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CASE STUDY
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Summary of Observations using Phyto-C_3™
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Summary

We have been testing Phyto-C_3™ (both the regular and the organic versions) as a water treatment in irrigated wine grape vineyards at the UC Davis Oakville Station since 2019. We have tested three main areas, in each case adding 1 to 4 ppm of Phyto-C_3™ to the irrigation water, and have established the following results:

- Water/energy savings: Adding Phyto-C_3™ kept lines and emitters clean and free flowing. This increased the distribution uniformity of the water, leading to water savings of $610 per acre and energy savings of $53 per acre (approx 30% reduction in pumping hours).
- Crop yields and health: Berry yields per vine increased 39% - 90%. Vines showed increased growth, metabolism and carbohydrate transport. Vines showed increased resistance to heat and water stress.
- Soil health: At full irrigation, Phyto-C_3™ increased AMF (Arbuscular Mycorrhizal Fungi) colonization 80%. At half irrigation (more stress), Phyto-C_3™ increased AMF coloniation 150%. The full report can be found here: https://bio-organic.com/wp-content/uploads/2021/03/boc_presentation_agriculture_kaan_study_young_vines.pdf

Evaluation of Organic Phyto-C_3™ Application Rate in a Young Vineyard.

The rate of Phyto-C_3™ application was evaluated in a young Cabernet Sauvignon vineyard. An untreated control, 2 ppm and 4 ppm of organic Phyto-C_3™ was evaluated during the 2021 growing season. Components of yield and berry composition was measured.

Factor	Berry w (g)	Cluster wt (g)	Yield (kg/vine)
Control	1.96 b	103.34	1.13 b
2 ppm	1.99 ab	110.93	1.57 b
4 ppm	2.12 a	112.98	2.89 a
Pr>F	0.0367	0.8088	0.0117

As indicated in the above table, yield of grapevine was beneficially affected. The berry mass increased with the inclusion of the organic Phyto-C_3™ in the weekly irrigation, although there was no effect on the cluster weight.

The berry composition of Cabernet Sauvignon was also measured. We measured total soluble solids, juice pH and titratable acidity as well as anthocyanin content per berry as these grapes were destined for wine making. Although increasing the amount of Phyto-C_3™ to 4 ppm reduced total soluble solids compared to no Phyto-C_3™ application, this reduction was not statistically significant.

Likewise, we did not see any differences in juice pH or titratable acidity. The anthocyanin content per berry was also not adversely affected as indicated in the table below.

Factor	TSS (%)	Juice pH	TA	Anthocyanin (mg/berry)
Control	24.2	3.61	0.72	0.93
2 ppm	22.0	3.55	0.74	1.17
4 ppm	22.6	3.56	0.74	0.97
Pr>F	0.1574	0.3722	0.8271	0.0922

In the annual evaluation, our results indicated that Phyto-C_3™ was beneficial in keeping emitters delivering the correct amount of water with minimal fouling which resulted in greater yields. Depending on production targets a rate between 2 ppm to 4 ppm would be suitable in wine grape vineyards.

Distribution Uniformity and Energy Savings using Phyto-C_3™.

A 2.3 acre Cabernet Sauvignon vineyard at the UC Davis Oakville Station was used. In this vineyard the vines were spaced 9' x 6' and equipped with 2 pressure compensating emitters capable of delivering 0.53 gph. There was a difference of 27 ft in elevation between the pump outlet and water level. The ump set-point was fixed: 75 gpm @ 64 psi . Water traveled from the pump outlet to the study vineyard through 3-in PVC pipe for 960 ft. Linear head losses due to friction along the water conveyance were calculated based on the flow rate of 75 gpm (0.167 cfs) as HLF = 4.5 ft.

Initial irrigation line cleaning:

Vineyard was irrigated for one hour. Emitter output was collected from 24 emitters that were equi-distantly spaced in the vineyard after one hour. Pressure at the manifold was also measured. Into the irrigation stream, 2.5 litres of organic Phyto-C_3™ was injected in 2000 litres of water and let sit overnight. The following day, the irrigation system was switched on and emitters were flushed. The results of pressure and distribution uniformity are presented in the below table. was switched on and emitters were flushed. The results of pressure and distribution uniformity are presented in the below table.

Factor	Pressure	Distribution Uniformity
Pre cleaning *	22 b	0.70 b
Post cleaning	28 a	0.95 a
t-test	0.0001	0.0001

The baseline conditions for water and energy savings are described below.

<u>Baseline conditions</u> ($_B$) refer to the **<u>pre-cleaning</u>** of the micro-irrigation system

Average measured low-quarter baseline distribution uniformity: $DU_B = 0.70$

Average measured emitters' application rate: $AR_B = 0.494$ gph (1.87 l/h)

Average measured pressure head available at the inlet of the manifold: $H_B = 22$ ps

Enhanced conditions ($_E$) refer to the post-cleaning of the micro-irrigation system with Phyto-C_3™

Average measured low-quarter baseline distribution uniformity: $DU_E = 0.95$

Average measured emitters' application rate: $AR_E = 0.515$ gph (1.95 l/h)

Average measured pressure head available at the inlet of the manifold: $H_E = 28$ psi

Methods and Assumptions

The actual consumptive vine water use (ETa) was measured with a commercial surface renewal energy flux station (Tule Technologies, Inc.) along the grapevine growing season of 2021.

The required gross irrigation depth (GID) was determined from the measured ETa, and the resulting water depletion in the effective rooting zone, and the measured system DU values to optimize the application efficiency (EQ). EQ is the water application efficiency of the low quarter and represents the percentage of gross water applied that is beneficially utilized for actual vine evapotranspiration.

For micro-irrigation, EQ is calculated as the mean low-quarter volume of irrigation water per unit area infiltrated and stored in the root zone. According to Keller and Bliesner (2000), EQ is primarily a function of DU, but it also depends on minor losses (runoff, leaks, filters and line flushing, and drainage), unavoidable losses to deep percolation (through cracks or water percolation beyond the root zone), and avoidable losses resulting from poor irrigation scheduling.

For well-watered crops grown with adequately maintained and properly operated micro-irrigation systems and accurately scheduled irrigation, EQ approximates the system DU.

For this specific study, given the well-watered conditions, the adequate irrigation system maintenance and advanced irrigation scheduling, we assumed that EQ ~ DU.

As such, dividing the ETa by DU (instead of by EQ) provides an estimate of the water depth that will infiltrate into the low quarter of the irrigated vineyard block (in well-drained soil). In this way, the low-quarter of the vineyard will receive sufficient water to return to field capacity and maintain good vine growth and production, while the remainder of the vineyard will receive more than sufficient water to refill the soil to field capacity.

Water Usage and Water Saving Calculation (from Baseline to Enhanced Conditions)

ETa (May 1 – Sept 15) = 19.30 ac-in/ac

Gross Irrigation Depth, (GID_B = Baseline; GID_E = Enhanced)

$GID_B = 19.30/0.70 = 27.60$ ac-in/ac = 2.3 ac-ft/ac

$GID_E = 19.30/0.95 = 20.30$ ac-in/ac = 1.7 ac-ft/ac

Potential Water Saving ($GID_B – GID_E$) = 2.3 – 1.7 = 0.61 ac-ft/ac

Potential cost saving for reduced water usage, assuming an average water cost of $1,000/ac-ft in Napa Valley:

Cost Saving $_{WATER}$: 0.61 ac-ft/ac x $1,000/ac-ft = $610/ac

Energy Usage and Energy Saving Calculation (from Baseline to Enhanced Conditions)

Total Dynamic Head, TDH = 27 ft + (64 psi x 2.31 ft/psi) = 175 ft

Estimated Energy Usage (EU_B = Baseline; EU_E = Enhanced)

For electric motor-powered pumps it takes on average 1.55 kWh per ac-ft of water per foot of lift (Nebraska Pumping Plant Performance Criteria, NPPPC).

EU_B = 2.30 ac-ft/ac x 175 ft x 1.55 kWh/ac-ft = 624 kWh/ac

EU_E = 1.70 ac-ft/ac x 175 ft x 1.55 kWh/ac-ft = 461 kWh/ac

Potential Energy Usage Saving (EU_B – EU_E) = 624 - 461 = 163 kWh/ac

Potential cost saving for reduced energy usage, assuming an average energy cost of $0.33/kWh in Napa Valley:

Cost Saving $_{ENERGY}$ = 163 kWh/ac x $0.33/kWh = $53.8/ac

Estimated reduction in GHG emissions was calculated assuming the CO_2 emission factors obtained from the US Environmental Protection Agency (https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf). For Electricity, we assumed the CO_2 emission factor of 0.000379 Ton-eq. CO2 per kWh.

GHG $_{REDUCTION}$ = 163 kWh/ac x 0.000379 Ton-eq. CO_2/kWh = 0.061 Ton-eq. CO_2/ac.

ESTIMATED REDUCTION OF PUMPING HOURS (from Baseline to Enhanced conditions)

Net irrigation volume to apply per vine, NIV = 19.30 ac-in/ac x 54 ft^2 x 0.623 = 649 gal/vine

Gross irrigation volume to apply per vine (GIV_B = Baseline; GIV_E = Enhanced)

GIV_B = 649/0.7 = 928 gal/vine

GIV_E = 649/0.95 = 682 gal/vine

Total estimated pump operation hours (PO_B = Baseline; PO_E = Enhanced)

PO_B = 928 gal/vine / (2 x 0.494 gph) = 939 hrs.

PO_E = 682 gal/vine / (2 x 0.515 gph) = 662 hrs.

Saving in pump operation hours (PO_B - PO_E) = 939 – 662 = 275 hrs.

Observations with the Application Rate of Phyto-C_3™ in Mature, Producing Vineyards.

We ran trials in 2019 and 2020 looking at the dose response of mature and fruiting Cabernet Sauvignon grapevines. The range of application rates were 1 ppm, 2 ppm and 4 ppm. In both years of the experiment there was a linear response of yield to application rate. Conversely, the fruit composition values responded differently where the highest application rate (4 ppm) resulted in the lowest anthocyanin content per berry. Meanwhile, applied fertilizer uptake (Nitrogen, Potassium, Calcium and Magnesium) increased linearly with the increase in Phyto-C_3™ application. Year-over-year, repeatable results were seen with the 2 ppm application rate without detrimental effects on fruit composition with this Phyto-C_3™.

Here is a summary of our findings. The full report can be found here: https://bio-organic.com/wp-content/uploads/2020/12/PhytoCat2020Report.pdf

Improved Carbohydrate Transport: Phyto-C_3™ treatment affects the transport of sugars from source to sink organs in grapevines, resulting in healthier plants, higher yields and greater resilience to heat and water stress. *"Sugar allocation to vegetative organs was highly affected by applied Phyto-C_3™ leading to different shoot to root biomass partitioning where shoot:root ratio, leaf non-structural carbohydrates, and photosynthetic pigments increased with greater applied Phyto-C_3™ ."*

Accelerated Plant Metabolism: Treatment with Phyto-C_3™ correlated with increased rate of photosynthesis, stem water potential and water use efficiency. 4ppm treatment showed a 136% increase in total chlorophylls over two years over control and a 78% increase in total Carote-noids. *"Leaf gas exchange variables were measured during the two seasons and 4 ppm had the high-est rates of photosynthesis (AN), stomatal conductance (gs) and better instantaneous water use efficiency (WUE); also resulting in higher leaf chlorophyll and carotenoid content. Mineral nutrient content for nitrogen and potassium increased linearly with the increase in applied Phyto-C_3™."*

Increased Growth: 4ppm Phyto-C_3™ treatment Increased root mass by 36%, leaves by 107%, trunk by 22%, shoots by 100% and shoot to root ratio by 35% over two years. *" Leaf, shoot and roots fresh weights increased with increased Phyto-C_3™ amounts... The bio-mass of leaf and root increased in the grapevines subjected to 4 ppm compared to 2 ppm and Control."*

Higher Yield: Phyto-C_3™ treatment of 4ppm showed Increased yield of 52% in 2019, and 90% in 2020 which saw significantly higher heat and water stress. Leaf area to fruit ratio was 68% greater after 2 years and berry mass was 35% greater. *"...grapevines that were not supplied with Phyto-C_3™ showed a reduced rate of photosynthesis, and water status, less photoassimilates in source (leaves) available for new growth and export-ed to sinks, and a lower plant BM due to the water restriction. Conversely, 4 ppm showed the highest photosynthetic performance and water status, which led to increased contents of soluble sugars and starch in leaves and greater yield. Finally, our data revealed that in 2 ppm treatment, the enhancement of sugar transport, mainly sucrose and raffinose, could slow down the detrimental effect of water deficits on yield."*