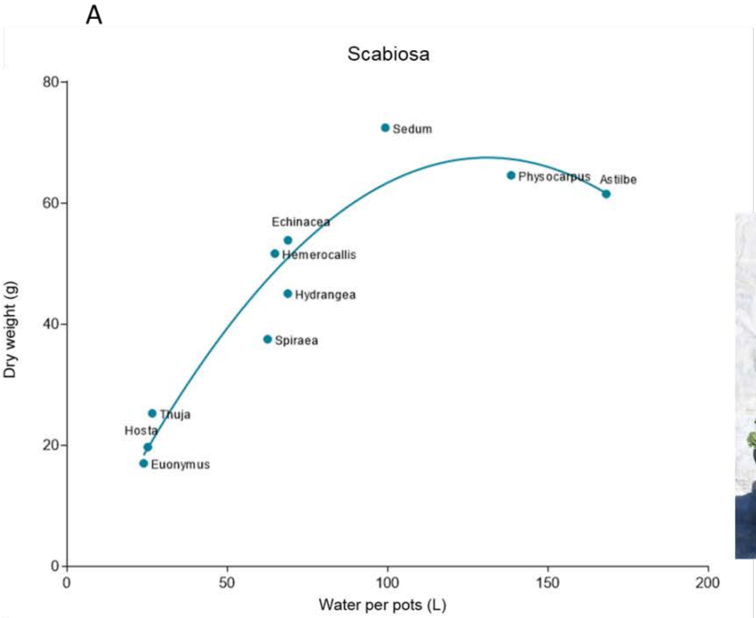
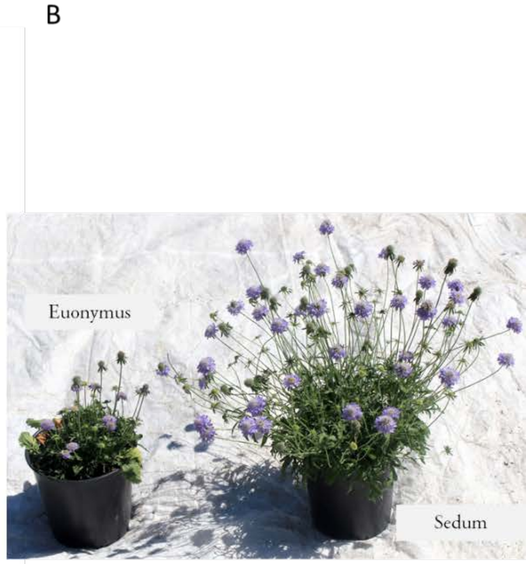


Figure 4. Clustering results for three species.

It is important to point out that the first month after transplanting can be really critical and since species often establish at different speeds, it is important to monitor each species individually at the beginning. It was particularly evident for species like *Physocarpus*, which despite needing a lot of water later in the season is slow to establish in the beginning. For that reason, the watering based on the clustering was implemented only after the establishment.

In figure 5 and in figure 6, we can see two opposite examples of clustering results. *Scabiosa columbaria* reacted with the typical curve associated with an increase in water availability (Figure 5A). The plants associated with *Hosta* or *Euonymus* were clearly smaller with less flowers and less leaves. An increase in watering allowed an improvement in plant quality up to a point where more water didn't translate into an increase in biomass. For *Scabiosa*, the best clustering would be with the *Sedum* which results in high quality plants while necessitating nearly 60% less water than if they were clustered with the *Astilbe*. For the *Dianthus*, all the clustering gave similar results (Figure 6). The absence of differences indicates that all the treatments gave enough water to *Dianthus* and that we can easily save water by clustering the species with the *Hosta* or the *Thuja* for example.





A) Dry weight at the end of the season. B) Differences in the growth between plants clustered with *Euonymus* and with *Sedum* in the beginning of August.

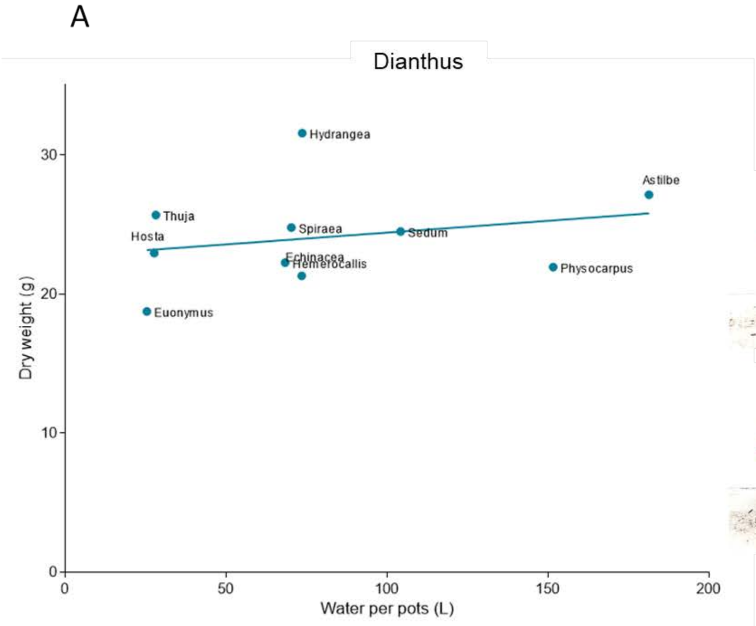


Figure 6. Clustering results for *Dianthus* 'Kahori'. A) Dry weight at the end of the season. B) Absence of differences in the growth between the different clusterings.

The clustering data also illustrates the great plasticity of most species. This plasticity means that growers could deliberately decrease the plant growth by reducing water use while still avoiding damages that would preclude the sale. In the next two examples, when can see the effect of aiming for the optimal growth or choosing to accept a decrease in biomass to save water. The figure 7 shows the effect of clustering *Calamagrostis* with five different species. There are no obvious damages with any of the clustered species, even with species needing a lot less water like *Thuja*. There are however strong differences in the growth and the optimal clustering would be with the *Hydrangea,* the *Echinacea* or the *Physocarpus*. Clustering with the *Hydrangea* or the *Echinacea* instead of the *Physocarpus* would allow a reduction of water use by nearly 50% without losing yields. If water is really scarce, a grower could cluster *Calamogrostis* with *Hemerocallis*. This would reduce by half the growth in comparison to a cluster with *Echinacea*, but it would also reduce water use by nearly 50%. This situation is similar with the lilac (*Syringa vulgaris*) (Figure 8). The optimal clustering is with the *Physocarpus* but it is possible to reduce by half the amount of water used by clustering with *Hydrangea* without causing visual damages. This reduction in water consumption decreases however the biomass by nearly 20%. The lilac example also illustrates the limit of plasticity as clustering with *Euonymus* created damages to the leaves and a stunt growth.

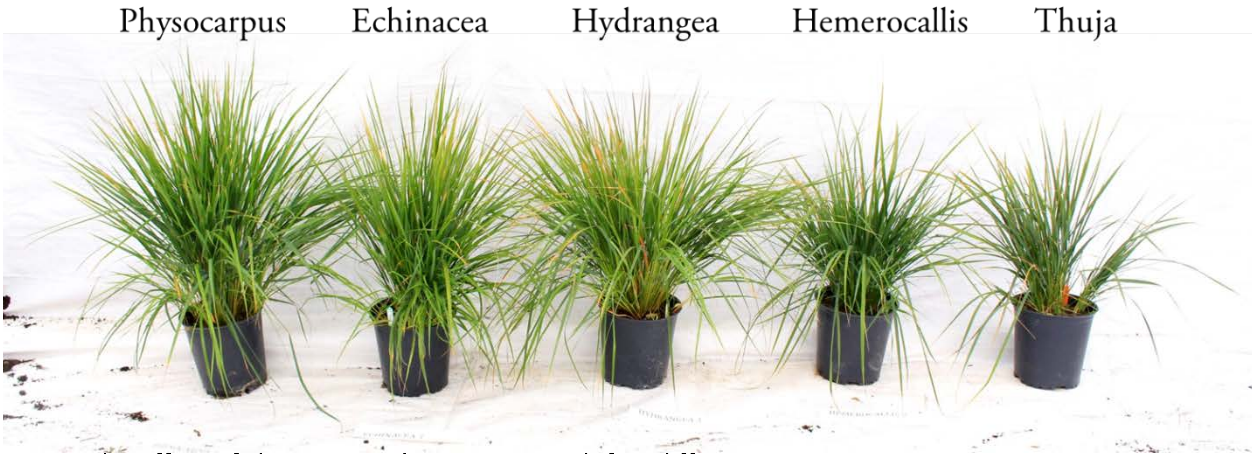


Figure 7. The effect of clustering *Calamogrostis* with five different species.

Figure 8. Growth differences associated with clustering *Syringa vulgaris* with *Physocarpus*, *Hydrangea* or *Euonymus.*

Conclusion

The different experiments allowed us to meet the objectives of this project that were i) to determine the best irrigation thresholds of container grown plants to optimize growth and water use, ii) to establish the best clustering practices for a wide range of plant species based on their water needs, and iii) to evaluate different irrigation strategies based on precision irrigation in a commercial nursery. The results of our experiments demonstrate that it is possible to reduce water use by adopting new practices that rely on the precise measurements associated with wireless tensiometers. Our data also provide guidelines to optimize water management by clustering plants based on their water needs. Overall the project demonstrates the potential of precision irrigation to improve water management in plant nurseries.

4. Lessons Learned:

Describe the key lessons learned gained as a result of executing the project (e.g., a more efficient approach to performing a specific task for activity / project).

Precision irrigation has the potential to reduce significantly water use in nursery plant production. Our project shows that wireless tensiometers provide reliable data that can be used to decide precisely when to irrigate. Moreover, it allows more operational flexibility by giving easy access to the data wherever the grower is. Our research also highlights the great diversity of water requirements between species and how it is possible to reduce water use by making efficient clustering of species.

5. Future Related Opportunities:

The results of the current project have shown the potential of precision irrigation to reduce water use in plant nurseries. The strategies explored will provide guidelines to the growers and there is a strong potential of adoption by the industry. We believe that the growers will be able to use our data to make more informed decisions. However, we think that we can go even further and optimize even more the irrigation management, notably by developing more the automation.

If we look at long term research outlook for precision irrigation in nurseries, there is an obvious need for a better knowledge of the specific needs for each species. Given the wide diversity of species grown in the industry and the new additions brought to the market every year, it is likely that this research field will stay relevant in the long-term future. The development of new tools to acquire data and a better integration of the results to control the irrigation will, without any doubt, allow a decrease in water use and improve the sustainability of the industry. As the value of water increases (either because of less resources or higher cost of irrigation labour), more experiments will be needed to fine-tune the irrigation management.

NOTE TO READER: This report has been edited from the original for formatting purposes only. There have been no changes made to the information provided by the researcher.