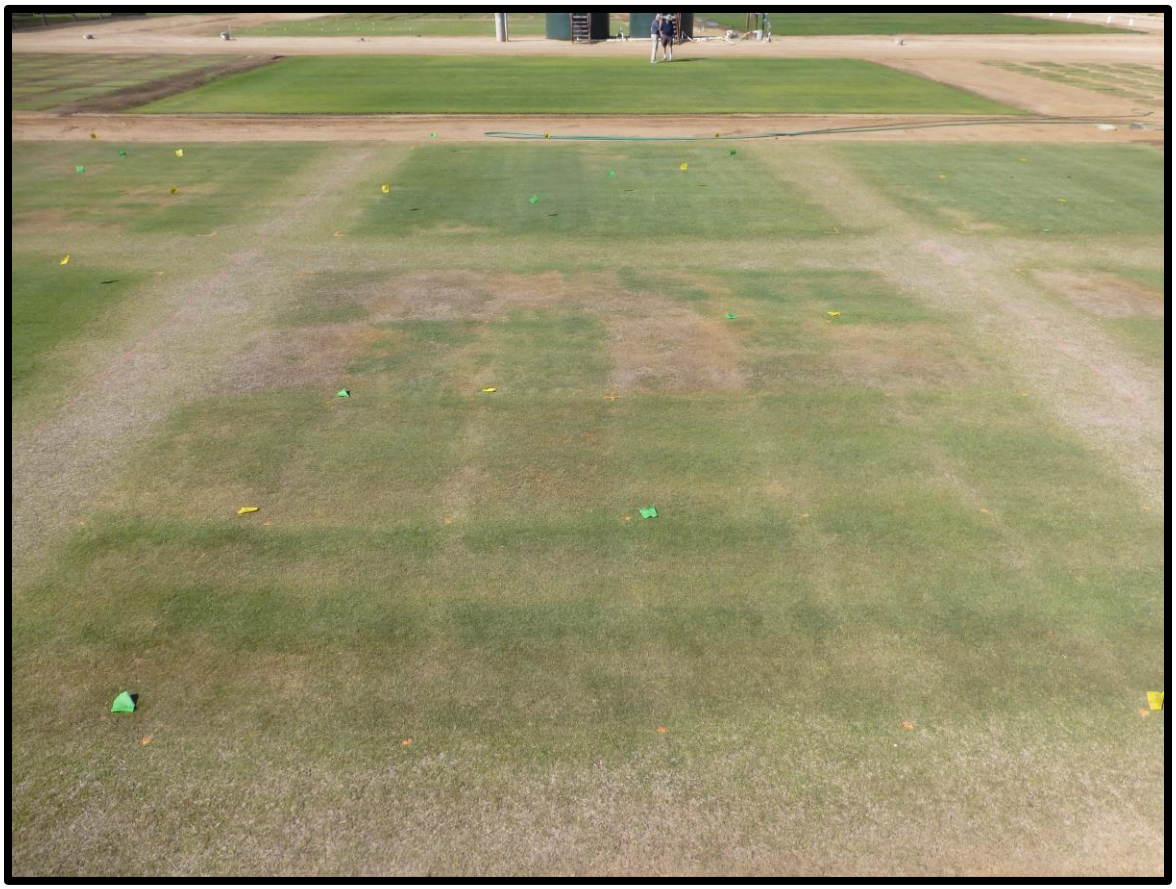
Best Management Practices for Bermudagrass under Deficit Irrigation



Bermudagrass 'Princess 77' irrigated at 70% ET_{os} (above) or 40% ET_{os} (below) replacement and treated with combinations of Revolution, Primo Maxx, and nitrogen (N) within sub-plots. Turf on borders of main plot areas received no chemical treatment or N during the study. Photo taken by Stan Kostka on 20 October 2016.

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Best Management Practices for Bermudagrass under Deficit Irrigation

2016-2017 Final Report

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The Bottom Line: This study sought to determine if Plant Growth Regulators (PGR; Primo Maxx), wetting agents (Revolution), and nitrogen (N) fertilization (6 different fertilizers compared at a rate of 5 lb/1,000 ft^2/year) could further reduce water use and enhance quality of bermudagrass 'Princess 77' irrigated at either 70% or 40% ET_{os} in Riverside, CA under fairway conditions. Product and irrigation treatments were applied from May thru October 2016 and 2017. Under less stressful 70% ET_{os} irrigation replacement, turf quality was highest in plots that received Primo Maxx and Revolution. The combination of Primo Maxx and Revolution also helped with green-up in the spring. Although no differences were found among fertilizer treatments, fertilizer alone was able to sustain bermudagrass quality at a minimum acceptable level at 70% ET_{os}. Revolution had the greatest positive effect on turf under severe deficit irrigation (40% ET_{os}), whereas Primo Maxx did not improve quality under more severe deficit irrigation. Experimental products ACA 1935 and 5000 improved bermudagrass quality under severe deficit irrigation toward the end of 2016 and through 2017. Moreover, the use of ACA 1935 and 5000 improved soil volumetric water content (VWC) in comparison to fertilizer alone. Overall, results indicate that sufficient N fertilization combined with Revolution, Primo Maxx, and ACA experimental products or Ocean Organics biostimulants can further sustain bermudagrass quality under deficit irrigation.

Introduction:

Drought and resultant water use restrictions call for implementation of best management practices to conserve water. Previous research conducted by UCR and other turfgrass researchers have identified that products including the wetting agent Revolution (Aquatrols), PGR Primo Maxx (Syngenta) and sufficient N fertilization help to maintain turf quality under drought or deficit irrigation. The objectives of this study were to identify the best combinations of these products for water conservation on golf course fairways and to further pinpoint fertilizer products that may be more effective than others for enhancing turf quality with less water.

Methods:

The study was conducted in 2016 and 2017 at the UCR Turfgrass Research Facility in Riverside on mature 'Princess 77' bermudagrass turf grown on Hanford fine sandy loam. Turf was mowed three times per week at 0.5 inches during the growing season. Environmental data for the site are provided in Table 1. The 60' x 90' field was divided into six 30' x 30' plots. From May 19 to October 31 of both years, the plots were hand watered three times per week to replace either 40% or 70% of previous week reference short crop evapotranspiration (ET_{os}) as determined by an on-site CIMIS weather station. Full ET_{os} replacement was restored in November when ET_{os} rates were decreasing and differences in watering times were negligible. Treatments were arranged in a split-plot design with 3 different factors randomized within ET_{os} replacement plots and 3 replicates. The plant growth regulator (PGR) Primo Maxx (trinexapac-ethyl; Syngenta) served as split plot; wetting agent Revolution (Aquatrols) as split-split-plot; and fertilizer products (Table 2) were randomized inside the wetting agent plots (plot size 24 ft^2) and applied monthly beginning in May. Each treatment received an equivalent of 1 lb N/1,000 ft^2/month, for a total of 5 lb N/1,000 ft^2/year. Granular treatments were applied with shaker jars, while spray treatments were applied using a CO_2-powered hand boom sprayer equipped with TeeJet 8004VS nozzles and output of 2 gal/1,000 ft^2. Revolution and granular fertilizers were irrigated with ca. 1/8 inches of water following application. Every two weeks, plots were evaluated for turf quality on a scale from 1 = worst to 9 = best, Naturalized Difference Vegetation Index (NDVI), soil volumetric water content (VWC) using time domain reflectometry (TDR), and dark green color index (DGCI) as well as percent green cover using Digital Image Analysis (DIA). Root samples were collected to a 6-inch depth using a soil probe on November 2, washed free of soil, and analyzed using WinRHIZO software. Visual turf quality ratings were taken in late November and early December to measure the effect of fertilizer and chemical treatments on bermudagrass winter color retention. On March 2017 and 2018 plots were evaluated for NDVI and DIA to assess spring green-up.

Data were subjected to analysis of variance (ANOVA). When necessary, multiple comparisons of means were assessed using Fisher's protected least significant difference test at the 0.05 probability level. Each graphical output is presented and discussed only if treatment effect, ET_{os} replacement effect, or their interaction was significant during one or more rating dates.

Results:

- ET_{os} had a huge impact on bermudagrass performance. Although some treatments had a positive effect on severely drought stressed turf plots, no plots irrigated at 40% ET_{os} showed quality, NDVI, or percent green cover comparable to those irrigated at 70% ET_{os}. Therefore results for both growing seasons will be discussed separately for ET_{os} replacement.
- At 70% ET_{os}, Primo Maxx and Revolution together had the most positive effect on turf quality (Fig. 1). NDVI and DIA confirmed these findings, especially during the summer of 2017, when the combination of the PGR and the wetting agent

was superior to any other treatment for each parameter measured. With the exception of May 2016 and 2017, bermudagrass irrigated at 70% ET_{os} always showed sufficient quality.

- No differences were detected for fertilizer treatments at 70% ET_{os} (data not shown). Our results suggest that, under this level of irrigation replacement, choice of N source doesn't appear to affect bermudagrass performance. However, surrounding turf that received no N showed drastically lower turf quality than any plot that received N fertilization, stressing the importance of sufficient N fertilization to overall turf health.
- At 40% ET_{os}, Revolution had the greatest impact on bermudagrass performance. Quality, NDVI, and green cover were improved in plots that received Revolution (Fig. 2). Plots treated with Revolution were not only superior to those that did not receive wetting agent treatments, but also were also able to sustain sufficient quality through the summer of 2017. Revolution provided the most help in alleviating symptoms of drought, and its use is strongly recommended prior to and during drought and water use restrictions.
- At 40% $ET_{os,}$ on plots that that did not receive Revolution, ACA 1935 and 5000 showed improved quality, NDVI and cover, toward the end of 2016 (Fig. 3), and through 2017 (Fig. 4). The two experimental products were followed by SeaBlend + Stress Rx + XP Micro and Gro-Power (Figs. 3 & 4). Conversely, Yara Liva showed the lowest turf quality. We believe that calcium nitrate, the source of N in this product, requires more water after application than our water budget allowed to prevent turf burning. More research is needed to determine the effect of ACA 1935 and 5000 under drought conditions and combined with different sources of N.
- Soil VWC was affected by fertilizer treatments. Plots treated with ACA 5000 and had the highest VWC and were matched by SeaBlend + Stress Rx + XP Micro, and ACA 1935 (Fig. 5).
- Root diameter was affected by the interaction of Revolution and year. Plots that received Revolution in 2016 had larger root diameter than plots that did not receive Revolution (Fig. 6). However no differences were detected in 2017.
- Fall color retention was affected by the interaction of ET_{os} replacement and Revolution applications (Fig. 7), by the interaction ET_{os} and Primo Maxx applications (Fig. 8) and the interaction of year and fertilizers (Table 3). Differences in spring green-up were affected by the interaction of ET_{os}, Primo Maxx and Revolution (Table 4).
- Generally the restoration of full ET_{os} replacements lead to tissue restoration of severely drought stress bermudagrass, therefore higher color retention was detected in December on 40% ET_{os} irrigated plots (Figs. 7 & 8). Plots treated with Revolution and watered at 40% ET_{os} almost scored a sufficient quality rating of 6 at the first week of December (Fig. 7), while Primo Maxx helped bermudagrass retain color longer only at 70% ET_{os} replacement (Fig. 8). In 2017 plots maintained darker green color in comparison to 2016 (Table 3). Curiously, the

two fertilizers that went into dormancy first in 2016 (ACA 5000 and SeaBlend + Stress Rx + XP Micro) were the ones that showed the darker color in 2017 (Table 3).

- Plots irrigated at 40% ET_{os} also greened up faster in comparison to 70% ET_{os} irrigated plots. Highest % green cover in the spring was recorded on plots that received only Revolution and no Primo Maxx (Table 4). However plots that received both Primo Maxx and Revolution were the only ones that, at 70% $ET_{os,}$ showed comparable cover to the severely drought stressed plots.

Acknowledgments:

Thanks to the California Turfgrass & Landscape Foundation, Aquatrols Corp. of America, Gro-Power Inc., Ocean Organics, Syngenta, and Yara International for financial support.

Table 1. Environmental data collected and reported by the California Irrigation Management System (CIMIS) for Station 44 (Riverside) during the study. Riverside, CA. Weather station located ≈ 100 ft away from study area.

Month Year	Total ETos (in)	Total Precip (in)	Avg Vap Pres (mBars)	Avg Max Air Temp (F)	Avg Min Air Temp (F)	Avg Air Temp (F)	Avg Max Rel Hum (%)	Avg Wind Speed (mph)	Avg Soil Temp (F)
May-16	6.21	0.02	12	71.2	55.5	62.6	80	4	67.8
June-16	7.21	0	13.6	89.4	61.5	74.5	74	4.4	73
July-16	7.74	0	14.3	93.5	64.2	77.5	73	4.2	75.9
Aug-16	6.88	0	14.4	92.6	63.6	76.5	74	4	75.4
Sep-16	5.3	0	12.6	87.9	60.8	72.9	71	4	71.5
Oct-16	3.87	0.87	11.2	80.7	56.6	67.7	70	3.5	66.4
May-17	5.95	0.06	12.9	78.5	54.4	65.6	62	4.6	68.6
Jun-17	6.98	0	16	88.8	60.5	73.5	59	4.3	74.5
Jul-17	7.11	0.03	18.7	93.8	65.7	78.5	57	4	78.6
Aug-17	6.4	0.39	19.8	93	65.7	77.5	61	4	78.1
Sep-17	4.92	0.06	16.6	87.1	62.2	73.4	60	4.1	74.3
Oct-17	4.54	0	10.8	85.5	57.8	70.6	47	3.9	67.4

Table 2. PGR, wetting agent, and fertilization study treatment list. Riverside, CA.

Plot	Treatment	Company	Rate	Frequency (wks)
Whole Plot	ET_{os} replacement	---	40%-70%	M-W-F
Split	Primo Maxx	Syngenta	0.25 oz/M	2
Split-split-plot	Revolution	Aquatrols	6 oz/M	4
Split-split-split-plot	Gro-Power (5-3-1)	Gro-Power	1 lb N/M	4
Split-split-split-plot	SeaBlend (12-4-5) + StressRX + XP Micro	Ocean Organics	1 lb N/M + 6 oz/M + 6 oz/M	4 2 2
Split-split-split-plot	Turf Royale (21-7-14)	Yara	1 lb N/M	4
Split-split-split-plot	Yara Liva (15.5-0-0)	Yara	1 lb N/M	4
Split-split-split-plot	Turf Royale (21-7-14) + ACA 1935	Yara Aquatrols	1 lb N/M + 4 oz/M	4 4
Split-split-split-plot	Turf Royale (21-7-14) + ACA 5000	Yara Aquatrols	1 lb N/M + 4 oz/M	4 2

Table 3. Fall color retention of plots fertilized with 6 different N sources in 2017 and 2017. All plots were fertilized with 5 lb N/M/year. Riverside, CA.

	Fall Color Retention	
	2016	2017
Gro-Power	4.46 E†	6.62 BCD
SeaBlend+StressRx+XPMicro	3.79 G	7.00 A
Turf Royale	4.58 E	6.37 CD
Yara Liva	4.08 FG	6.29 D
Turf Royale+ACA1935	4.33 E	6.70 ABC
Turf Royale+ACA5000	4.50 F	6.75 AB

† values followed by the same letter are not significantly different from one another (Fisher's protected least significant difference, α=0.05)

Table 4. Spring green-up assessed by digital image analysis (DIA) irrigated at 70% or 40% ET_{os} untreated or treated with Primo Maxx, Revolution, or a combination of the two. 2017. Riverside, CA.

	% Green Cover	
	40% ET_{os}	70% ET_{os}
No Primo + No Revolution	65 B†	49 C
No Primo + Revolution	73 A	49 C
Primo + No Revolution	67 AB	55 C
Primo + Revolution	69 AB	62 B

† values followed by the same letter are not significantly different from one another (Fisher's protected least significant difference, α =0.05)

Figure 1. Quality, Naturalized Difference Vegetation Index (NDVI), and % green cover of plots irrigated at 70% ET_{os} untreated or treated with Primo Maxx, Revolution, or a combination of the two. All plots were fertilized with 5 lb N/M/year. 2016 and 2017. Riverside, CA.

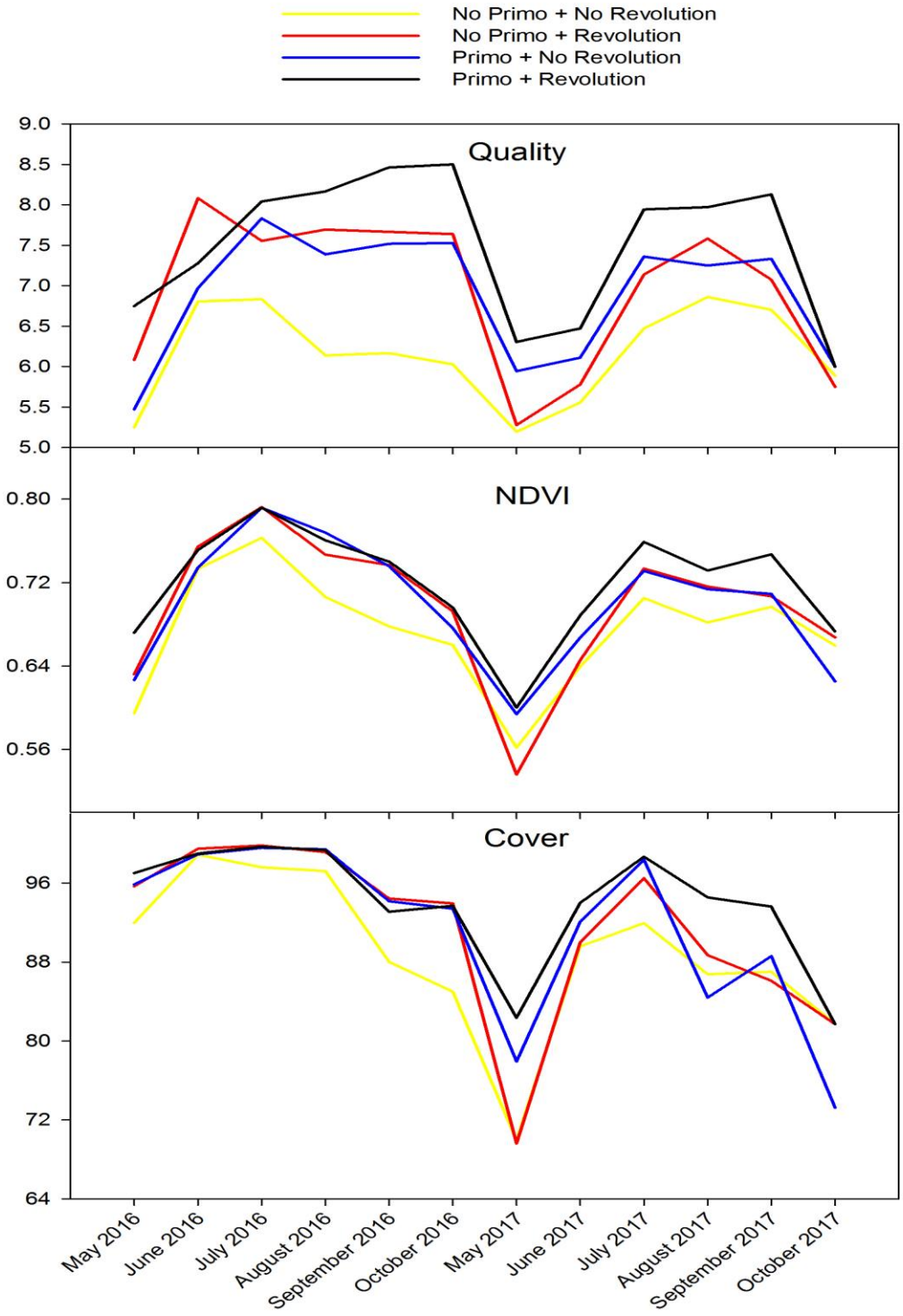

Figure 2. Quality, Naturalized Difference Vegetation Index (NDVI), and % green cover of plots irrigated at 40% ET_{os} and treated with either Revolution or untreated. All plots were fertilized with 5 lb N/M/year. 2016 and 2017. Riverside, CA.

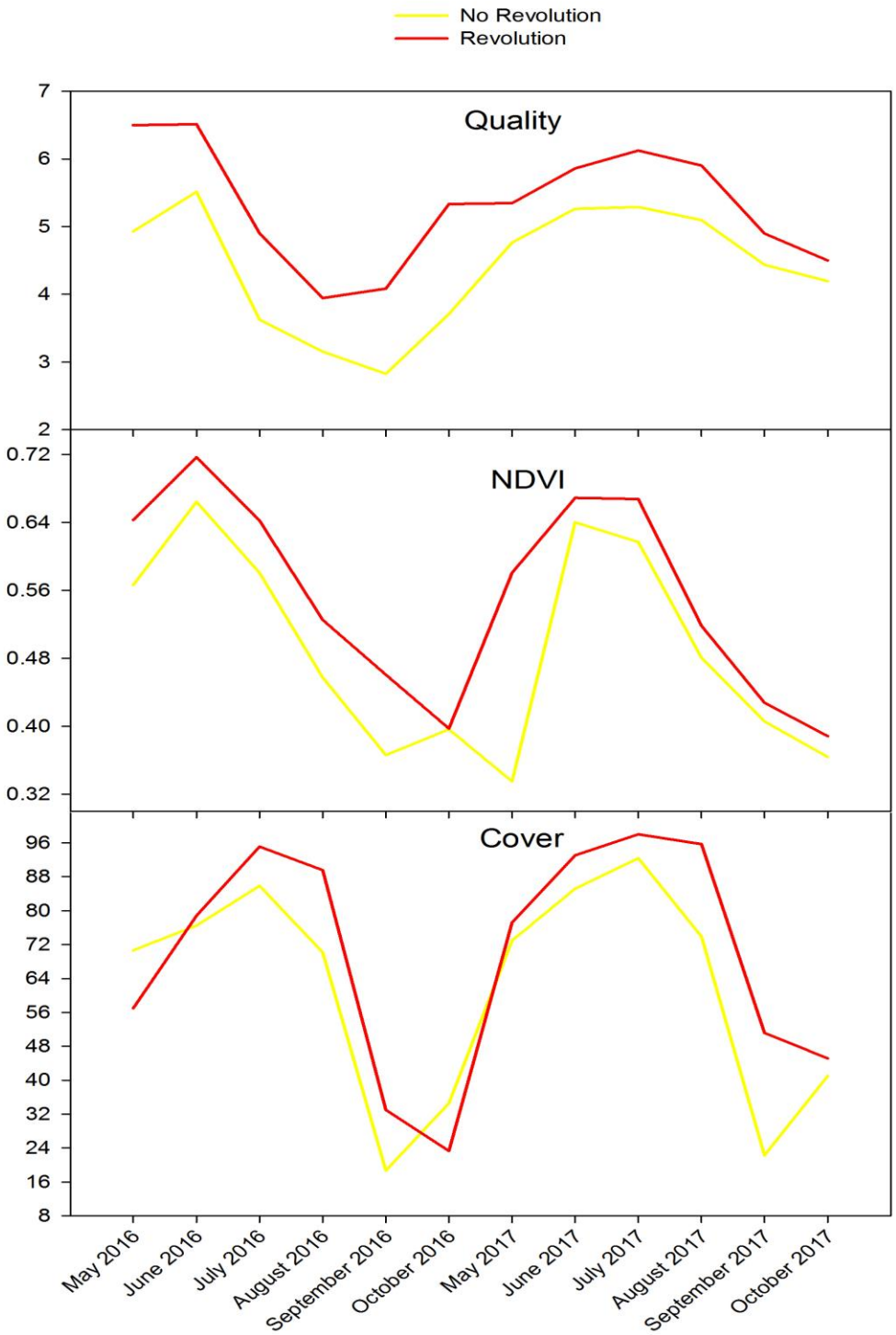

Figure 3. Quality, Naturalized Difference Vegetation Index (NDVI), and % green cover of plots irrigated at 40% ET_{os} that did not receive Revolution and fertilized with 6 different N sources. All plots were fertilized with 5 lb N/M/year. 2016. Riverside, CA.

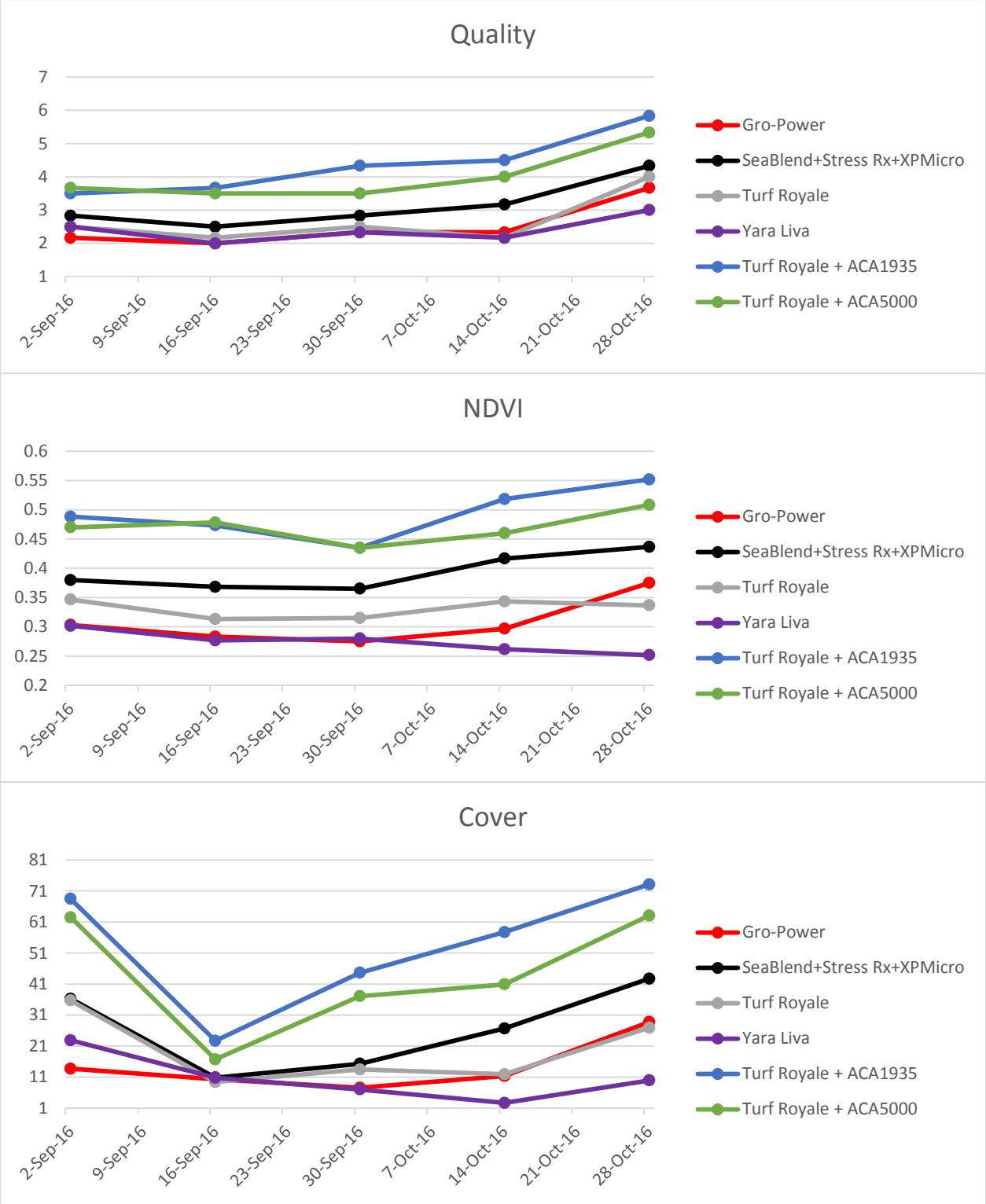

Figure 4. Quality, Naturalized Difference Vegetation Index (NDVI), and % green cover of plots irrigated at 40% ET_{os} that did not receive Revolution and fertilized with 6 different N sources. All plots were fertilized with 5 lb N/M/year. 2017. Riverside, CA.

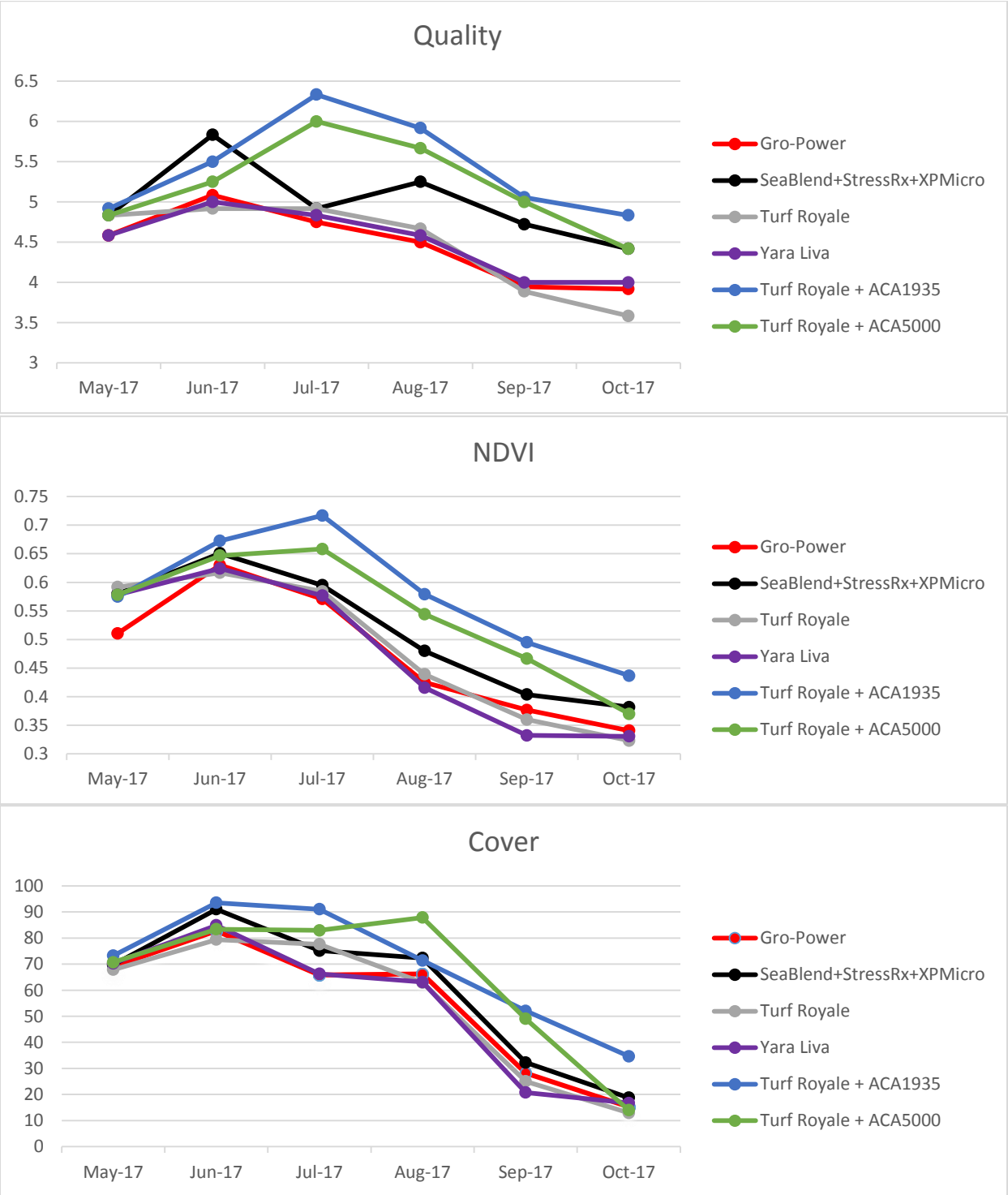

Figure 5. Soil volumetric water content (VWC) of plots fertilized with 6 different N sources. All plots were fertilized with 5 lb N/M/year. 2016 and 2017. Riverside, CA.

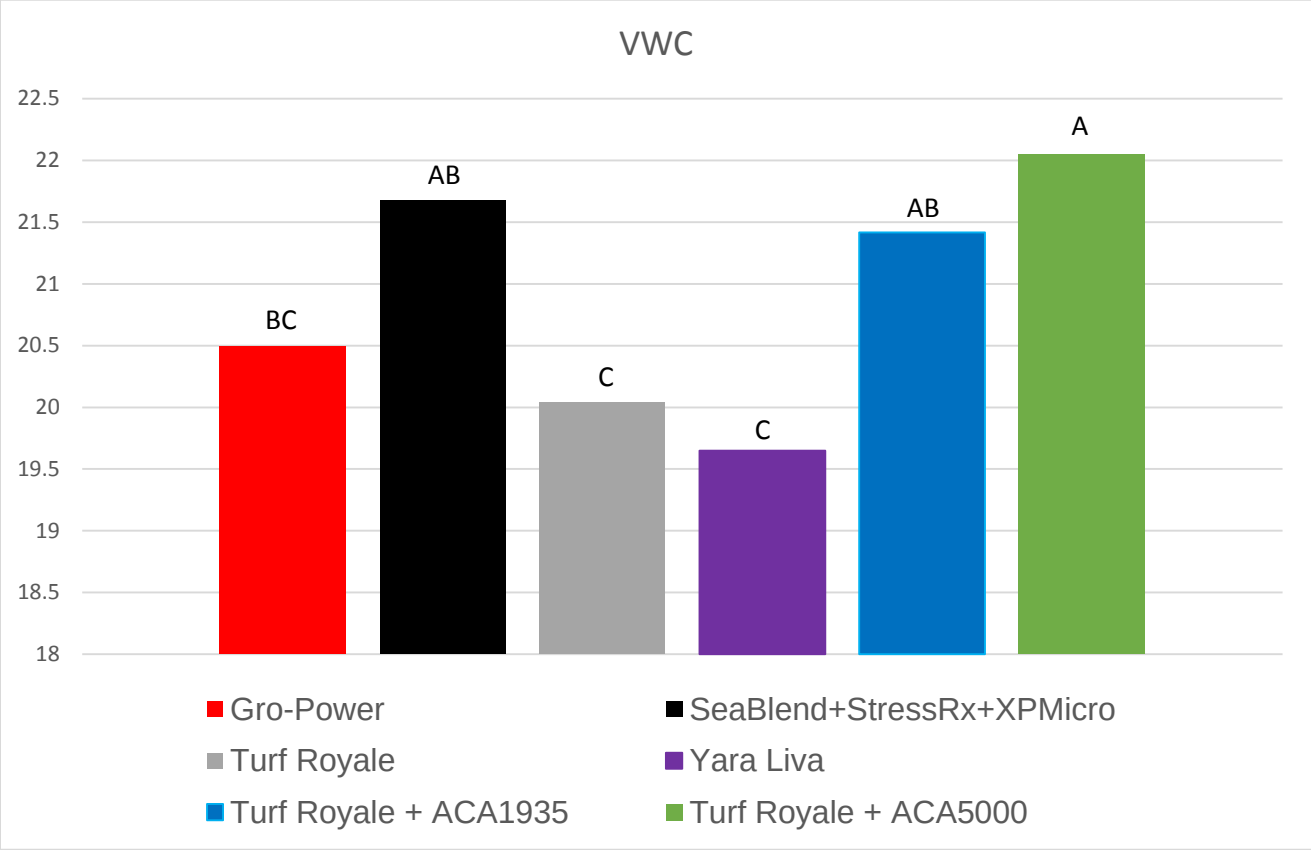

Figure 6. Root diameter (cm/cm^3) of plots either treated with Revolution or untreated in 2016 and 2017. Riverside, CA.

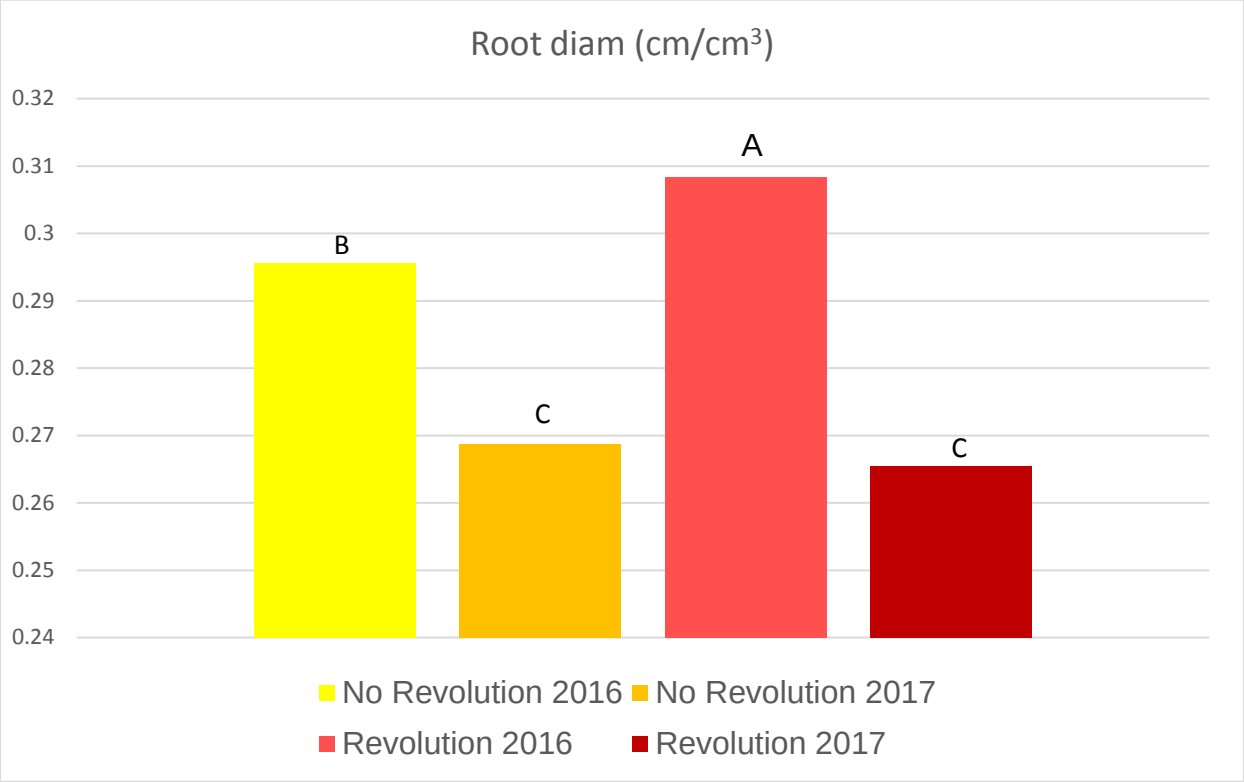

Figure 7. Fall color retention of plots untreated or treated with Revolution and watered at either 40% ET_{os} or 70% ET_{os}. 2016 and 2017. Riverside, CA.

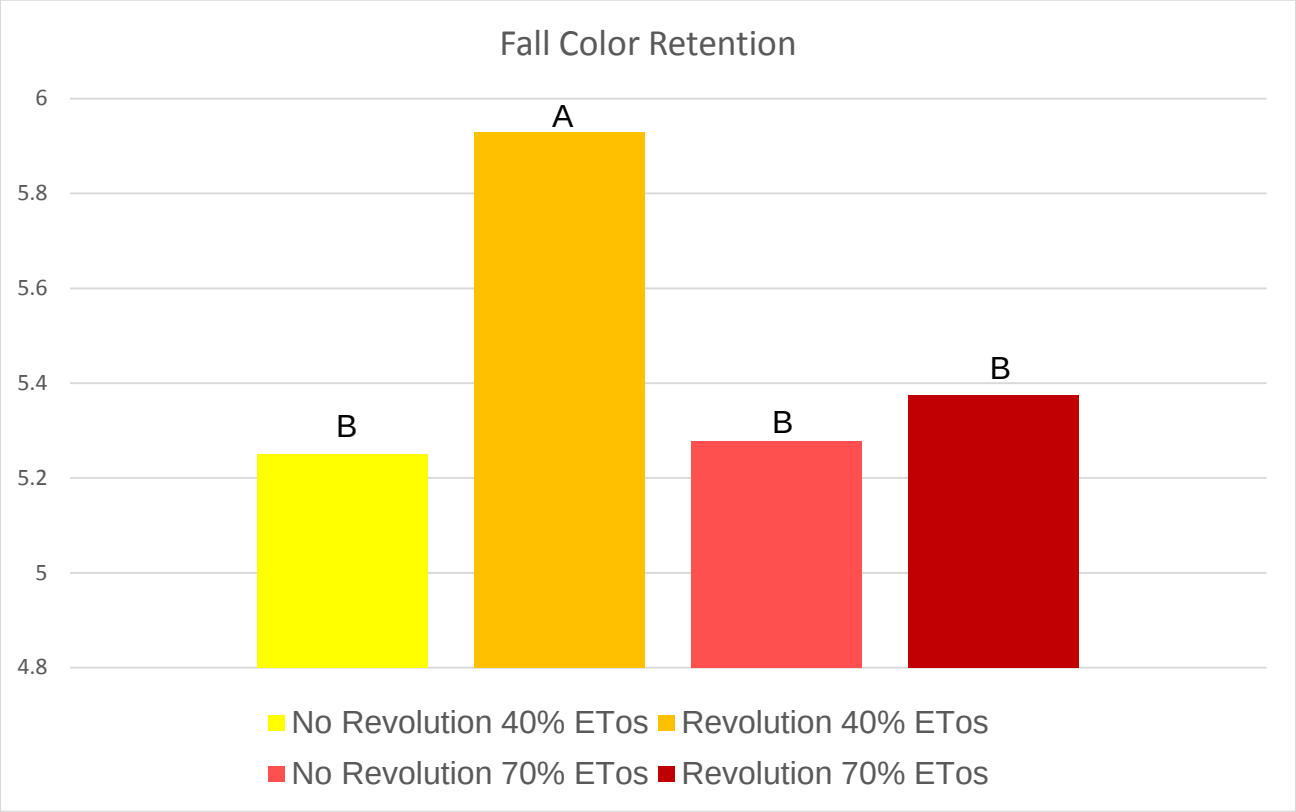

Figure 8. Fall color retention of plots untreated or treated with Primo Maxx and watered at either 40% ET_{os} or 70% ET_{os}. 2016 and 2017. Riverside, CA.