Injectable co-polymers: A tool for soil moisture management

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Abstract. *Polymers have been used as soil amendments in agriculture for several decades. Some polymer chemistries are specialized for improving soil moisture distribution uniformity, while others are specialized for improving soil water retention. In this study, we combined two distinct polymers to provide both functions, and applied them to newly-transplanted Valencia oranges to evaluate their effects on soil moisture and plant health. Application of the co-polymer resulted in increases in tree height and trunk diameter in 2016 and 2017. Sap flow sensors indicated that a treated tree receiving the same amount of irrigation used approximately 30% more water throughout the 2017 growing season, indicating an increase in irrigation efficiency. Soil moisture data from 2017 show that the co-polymer resulted in more moisture at 12" (30 cm) and 24" (61 cm) depths. The results of this study provide evidence that co-polymers can be useful tools for soil moisture management, allowing growers to either decrease irrigation amounts or increase water-use efficiency with similar inputs. The co-polymer system investigated in this study may be especially useful to growers due to its ease of application through various types of irrigation systems.*

Keywords. Chemigation, water-use efficiency, deficit irrigation, irrigation management, water conservation

Moisture-Retention Polymers in Agriculture

Polymers have been used as soil amendments in agriculture for several decades, and different classes of polymer chemistry have different unique functions (Milani et al., 2017). Some polymers are specialized for decreasing surface tension and improving moisture distribution uniformity in the soil, while others are specialized for absorbing and retaining water in the soil. Moisture-retaining polymers, including polyacrylamide and polyacrylate, have well-proven benefits for soil conditioning and water management, but their application in commercial agriculture has been limited because they are often difficult to apply (Sojka et. al., 2007). The objective of this study was to evaluate soil moisture dynamics and plant health effects from application of a co-polymer (AquiMax®, Exacto, Inc., Sharon, WI) containing an inverse micro-emulsion polyacrylamide formulated with an EO/PO block co-polymer surfactant.

Materials and Methods

Valencia oranges on Carrizo citrange root stocks were transplanted in October of 2015 in Sanger, CA at a facility managed by SynTech Research (Fig. 1). Trees were irrigated via microsprinkler at 15 PSI with BowSmith Fan-Jet Style-J2 nozzles. The experimental control at 100% grower standard irrigation utilized size 35 nozzles which had an output of 7.3 gal h^{-1} (27.6 L h^{-1}). Experimental treatments were evaluated on trees irrigated with size 30 nozzles, which had an output of 5.2 gal h^{-1} (19.7 L h^{-1}), approximately 30%

less water than the grower standard (GS) control. In July of 2016, a study was initiated with a randomized compete block design with six replications, where each plot was represented by a single tree. The trees were treated with co-polymer at one of two rates and compared to an untreated control (Table 1) for a total of two applications in 2016 and two in 2017. Treatments were injected directly into microsprinkler lines over a period of 1-3 hours and watered in with approximately 0.25" of water after the applications to clear sprinkler lines and move the product downwards in the soil. The co-polymer was injected neat, and not pre-diluted with water prior to the application.

Figure 1. Valencia orange grove where study area was located in Sanger, CA.

Table 1. Irrigation quantities and application rates for trial on Valencia orange transplants.

Irrigation Amount	---------------------- Co-Polymer Rate ----------------------	
	1st Application[a]	2nd Application[a]
100% GS[b]	-	-
70% GS	-	-
70% GS	1 gal ac^{-1} (9.3 L ha^{-1})	1 gal ac^{-1} (9.3 L ha^{-1})
70% GS	2 gal ac^{-1} (18.6 L ha^{-1})	1 gal ac^{-1} (9.3 L ha^{-1})

a. Application Dates: 8/10/16, 8/26/16, 6/6/17, 8/3/17
b. GS, grower standard

Tree height and trunk diameter were measured prior to study initiation, and then 2-3 times per year through 2016 and 2017. Data were subjected to Analysis of Variance (ANOVA) to determine whether there were differences among treatments, and means were separated by Fisher's protected LSD.

In June 2017, sap flow sensors were installed on one tree for the 70% irrigation control, and the 70% irrigation co-polymer receiving two applications of 1 gal ac^{-1} (9.3 L ha^{-1}) annually. Sap flow was measured with the "SapIP" systems and sensors (Dynamax, Inc., Fresno, CA), which use heat flux between two locations on the trunk to calculate sap flow every 15 minutes. The sap flow values were normalized to account for differences in tree size. Volumetric water content was measured beginning August 1, 2017 by time-domain reflectometry and logged to a datalogger every 15 minutes at 12" (30 cm) and 24" (61 cm) adjacent to the same trees where sap flow measurements took place.

Results and Discussion

Four total application of the co-polymer were made in 2016 and 2017. We did not observe issues or difficulties related to product viscosity during any of the applications.

Experimental treatments resulted in numerical differences in trunk diameter and tree height from 7/7/16 through 9/6/17, although the differences were not statistically significant (Table 2). There was a trend towards greater trunk diameter and tree height with application of co-polymer at both 1 + 1 gal ac^{-1} (9.3 + 9.3 L ha^{-1}) and 2 + 1 gal ac^{-1} (18.6 + 9.3 L ha^{-1}) with 70% GS irrigation, and these increases were similar to those obtained in the 100% GS irrigation. These findings suggest that growers can achieve similar rates of tree growth on new stands with 30% less water with application of co-polymer at 2 gal ac^{-1} (18.6 L ha^{-1}) per growing season. The increase in growth in co-polymer treatments at 70% GS irrigation suggest an increase in water-use efficiency.

Table 2. Trunk diameter and tree height as affected by experimental treatments from 7/7/16 to 9/5/17.

Irrigation	Co-Polymer Rate	Trunk Diameter (in)			Tree Height (in)		
	gal ac^{-1}	7/7/16	9/5/17	% Change[a]	7/7/16	9/5/17	% Change[a]
100% GS[b]	-	0.830	1.345	62.20%	28.50	52.77	85.20%
70% GS	-	0.903	1.356	50.20%	33.17	54.79	65.20%
70% GS	1+1	0.839	1.414	68.50%	29.50	56.90	92.90%
70% GS	2+1	0.845	1.395	65.10%	27.25	53.56	96.50%
P<0.05				0.280			0.352
LSD				17.36			31.42

a. From 7/7/16 through 9/5/17
b. GS, grower standard

Volumetric water content (VWC) of the soil was generally greater at 24" (61 cm) than 12" (30 cm), with the exception of the first several days of measurement between 8/1/17 and 8/3/17. During this stretch, the volumetric water content of the treated plot was over twice as high at 12" (30 cm) compared to 24" (61 cm), whereas the untreated control had more moisture at 24" (61 cm) than 12" (30 cm). Plots had been lightly-irrigated in the preceding weeks, so it is possible that the irrigation events were insufficient to wet the soil profile below a 12" (30 cm) depth for the treated plot. The co-polymer has been shown to decrease saturated hydraulic conductivity and improve lateral water movement, so it is possible that these factors prevented the 24" (61 cm) depth from wetting in the early period of measurement. Deeper irrigation cycles resumed after 8/3/17 and after that point, moisture was typically greater at 24” (61 cm) than 12” (30 cm) for all treatments.

The VWC of plots treated with copolymer was greater than the untreated control for most of the measurement period. To compare the total water content of each plot, the area under the moisture curve (AUMC) was calculated by summing the total area between each set of data points, which was calculated by the following equation:

$$\text{[Eq. 1]} \qquad \frac{((T_2 - T_1)x\,(VWC_B - VWC_A))}{2}$$

where T_2-T_1 is the different in minutes between two consecutive measurements, and VWC_B-VWC_A is the difference in VWC between two consecutive measurements. The combined AUMC for the co-polymer-treated plot at both depths was 224,599 (unitless) compared to 195,497 in the untreated control, which is a 15% increase in AUMC.

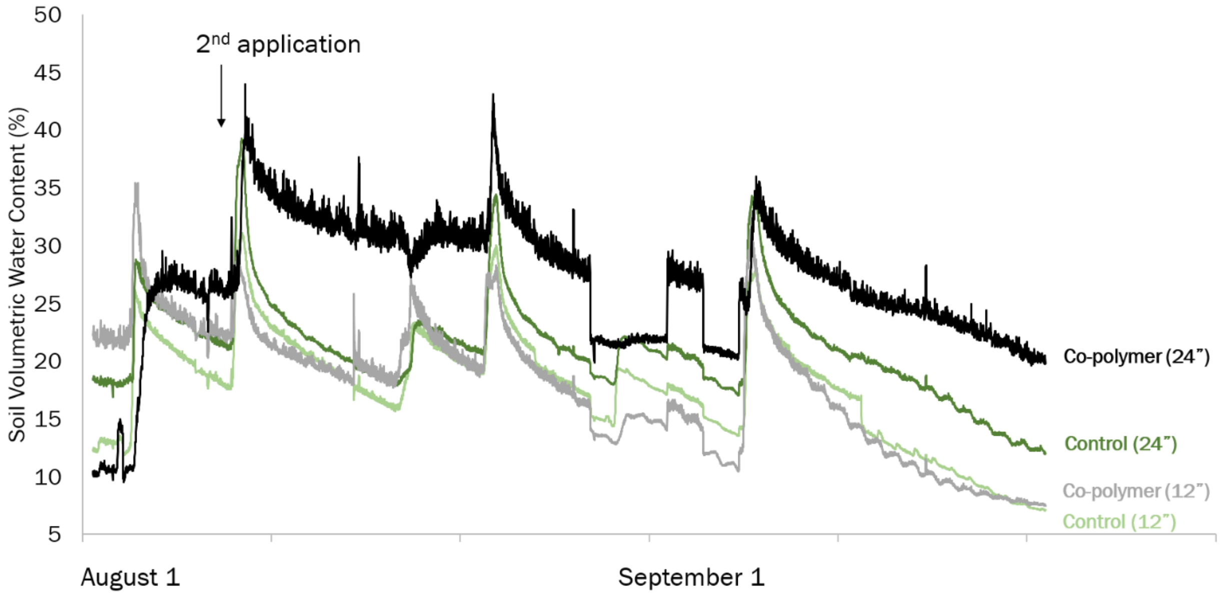

Figure 2. Soil moisture data from August 1 through September 22, 2017.

The sap flow in the co-polymer-treated tree was greater than that of the untreated control on most observation dates in 2017 (Fig. 3). In the month of July, the treated tree used an average of 1.434 gal day^{-1} (5.428 L day^{-1}) compared to 1.113 gal day^{-1} (4.213 L day^{-1}) in the control, an increase of 28.8%. In Aug., the treated tree had an average sap flow of 1.683 gal day^{-1} (6.371 L day^{-1}) compared to 1.496 gal day^{-1} (5.663 L day^{-1}) in the control, an increase of 12.5%. The lower difference between co-polymer and the control in Aug. might have been attributed to more frequent irrigation events and higher soil water content during this period. In Sept., the treated tree had an average sap flow of 1.630 gal day^{-1} (6.170 L day^{-1}) compared to 0.973 gal day^{-1} (3.683 L day^{-1}) in the control, an increase of 67.5%. Between 7/5/17 and 9/22/17, the treated tree transpired a total of 128.73 gal (487.30 L) of water compared to 97.55 gal (369.27 L) in the control, an increase of 32.0%. Given that both trees were irrigated with same amount of water throughout the growing season, this difference indicates an increase in irrigation efficiency. The lower difference during the month of Aug. when soil moisture was generally greater indicates that benefits of the co-polymer will be more pronounced during periods of crop water stress.

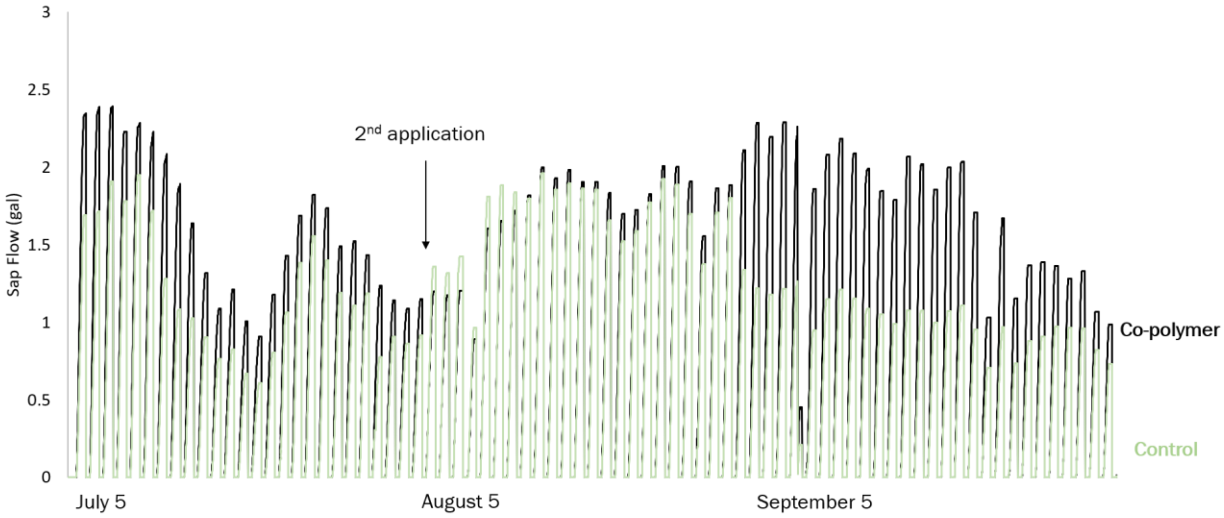

Figure 3. Cumulative sap flow from July 5, 2017 through September 22, 2017. Values were truncated to zero at midnight each day.

The soil moisture and sap flow data show that the co-polymer increased the amount of water held in the soil profile, and this translated to an increase in transpiration. The morphological measurements of the trees indicate that the injectable co-polymer had a positive effect on tree health and increased the rate of growth of these young orange transplants. These findings are relevant for citrus growers who may be replanting orchards after damage from citrus greening or weather-related events. In addition to improving tree health, the results suggest that the co-polymer could allow growers to either cut back on irrigation volumes while achieving similar results, or increase irrigation system and water-use efficiency with the same amount of irrigation. This is particularly useful for regions where water is scarce and periodic droughts limit water reserves.

Conclusion

The results of this study show that injectable co-polymer systems are a useful water-management tool for tree crops. Injection of the co-polymer provided an increase in trunk diameter and tree height from July 2016 to September 2017, an increase in soil moisture at 12” (30 cm) and 24” (61 cm), and an increase in irrigation system and water-use efficiency. The data from this study suggest that the injectable co-polymer positively affects tree health during non-bearing years and increases the rate of maturation of newly-transplanted orchards. Future research must continue to look at non-bearing trees as they mature and begin to bear fruit to determine whether these improvements in plant health translate to improvements in orange yield.

References

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