Establishment of Newer PM2.5 Emission Factors with Various Almond Harvesting Machinery

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Problem and Significance

Newer PM2.5 emission factors are necessary to support the new PM2.5 State Implementation Plan (SIP) for California. Incentive programs will encourage almond farmers to switch to low emissions harvester thereby lowering the dust emissions from harvesting operations.

Our **goal** is to answer the following:
1. Can we measure significant differences in PM emissions between an old harvester and a new low dust emissions harvester?
2. How much reduction in emissions can be achieved by the harvesting machinery?
3. Are the collection efficiencies of newer machines as effective or better that older models?
4. What is the ratio between FRM PM10 and FRM PM2.5?

Significance. Establishment of newer and up-to-date PM2.5 data using CARB Approved Federal Reference Method (FRM) samplers will provide greater confidence in the implementation of the PM2.5 SIP in the valley.

Methodology

Selection of Orchard in Riverdale, CA c/o Matthew Efird/Roger Isom

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Sampling Methodology Discussed and Approved by All Concerned Parties

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Sampler Assembly and Deployment: FRM PM2.5, FRM PM10 and TSP

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Simultaneous Air and Soil/Windrow Sampling

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Observation by Air District Representatives, Manufacturers, Almond Board Members and Farmer's Cooperative Support Groups

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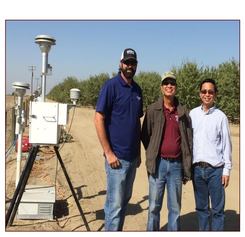
Analysis Overview:
Emission Reduction/PM Ratio
Particle Size Distribution
Soil Characterization
Collection Efficiency



Machinery Tested


Control = Flory 480


Flory 860

Order of Runs

REP 1	REP 2	REP 3
cA	D	B
A	cD	cB
cC	A	C
C	cA	cA
B	C	A
cB/cD	cC/cB	cA/cD
D	B	D


Weiss McNair 9800

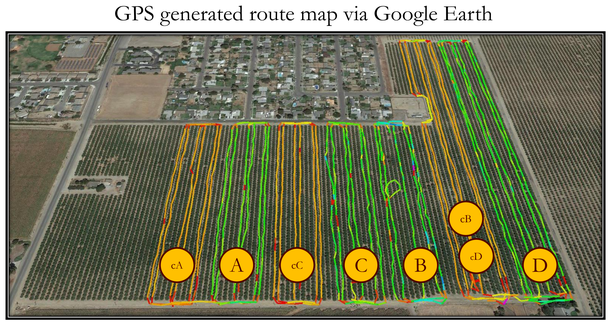

Jack Rabbit


Exact 3800

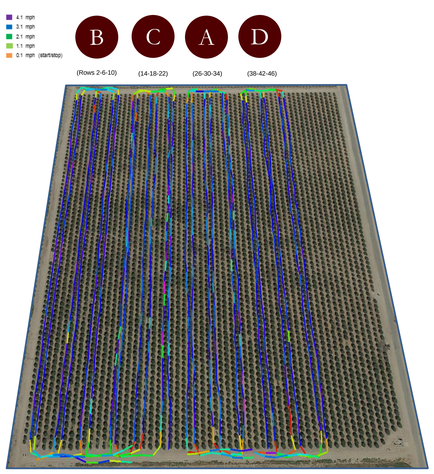
Results

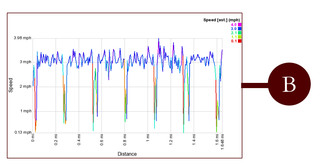
Harvester Route (Replicate 1)

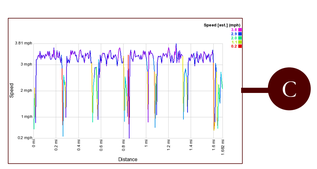
GPS generated route map via Google Earth

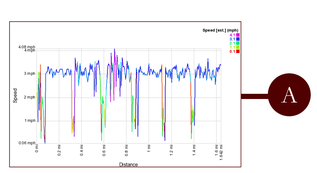


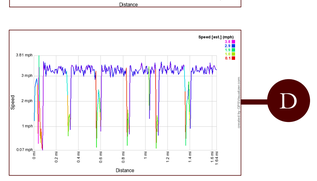
Speed Profile




B


C


A


D

Machine	Total Distance Covered (mi)	Speed (mph) Max	Ave	Ave (motion)
A	1.65	4.0	2.0	**2.9**
B	1.68	3.8	2.4	**2.9**
C	1.64	4.1	1.7	**2.8**
D	1.64	3.8	1.8	**2.9**

Results (continued)

Collection Efficiency

Category	Mass Fraction (%) Harvester **A**	Control
Nuts	53.6 (7.2)	50.1 (9.5)
Leaves, Grasses, Small Nuts	32.3 (2.4)	30.5 (3.8)
Small Twigs	0.5 (0.07)	0.3 (0.05)
Soil	13.7 (4.7)	19.1 (5.7)

Category	Mass Fraction (%) Harvester **B**	Control
Nuts	46.2 (4.5)	45.6 (7.9)
Leaves, Grasses, Small Nuts	31.8 (2.6)	19.7 (7.7)
Small Twigs	1.1 (0.15)	0.1 (0.01)
Soil	20.9 (2.1)	34.6 (0.3)

Category	Mass Fraction (%) Harvester **C**	Control
Nuts	47.0 (9.7)	45.6 (7.9)
Leaves, Grasses, Small Nuts	21.1 (6.7)	19.7 (7.7)
Small Twigs	0.5 (0.04)	0.1 (0.01)
Soil	31.4 (2.9)	34.6 (0.3)

Category	Mass Fraction (%) Harvester **D**	Control
Nuts	51.0 (3.2)	50.1 (9.5)
Leaves, Grasses, Small Nuts	32.1 (6.9)	30.5 (3.8)
Small Twigs	1.0 (0.1)	0.3 (0.05)
Soil	15.9 (3.5)	19.1 (5.7)

Percent Reduction from All Runs

Machine	% Reduction in $PM_{2.5}$ Concentration	% Reduction in PM_{10} Concentration
A	43.5% ± 11.9% [31.6 - 55.4]	53.5% ± 9.6% [43.9 - 63.1]
B	61.5% ± 14.0% [47.5 - 75.5]	37.3% ± 18.4% [18.9 - 55.7]
C	57.7% ± 13.8% [43.9 – 71.5]	43.6% ± 12.1% [31.5 - 55.7]
D	42.1% ± 32.5% [9.6 - 74.6]	33.0% ± 31.1% [1.9 - 64.1]

Experimental Design and Statistics = Goodness of Fit (Normality) Test (Shapiro-Wilk) with 95% Confidence Interval or $\alpha = 0.05$

Ratio of PM10 to PM2.5 based from FRM Sampler Results

Machine	Average from All Replicates
A	14.4%
cA	15.7%
B	17.9%
cB	8.3%
C	8.4%
cC	10.7%
D	15.9%
cD	11.5%
Overall Average	**12.5%**

Conclusion

- Reduction in PM2.5 and PM10 emissions can be measured between comparative machines
- Range of reductions varies from about 10% to 75% in PM2.5 emissions
- Range of reductions varies from about 2% to 65% in PM10 emissions
- Harvesting efficiency is not affected. Old machine gathers more soil.
- The average ratio between PM10 and PM2.5 emissions is about 12.5%

Recommendations
- Continued measurements must be made using other machinery models and other factors such as time of harvest, soil types, weather influence, etc.
- There are various machine adjustments that could be made to further reduce PM emissions such as speed of harvesting, early harvest, effect of orchard orientation, soil type, ground preparation, windrow cleanliness, windrow leveling, effect of wind speed, among others

Acknowledgement

❖ The Almond Board of California (Major Funding and Observation Representatives)
❖ The San Joaquin Valley Air Pollution Control District (Additional Funding and Observations)
❖ Matthew Efird (Efird AG Enterprises, Orchard Site, Operators and Some Machinery)
❖ BETA Lab Crew for Sampling
❖ Roger Isom (Western Agricultural Processors Association (Orchard Site and Observations)