1-Aminocyclopropane Carboxylic Acid as a Potential Replacement for Ethephon as a Coloring Agent

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Introduction – Grape Berry Coloring

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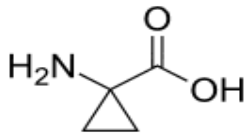
- Global table grape markets demand high-quality bunches that include large berry size, high sugar content, and adequate berry color. Among these, full-color development is a critical factor in maximizing return on investment. Low color results in lower berry quality, lower marketable yields and potentially significant economic losses for the grower.
- In red and black table grape cultivars, color is mainly determined by the amount and composition of anthocyanins in the skin.
- There are numerous coloring agents available commercially, including biostimulants (e.g. potassium fertilizers), jasmonic acid (PDJ), **ethephon and *S*-abscisic acid.**
- Because of the increasing regulatory and consumer scrutiny regarding residues related to ethephon, there is a strong need by growers for better alternative (consistent efficacy, no residue issues, etc.) to improve color of red table grapes.

What is ACC ?



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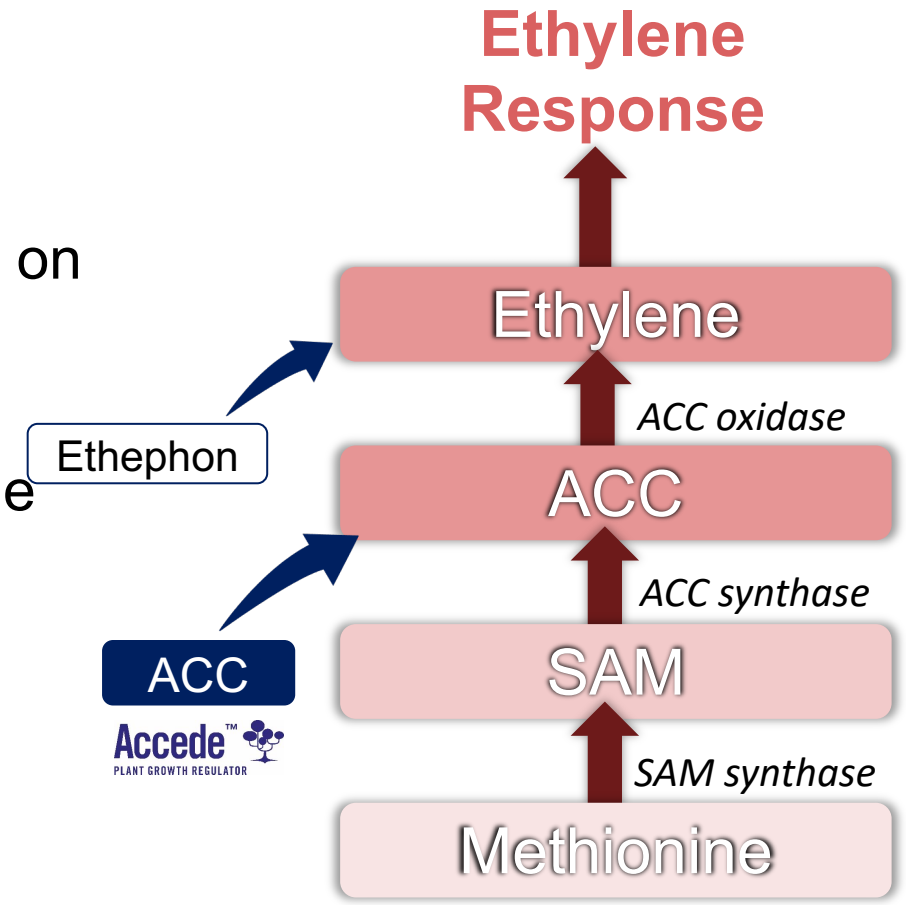
- 1-Aminocyclopropane carboxylic acid
- Naturally occurring non-protein amino acid
- Present in all plants, fruit, vegetables humans consume on a daily-basis.
- Immediate precursor to ethylene
- Rapidly converted into ethylene by ACC oxidase enzyme using the plants natural biochemical pathways
- Rapidly metabolized in soil by bacteria containing ACC deaminase e.g. PGPR
- Leaves no residue at harvest (US EPA tolerance exemption)
- Commercially available as ACCEDE Plant Growth Regulator



2016-2023 Trials: 5 countries, ~10 varieties

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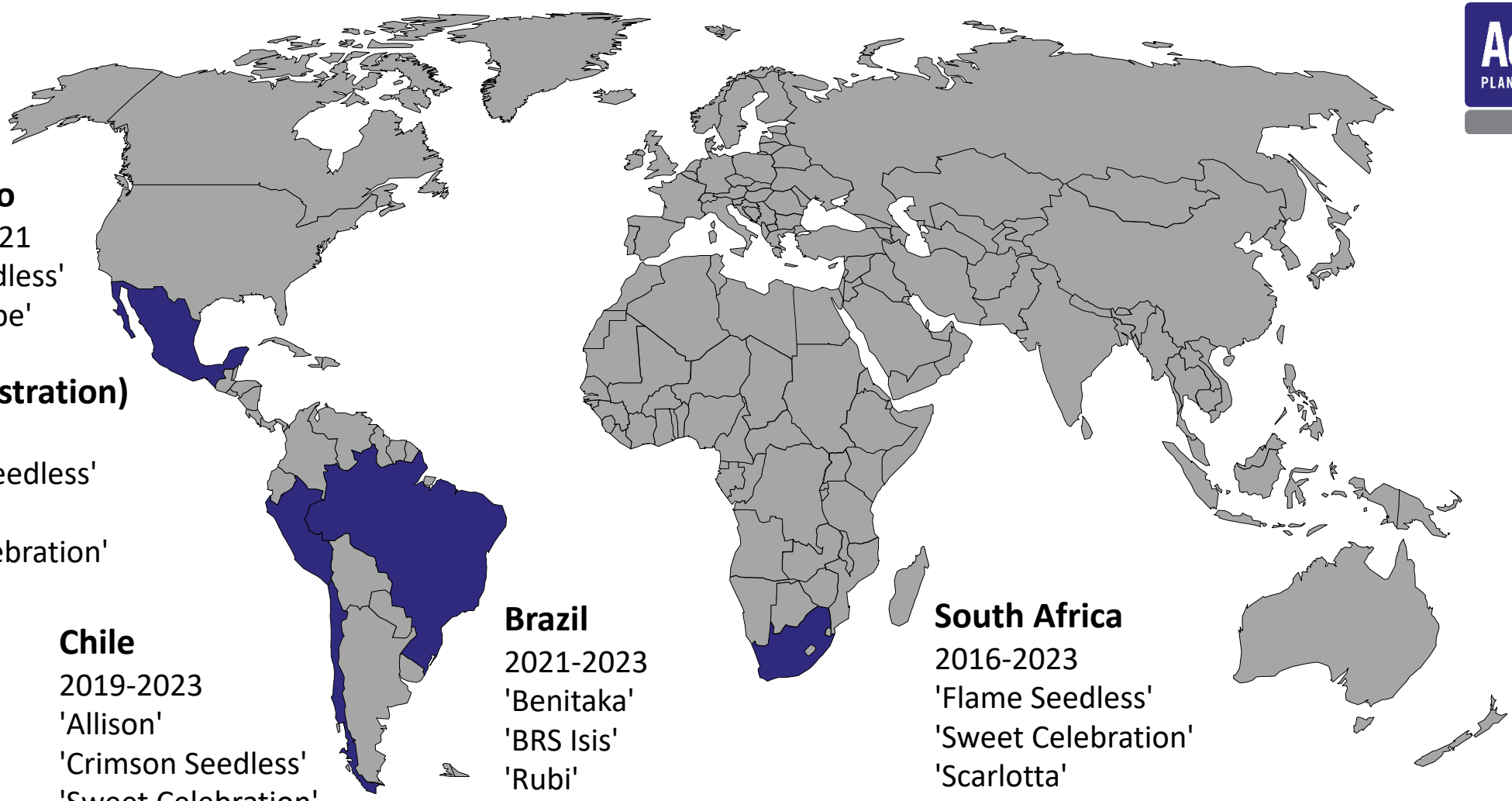

Mexico
2020-2021
'Flame Seedless'
'Red Globe'

Peru (registration)
2020-2023
'Crimson Seedless'
'Red Globe'
'Sweet Celebration'
'Timco'
'Allison'

Chile
2019-2023
'Allison'
'Crimson Seedless'
'Sweet Celebration'
'Timco'

Brazil
2021-2023
'Benitaka'
'BRS Isis'
'Rubi'

South Africa
2016-2023
'Flame Seedless'
'Sweet Celebration'
'Scarlotta'
'Crimson Seedless'

Protocols

- **Years:** 2016-2023
- **Formulations:** SL 11.2 v/v (10%) and SG 40%
- **Rates tested:** 100, 200, 300, 400, 500 and 800mg L^{-1} (+/- 0.015 to 0.05% nonionic surfactant)
- **Timing:** One and/or two sprays: *veraison + 7 days*, *veraison* + 14 days; 50% softening, 80-100% softening, 4, 7, 14 and 21 days after
- **Comparison:** UTC, Ethephon or/+ ProTone (S-ABA) at the commercial rates and reccomended timing.
- **Spray pattern:** whole canopy (1000 L/ha) and directed to the bunch sprays (300 to 800 L/ha)
- **Evaluations:** phytoxicity, red color development (rating: 1 to 8 or 1 to 5), berry color uniformity (1-3), color index (colorimeter), number of bunches harvested in each harvest date (1-3), bunch weight, total yield, total anthocyanins, brix, acidity, firmness and pH, 30-day postharvest life: brix, firmness, raquis quality and berry shattering.
- **Combinations and programs:** Tank mixtures of ACC (100-400 ppm) + ProTone (S-ABA – 100-400 ppm)

Brazil - Main Findings

- **In general, rates higher than 200 mg L^{-1} applied 7 days after veraison (BBCH81) presented good efficacy to increase coloring** when compared to comercial rates of Ethephon or ProTone. 'Rubi' seems to be slightly harder to color. Label will allow up to 500 mg L^{-1}
- **No differences were found between whole canopy sprays (1000 L/ha) and sprays directed to the bunch (500 L/ha)**.
- In general, there was no effects on berry quality parameters at all rates tested, except for one year and one trial where ACC increased brix and reduced acidity.
- Some level of phytotoxicity was observed, however with no negative effects on berry quality or harvest.
- Next steps: we are looking into tank mixes of ACC plus *S*-ABA, and in a program with *S*-ABA

Vale do San Francisco, Brazil
Benitaka, 2022

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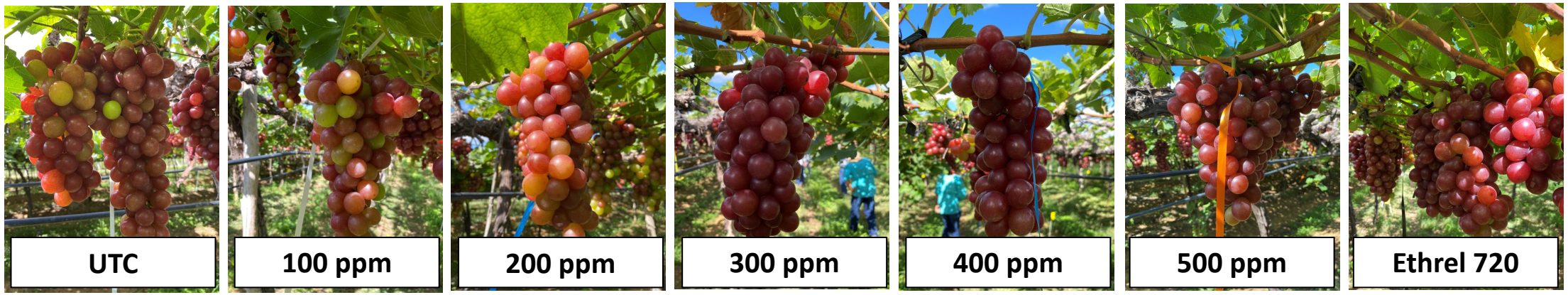
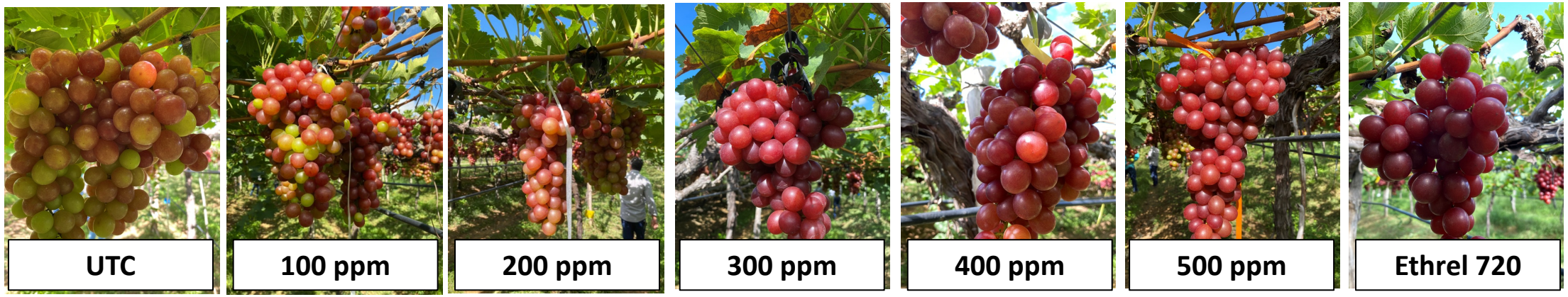
Bunch sprays of ACC – 14 DAA



Whole canopy spray of ACC – 14 DAA



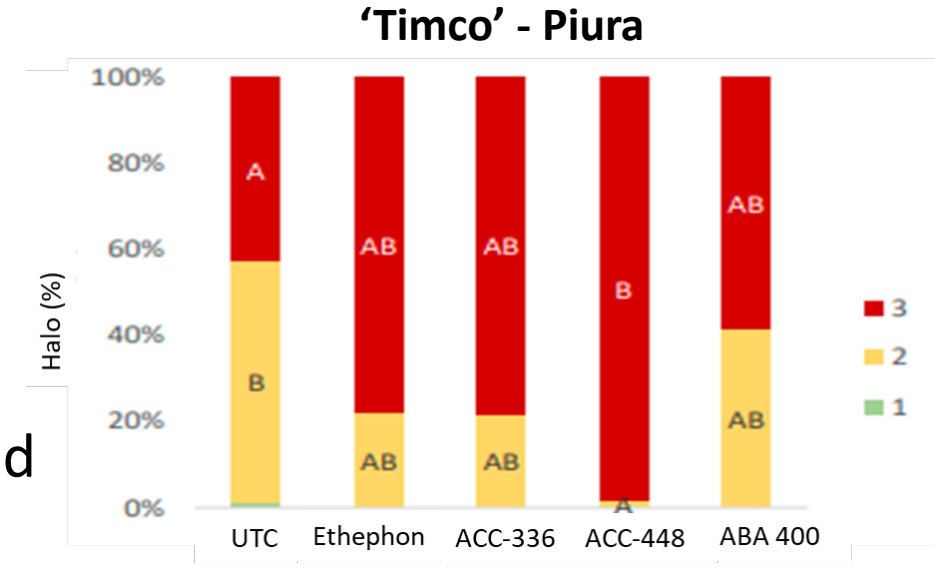
Peru & Chile - Main Findings

- Great color efficacy with **ACC at 336 ppm applied at 50-100% of softening or 7 days after**. Color development was in general faster than the standard commercial Ethephon at 720 ppm at 100% of softening.

- ACC also promoted a more uniform color of berries; common problem of new varieties such as Timco and Allison.

- Light-moderate phytotoxicity (leaf yellowing) was observed in few cases, with no effect on vine, bunch and berry quality.

- Postharvest: in general, no influence in postharvest berry and raquis quality.



Crimson, Chiclayo, Region Lambayeque, Peru, 2022

Effects of 336 ppm of ACC applied at different timings on color development of ‘Crimson’, compared to UTC and the commercial standard application Ethephon.

ACC applied at 50% softening and 7 days after (100% softening) induced faster color development, therefore anticipating harvest.

Treatments

Time of evaluations

	UTC	A: ACC 50% Soft.	ACC 7 DAA	ACC 14 DAA	ACC 21 DAA	ACC 28 DAA	Ethephon 7 DAA
7 days after A: 50% Soft.							
14 days after A: 50% Soft.							
21 days after A: 50% Soft.							
28 days after A: 50% Soft.							
35 days after A: 50% Soft.							

Chile – Region Metropolitana 2021-22

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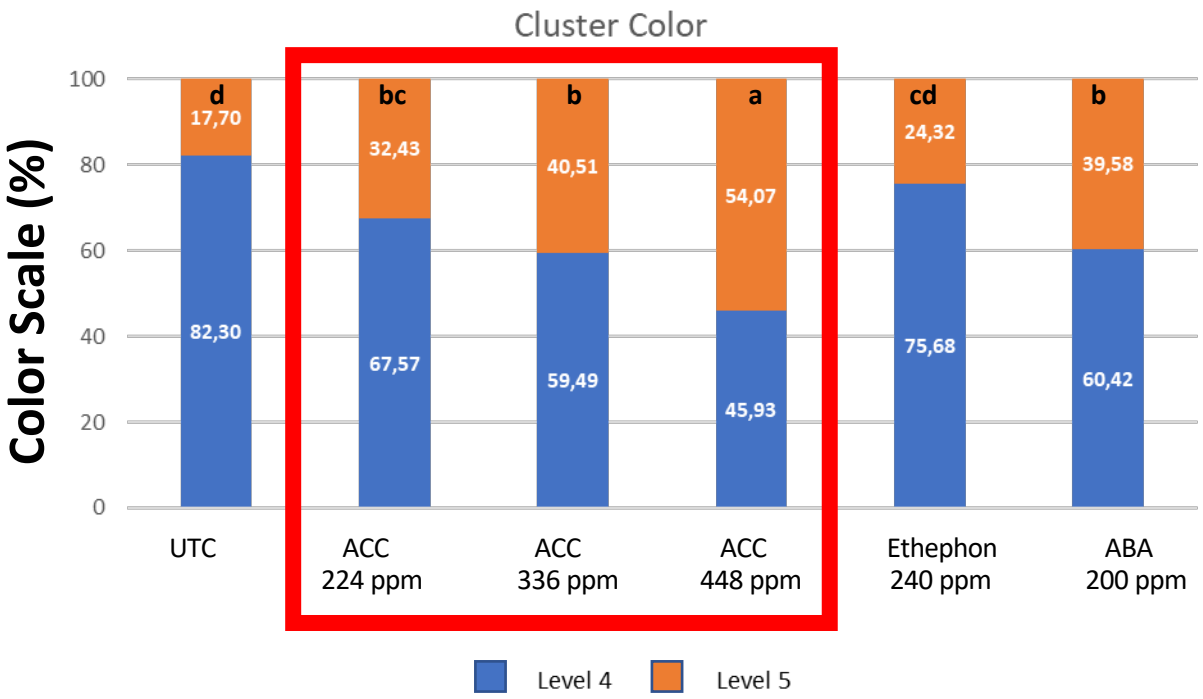
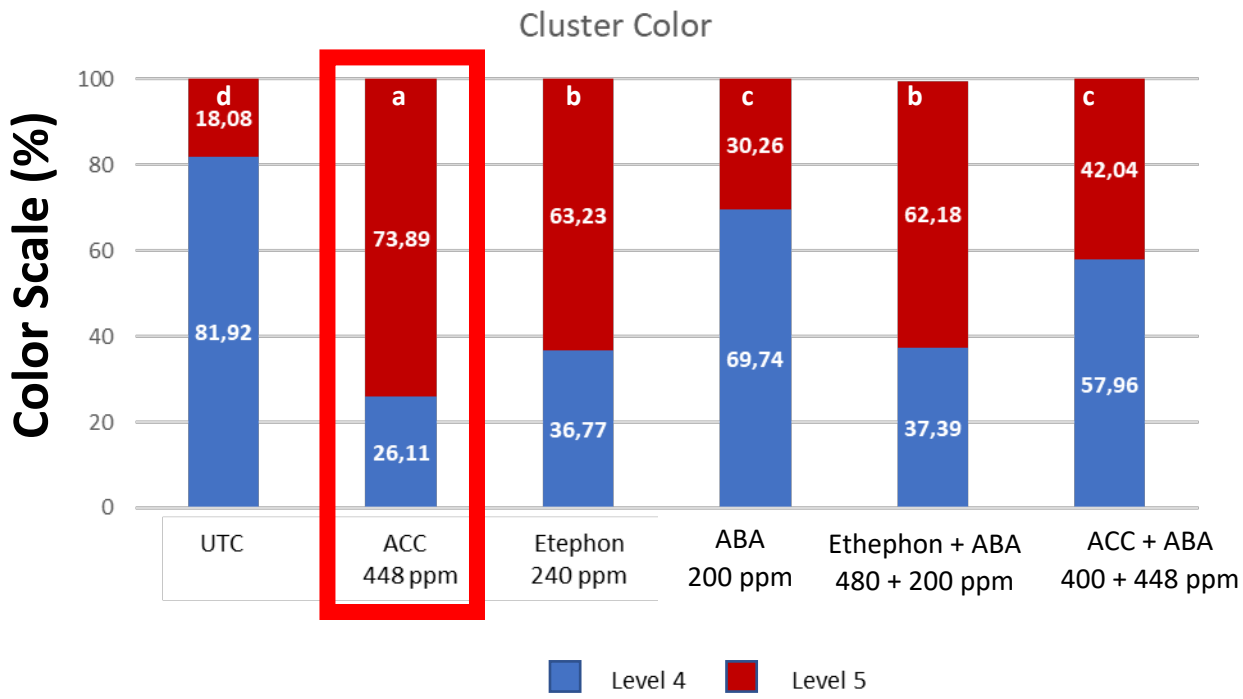
‘Crimson’



‘Sweet Celebration’



1- No color | 2- Poor | 3- Medium | 4- Optimal | 5- Optimal

Color scale from the 1st harvest
All treatments applied twice at 80-100% softening and 7 days after

Mexico – Main Findings

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- Zacatecas (Red Globe):
  - **Two consecutive sprays of 400 mg L^{-1} T 600 L/ha applied at *veraison (beginning of berry soft) and 4 days later*** consistently advanced red coloration in all 5 trials.
  - In Red Globe, sugar content increased as ACC rate and sprays increased
  - Phyto (yellow leaves) at the high rates and double sprays
- Sonora (Flame):
  - **All ACC treatments (either alone, in a program with *S*-ABA and multiple applications) improved berry coloring in comparison with UTC; however the number of bunches harvested during the first picks was low compared to the standard program (ethephon), in all the three years tested**;
  - We believe that **high temperatures (often above 35 C)** registered during the applications/harvest may be the reason for the poor performance of ACC.
  - Next steps: Tank mixes ACC + *S*-ABA applied multiple times.

Red Globe – Zacatecas, MX, 2020

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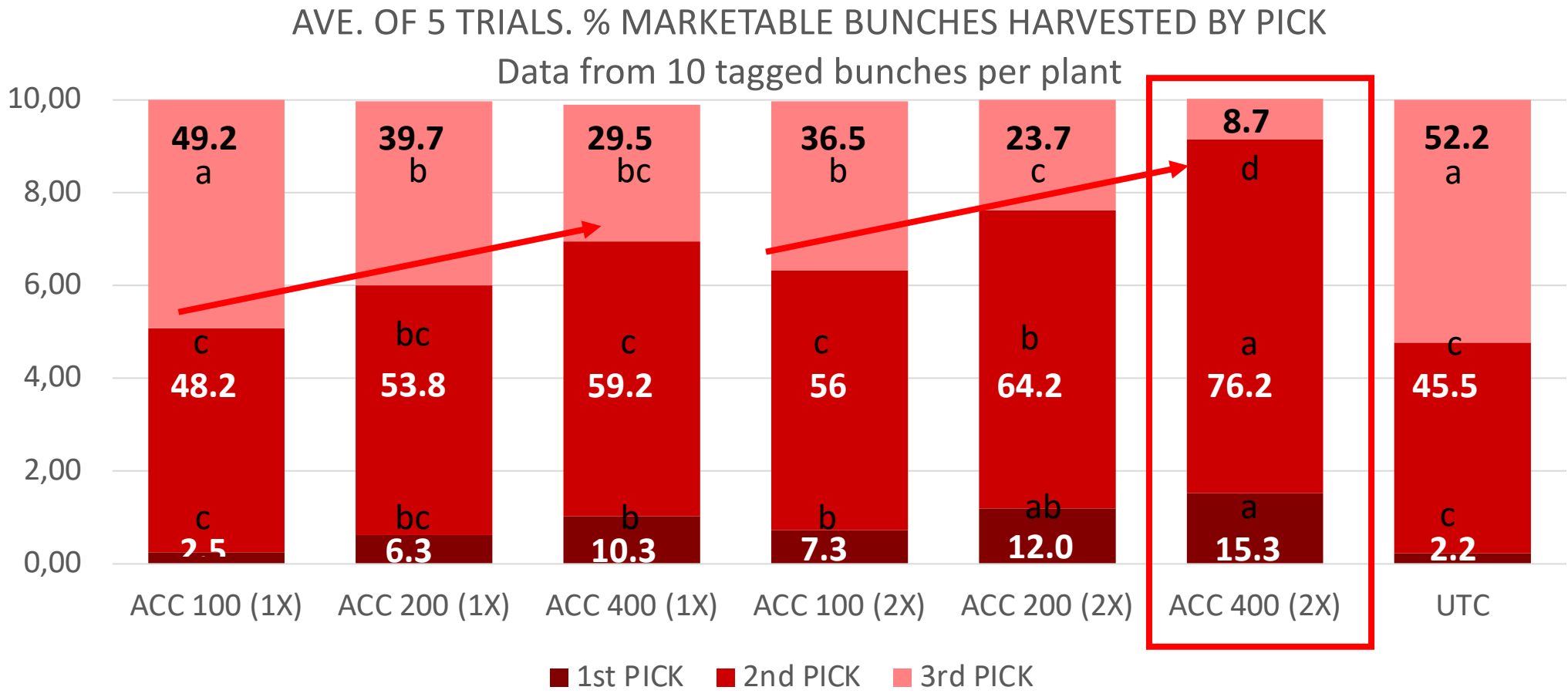
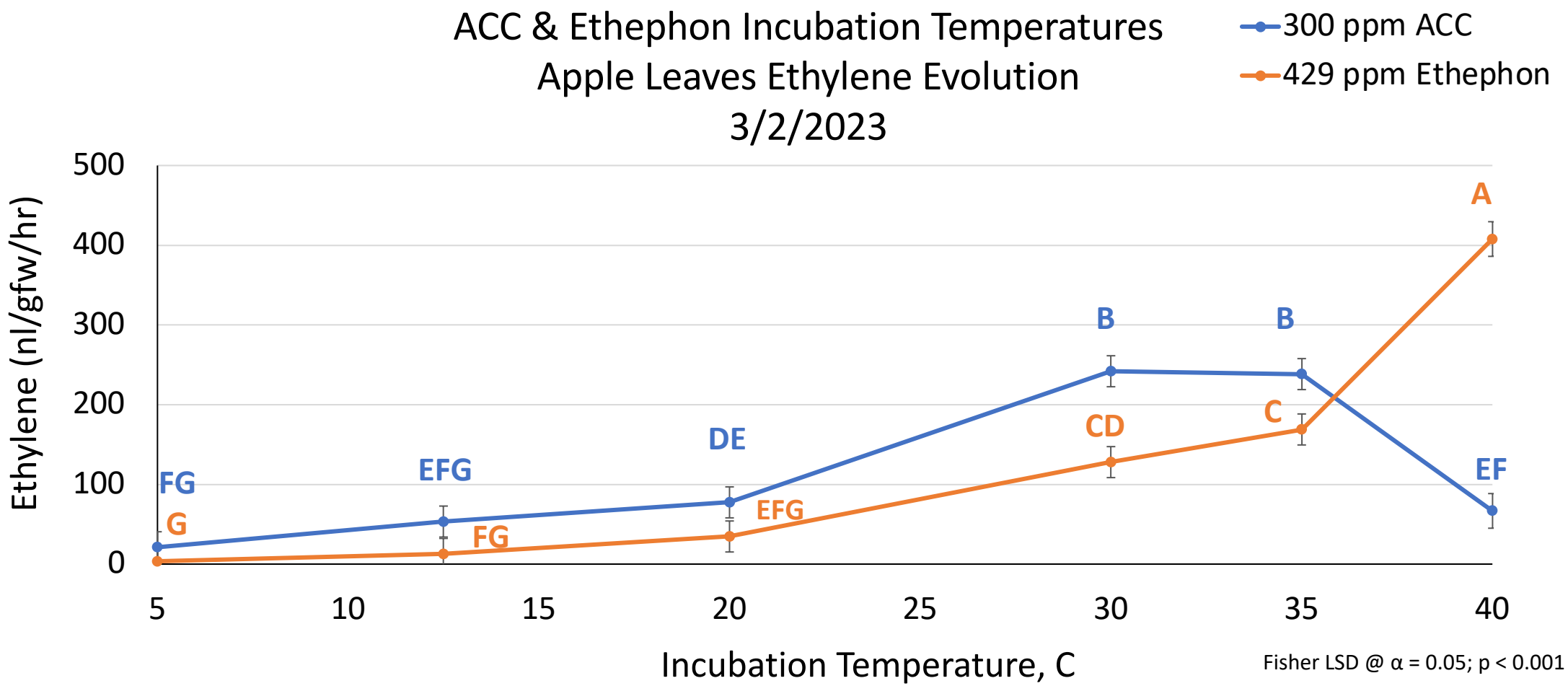


In general, 2 sprays of 400 mg L of ACC consistently increased the number of bunches harvested in the first and second pick.
Efficacy increases as rate increases

Effects of Ethephon and ACC on Ethylene production in apple leaves



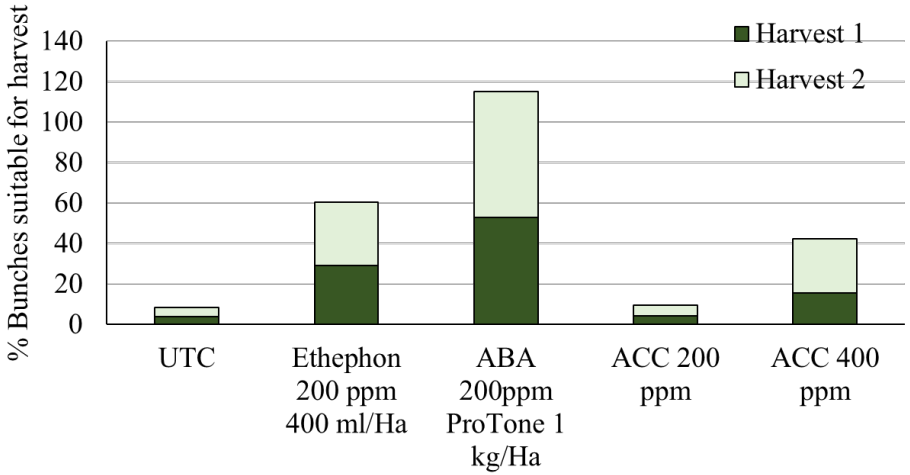
Fisher LSD @ α = 0.05; p < 0.001

South Africa - Main Findings

ACC applications

- ❑ **For easy-to-color varieties and conditions, ACC at 400 ppm showed similar efficacy to Ethephon at 200 ppm or ProTone at 200 ppm AI**.
- ❑ **For hard-to-color conditions (high temps for e.g., combinations will be required (see graph)**
- ❑ Some phyto were observed on the leaves as with comparison products, but no negative effect on berry quality

Crimson Seedless, Orange River, 2022
(Difficult to color conditions)

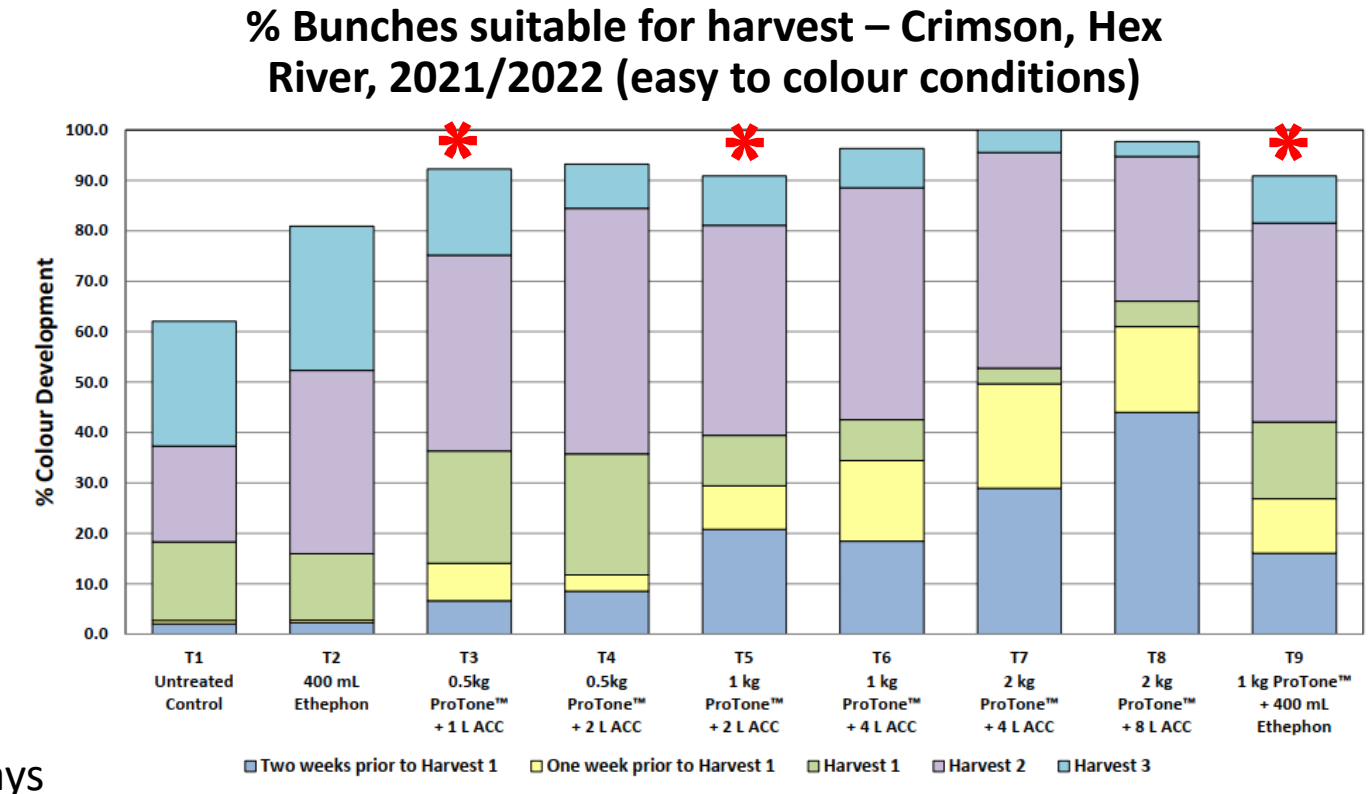


Two sprays: *Veraison* + 7 days and *Veraison* + 14 days

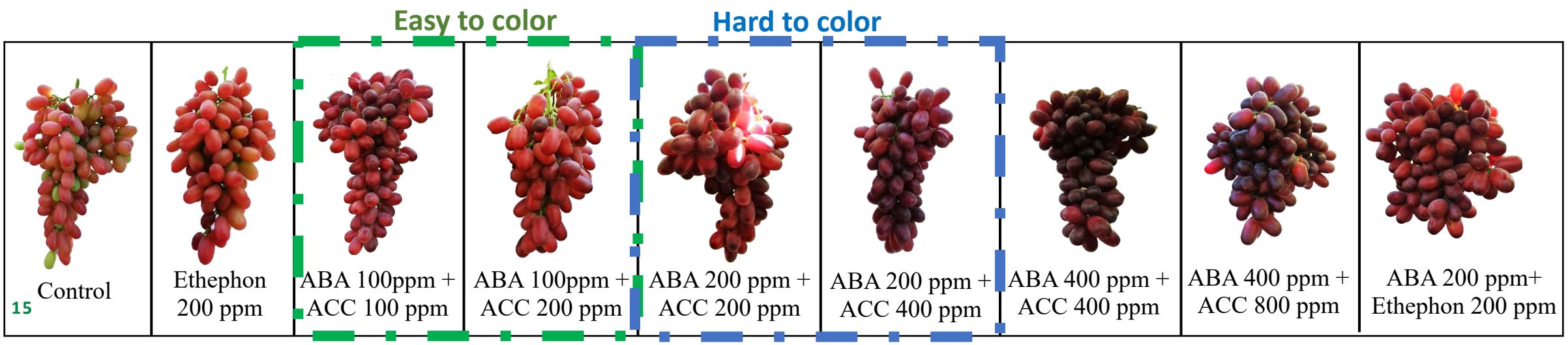
Tank mixtures ABA+ACC

- ❑ Tank mixtures of *S*-ABA (ProTone) + ACC is needed in difficult to color conditions.
- ❑ ***S*-ABA + ACC combinations performed better than Ethephon only.**
- ❑ In overall, *S*-ABA at 100-400 ppm + ACC at 200-400 ppm were on par with the commercial standard ProTone at 1 Kg/ha + Ethephon at 400 ml/ha
- ❑ Some phyto were observed on the leaves as with comparison products, but no negative effect on berry quality
- ❑ **Ethephon Residue Free coloring program for exports to the European markets.**

South Africa ‘Crimson’



Two sprays: *Veraison* + 7 days and *Veraison* + 14 days



Final Conclusions

Red Globe

0 ppm | 100 ppm | 200 ppm | 300 ppm | 400 ppm

- ACC is rate dependent.
- In most years and regions, ACC exhibited similar or superior efficacy as a coloring agent compared to Ethephon.
- ACC provides uniform color of berries (full coverage)
- Two applications usually gives better results

- Combinations of ACC + *S*-ABA and multiple applications are recommended for hard-to-color varieties and conditions.
- No changes in acidity and firmness at the commercial harvest, and no postharvest effects. Few trials show increase in sugar content.
- Phyto (leaf yellowing) can be observed after ACC sprays, but it has no effect on berry quality.
- In many cases, ACC promoted a more uniform coloring, anticipating harvest with more bunches being harvest in the first pick.
- ACC can be an effective alternative to be used in ethephon-free coloring programs as it can be applied close to harvest without risk of residues in the fruit.

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Thank you!

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