Manipulating Irrigation Patterns to Evaluate Fine Root Traits, Root Production Rates, and Fine Root Physiology in Almond Trees

Project No.: **17-PREC5-Volder**

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Objectives:

1) Establish an almond research site at the UC Davis research farm
   a. Compare impact of different nursery root treatments (bare root, root pruning pot, ellepot) on Nonpareil tree establishment and above- and belowground growth
   b. Measure impact of irrigation on root growth & turnover
   c. Assess impact of pruning on root and tree growth

Interpretive Summary:

Root, shoot and vascular traits are tightly linked to expected survival and growth rate under drought conditions. The supply of water to and within plants is determined by soil water availability (water content and soil type), plant architectural traits (e.g., root:shoot ratio, root depth, root surface area, leaf area, tissue density), as well as axial and radial hydraulic conductance of the root system. In general, a tradeoff exists between the characteristics that confer stress resistance and those that allow a high physiological activity. We aim to study variation in root morphological, anatomical and physiological traits in response to drought (reduced irrigation). The overall goal is to combine information derived from this project (root phenology, root morphology and root water and nutrient uptake), with information from

associated projects (N uptake rates and N movement in soils) to improve the design of irrigation and fertigation systems as well as recommend optimal irrigation strategies.

A dedicated field trial was installed at UC Davis to allow for a detailed study where both temporal and spatial patterns of root production, morphology and physiology in response to drought conditions can be studied. Trees were planted in February 2015 and differential irrigation treatments were imposed in June 2016. Data will be used to project root responses of almond to different drought scenarios.

Materials and Methods:

Funding provided by the Almond Board of California with trees donated by Sierra Gold Nurseries has allowed us to install a research site at the UC Davis field research station in Davis. This site consists of 4 blocks with 6 treatment rows and 2 guard rows. Irrigation for each row is independently measured and controlled. We planted bare root and potted (root pruning and ellepot) Nonpareil grafted on Krymsk 86, with bare root Monterey and Wood Colony as pollinizers. Each treatment row has a pair of bare rooted trees, a pair of trees established from root pruned pots, and a pair of trees established from ellepots. Pollinizer trees were planted in the same row, in between the potted versus bare root treatments. Guard trees (bare root Nonpareil on Krymsk 86) were planted at the beginning and end of each row to minimize edge effects. The two outermost rows had the same pattern of two Nonpareil and alternating pollinizers as the rest of the orchard. All treatment trees and pollinizers were pruned but were left at the height as received from the nursery (not headed). **Table 1** lists the characteristics of potted versus bare root trees at the time of planting.

Table 1. Detailed characteristics of Nonpareil on Krymsk 86 trees before planting at the UC Davis research farm. Note that despite large differences in size, both bare root and potted trees had similar root surface area.

	Bare root	***Potted***
Trunk diameter (mm)	16.6	5.50
Stem cross section area (mm^2)	216	23.0
Aboveground mass (g)	480	28.2
Root mass (g)	110.2	6.38
Root length (m)	49.8	103
SRL (m_{root} g^{-1}_{root})	0.45	16.5
Mean root diameter (mm)	1.64	0.77
Root surface area (cm^2)	2395	2378
% Surface area in roots <1 mm diameter	23	58

Trees were planted early February 2015, with minirhizotron root observation tubes installed in April 2015. Initial irrigation was applied using a drip system and switched to micro sprinklers in June 2015. In February and April 2016 half of the treatment trees were severely pruned. Differential irrigation treatments started June 2016 although the soil started drying significantly in April 2016 and first irrigations were applied in May (**Figure 1**). Trees were monitored for stem diameter growth, water potential and, starting in February 2016, root production using minirhizotron tubes.

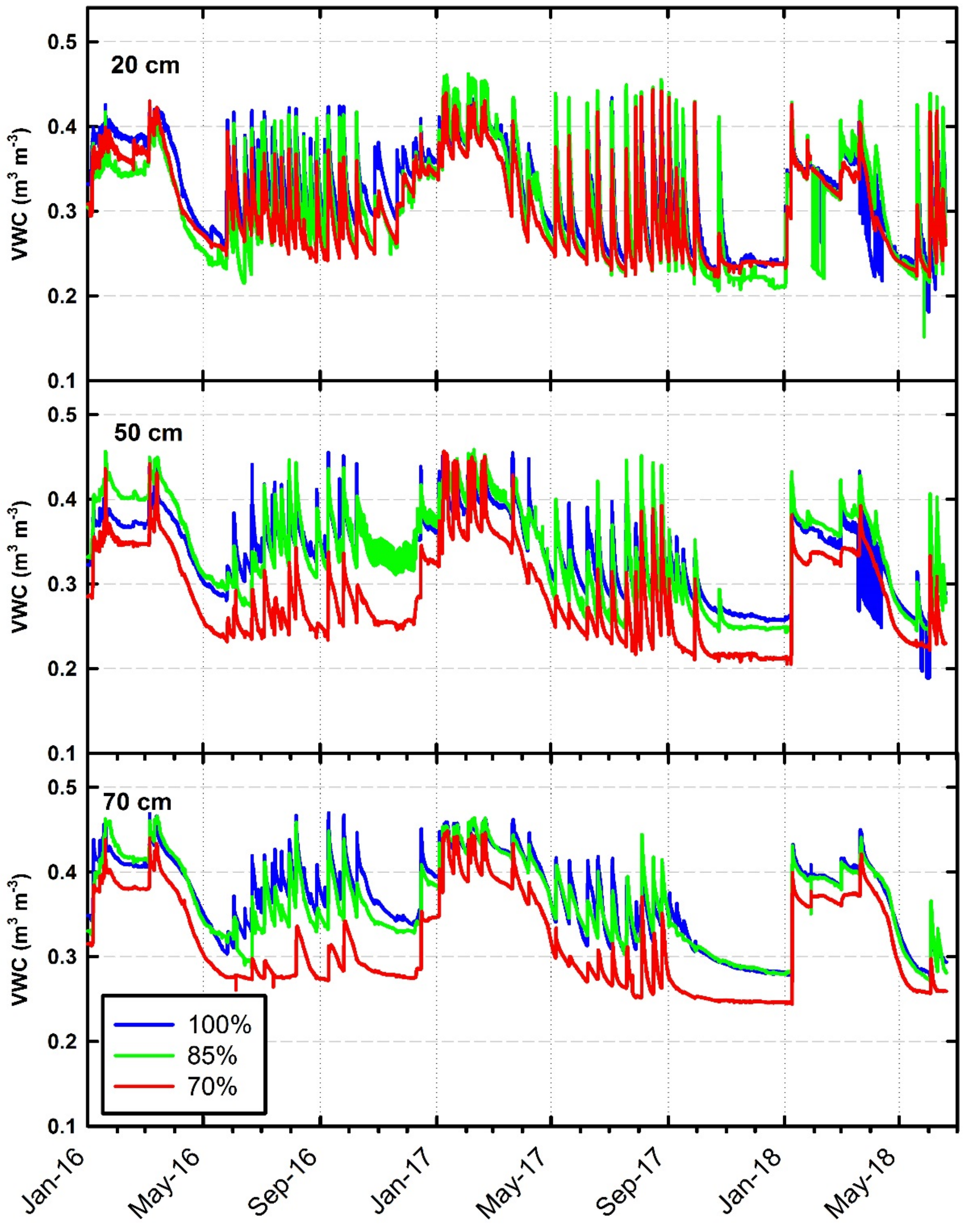


Figure 1. Soil water content at 20, 50, and 70 cm depth in the three different irrigation treatments. Differential irrigation started June 1, 2016. Total irrigation applied in 2016 was 30 inches in the 100% treatment, 24 inches in the 85 % treatment, and 20 inches in the 70% treatment, and 27 inches in the 100% treatment, 23 inches in the 85 % treatment, and 20 inches in the 70% treatment in 2017 as measured using independent water meters on each irrigation line (24 lines).

Guard trees (all bare root) were used for a separate experiment where half the trees were headed, and the other half left unheaded. Within each heading treatment half the trees had side branches pruned off and the other half was left unpruned.

Results and Discussion:

Bare root Nonpareil trees were larger at planting in February 2015, and still larger three years after planting. However, these trees had the lowest growth rate per unit existing stem area at every level of irrigation and pruning, compared to those originating from ellepot or root pruning pots. Reducing irrigation from 100% (30 inches applied during growing season) to 70% (20 inches applied during growing season) reduced average tree growth rate from 0.85 to 0.75 mm^2 mm^{-2} $year^{-1}$ (-11%), while canopy pruning decreased average growth rate from 0.92 to 0.68 mm^2 mm^{-2} $year^{-1}$ (26% decrease). Thus, in 2016, pruning had a much greater negative impact on tree growth than reducing irrigation by 30%. This led to reduced trunk areas in pruned trees in March 2017, which persisted into February 2018 (**Figure 2**). Reducing irrigation to 70% of maximum applied had a greater effect on trunk area of potted trees than bare root trees.

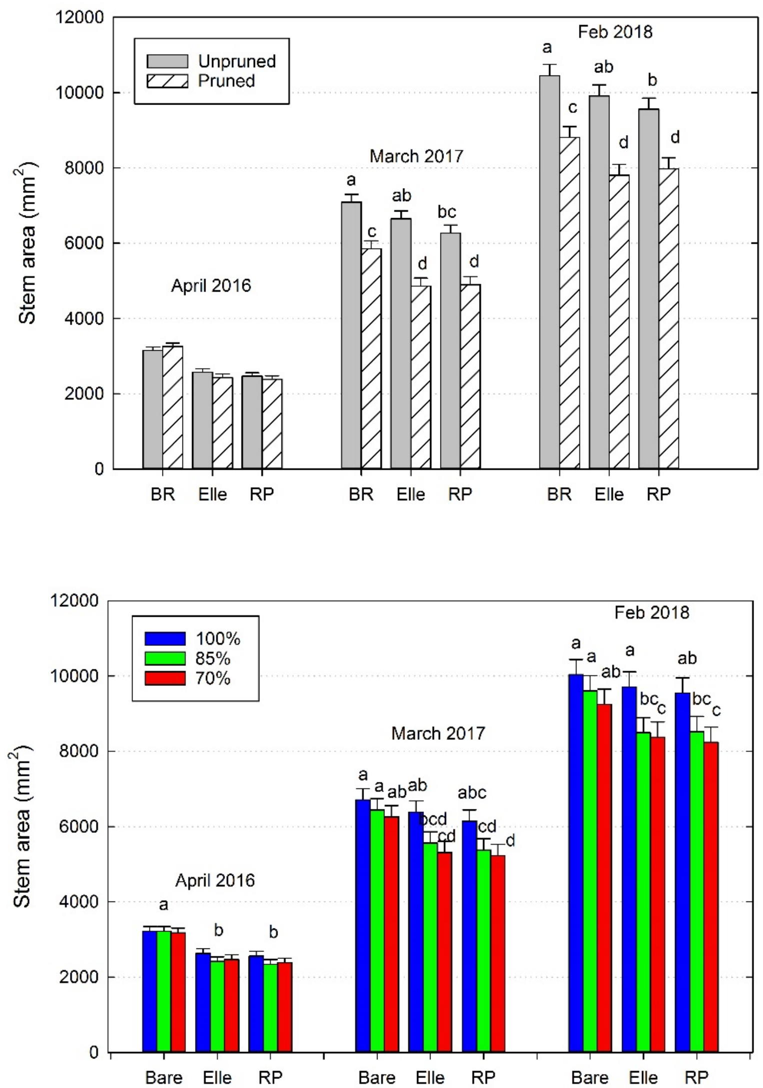
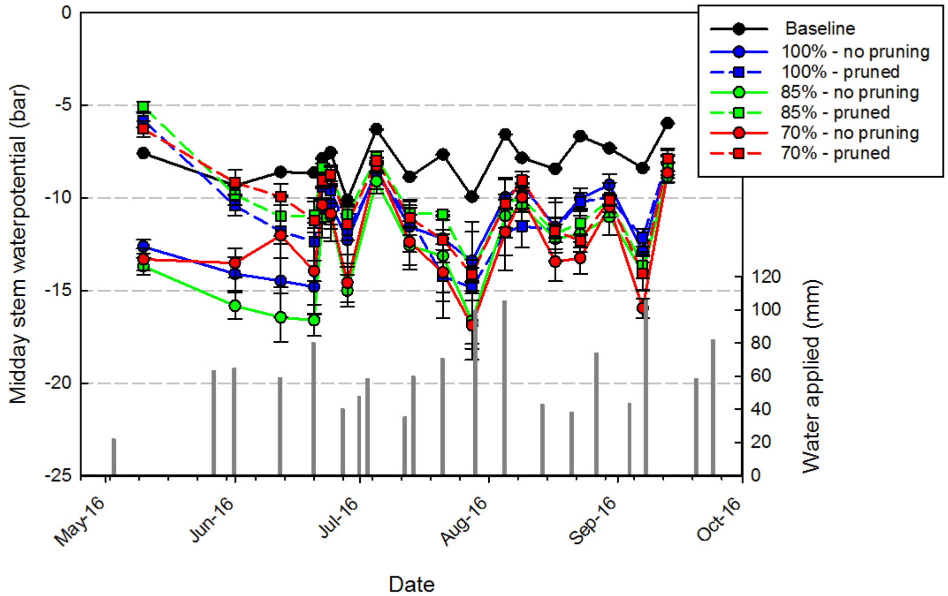


Figure 2. Stem area in the period April 2016 (one year after planting) to February 2018. Impact of pruning (top) and irrigation (bottom)



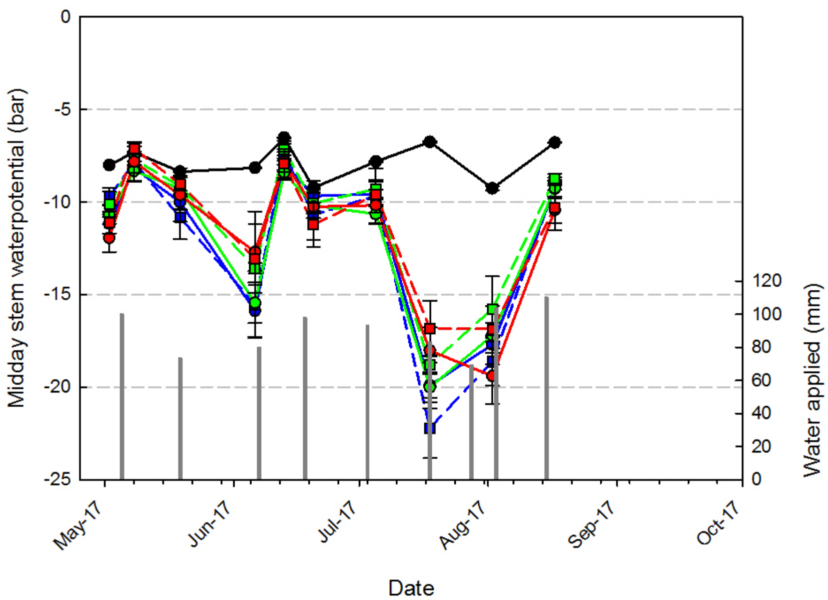


Figure 3 Impact of pruning and irrigation amount on stem water potential in 2016 (a) and 2017 (b). 100 = trees with highest level of applied irrigation, 85 and 70 are 85% and 70% of the amount applied to the 100% trees. Irrigation treatments were imposed June 1, 2016. Solid line = baseline (expected water potential for well-watered trees).

The pruning treatment was nested within irrigation lines, making it difficult to target the right amount of water to apply to not drown the smaller (pruned) trees while still stimulating growth in the larger unpruned trees. Stem water potential varied from above the baseline for pruned trees in May, to consistently well below the baseline for unpruned trees (**Figure 3**). Unpruned bare root trees exhibited more negative stem water potential than unpruned potted trees early in 2016, but not in 2017. Even though average soil water content was reduced at every depth

in the 70% treatment (**Figure 1**), this was not clearly reflected in the stem water potential in 2016 or 2017, except for later in the season (mid July - August in both years).
Root images (**Figure 4**) were collected every 3 weeks on half of the installed tubes (72 tubes) to 1.5 m depth. For the remaining 72 tubes, images were collected every 3 months. Processing of images is in progress. We have analyzed 4 tubes per production method x pruning combination within the 100% irrigation treatment (24 tubes) through Feb 2017 and have nearly finished the 24 tubes in the 70% irrigation treatment through Feb 2017 (22 tubes currently).

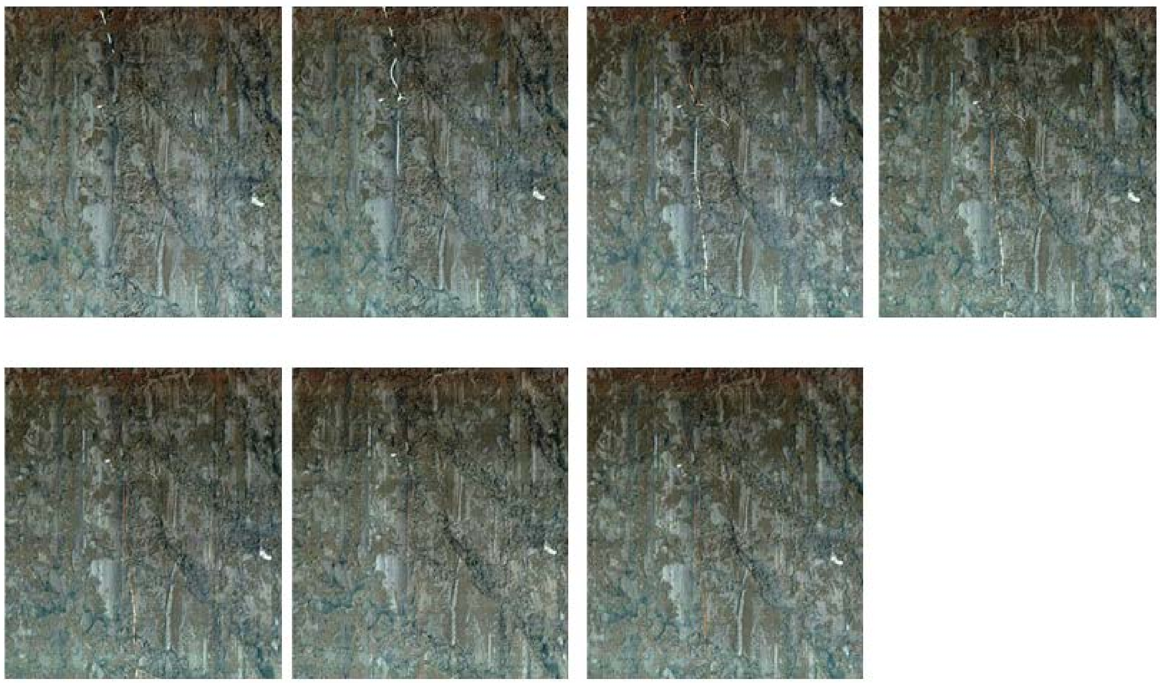


Figure 4. Sequence of images of roots appearing and disappearing in the guard row. The first image was collected July 21, and then weekly thereafter.

Reducing irrigation reduced new root production and the length of the period that new roots are being produced (**Figure 5**). New root production showed a clear peak in the spring, but not in the fall.

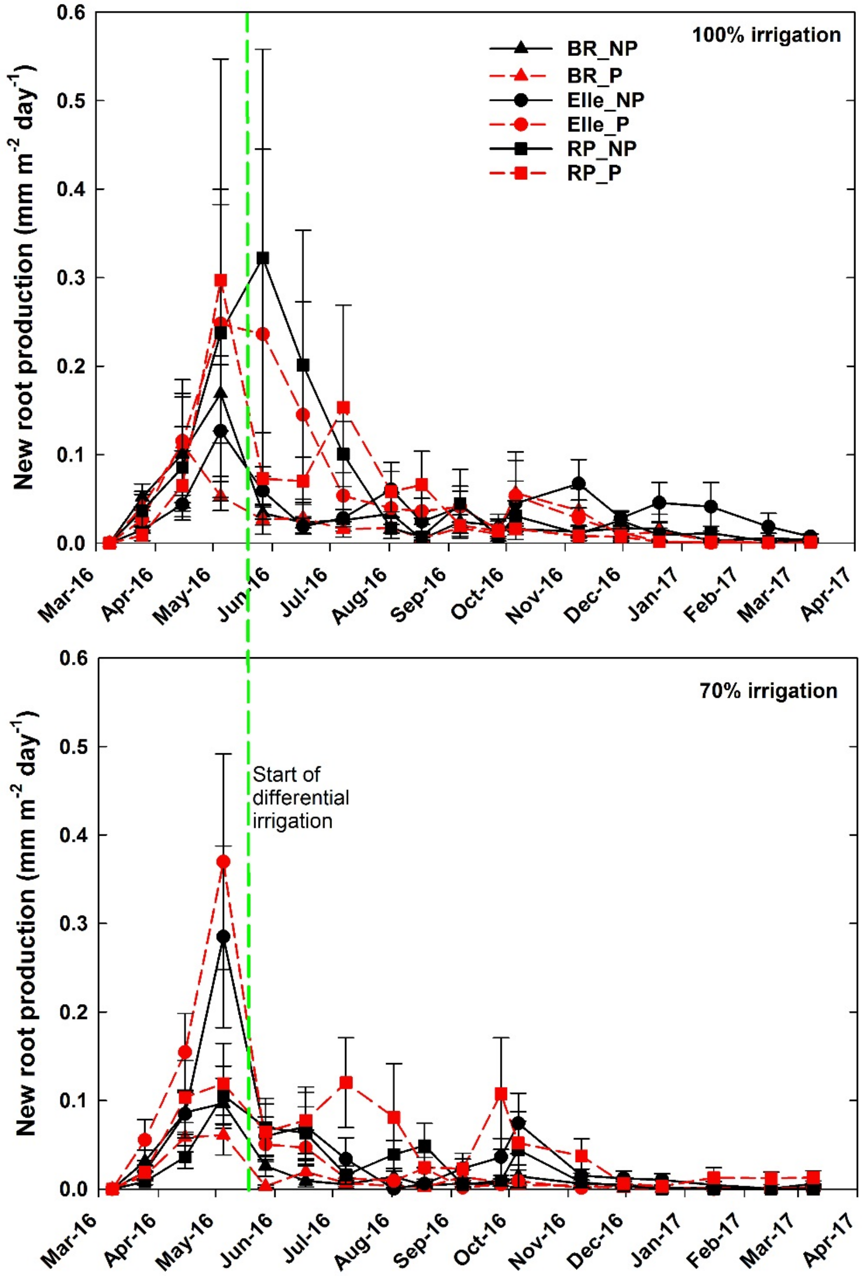


Figure 5. New root production one year after planting as affected by planting origin (bare root vs ellepot vs root pruning pot), and pruning treatment – no pruning (NP, black symbols/line), and heavy pruning (P, red symbols/line). Green vertical line indicates the start of divergent irrigation treatments. Pruning treatments were first implemented February 2016.

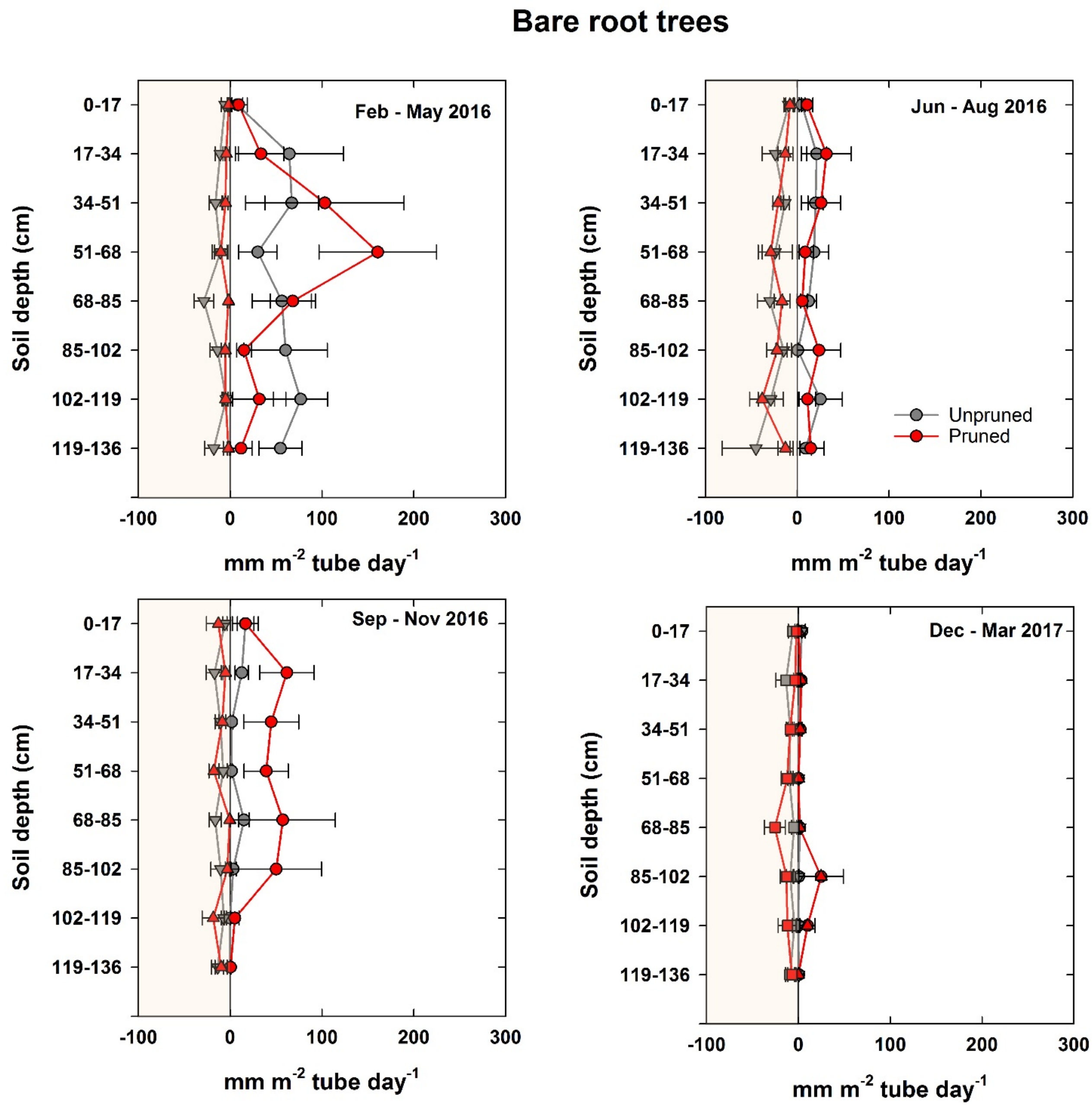


Figure 6. New root length production (blank zone, circles, positive numbers) of bare root trees and root length death (yellow zone, triangles, negative numbers) as a function of pruning (unpruned, gray, and pruned, red) and depth through 4 seasons.

Pruning reduced root length production at depth (deeper than 85 cm) during the spring in all three planting treatments (**Figures 6, 7, 8)**, likely as a result of carbohydrates being used for shoot regrowth rather than root production. Over the growing season at least 30% of the new roots are produced below 68 cm (~ 2 feet) to up to 70% of new root length produced below 68 cm in the unpruned ellepot and root pruning pot trees. All treatments showed greater new root length production than root death in spring. However, more root length died over the summer than was produced in both bare root (**Figure 6**) and ellepot trees (**Figure 7**). Only bare root trees showed greater root length production than death in the fall, where trees from root pruning pots showed no root production (or death) in the fall (**Figures 6, 8**). Very few roots were produced (or died) in the winter period (Dec-Mar).

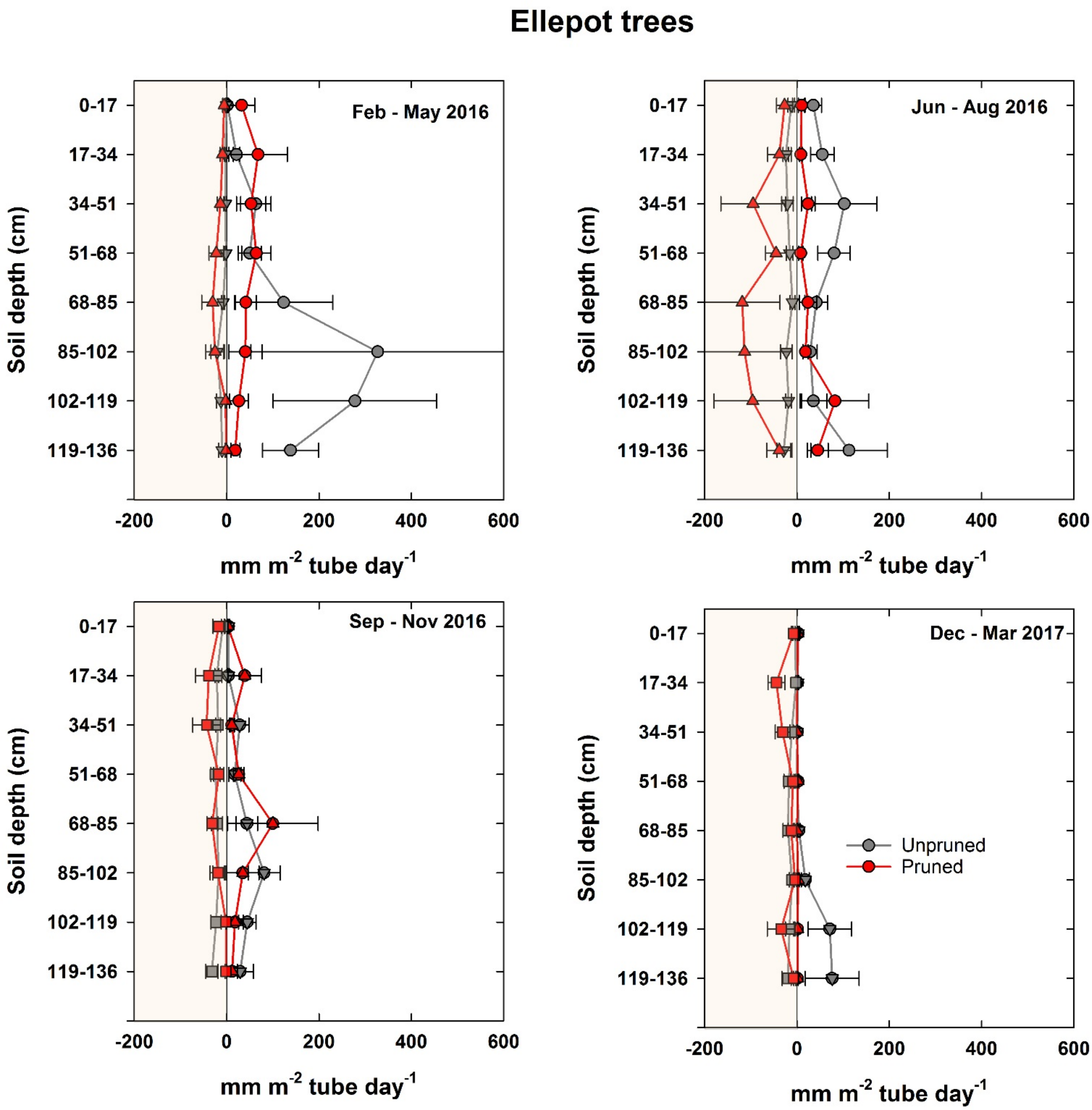


Figure 7. New root length production (blank zone, circles, positive numbers) of trees planted from ellepots and root length death (yellow zone, triangles, negative numbers) as a function of pruning (unpruned, gray, and pruned, red) and depth through 4 seasons.

The overall goal is to combine information derived from this project (root phenology, root morphology and root water and nutrient uptake), with information from associated projects, such as root carbohydrate observations, to improve the design of irrigation and fertigation systems as well as recommend optimal irrigation strategies. We are in the process of using this information to start modelling almond root behavior in response to water availability and general growth conditions. Our next step is to do a detailed analysis of soil conditions versus root distribution to better inform our model.

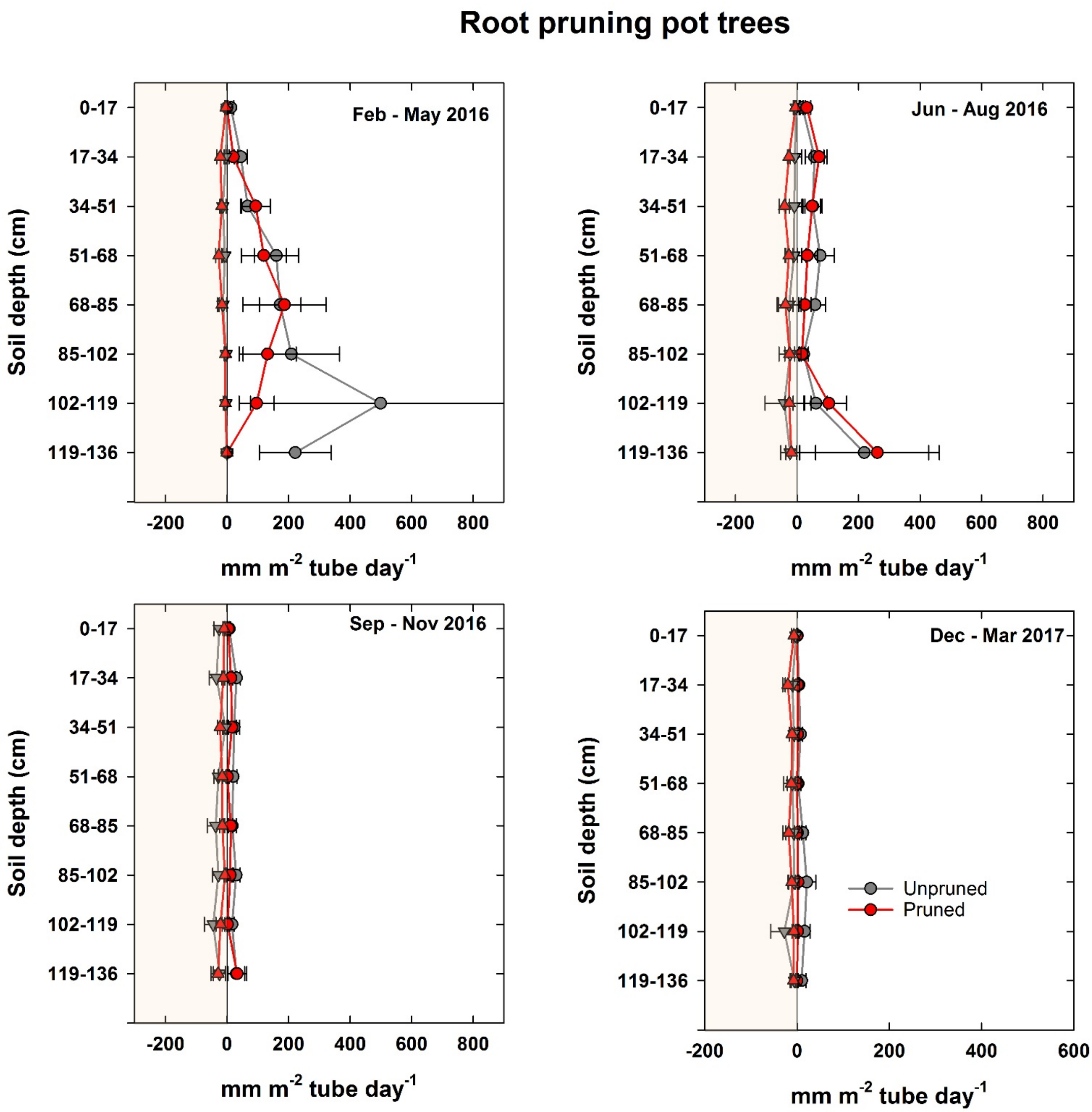


Figure 8 New root length production (blank zone, circles, positive numbers) of trees planted from root pruning pots and root length death (yellow zone, triangles, negative numbers) as a function of pruning (unpruned, gray, and pruned, red) and depth through 4 seasons.