Measurement of Harvest Dust Generation

Project No.: **08-AIR1-Giles**

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Objectives:

The project objectives were to establish the effects of harvester fan speed on the intensity of the dust cloud produced during nut pick-up operation and the resulting effects on the cleanliness of the harvested material.

Interpretive Summary:

While the high air volume and air velocity from the fans on standard nut harvesters are important for separation of the nuts from orchard debris, the emitted air jet produces significant amounts of visible and mobile dust. The smaller size fractions, namely, PM_{10} and $PM_{2.5}$, of this emitted dust, are important for regulatory considerations related to air quality. Also, reducing the total dust emitted, particularly, the visible fraction is a stewardship and environmental objective for the industry.

Previous work has determined that grower-controlled operational decisions and practices such as ground speed, sweeper settings and the direction of blower discharge can produce beneficial reductions in observed and measured dust intensity near the harvest operation. Experiments in the 2008 harvest season investigated the effects of a simple mechanical change to existing harvester operation, namely, the reduction in fan rotational speed, on the dust produced within the orchard. The experiments also investigated any simultaneous change in the cleanliness of the harvested product due to the reduction in separation, i.e., cleaning, air volume.

Experiments were conducted in a commercial almond orchard using a standard commercial harvester operating at 3.2 mi/hr. Typically, the normal operating speed of the harvester fan was 1080 rpm (at a tractor PTO speed of 540 rpm). That typical speed, 1080 rpm, was tested along with experimental operational speeds of 910, 715

and 0 rpm. Dust discharge was measured using opacity and gravimetric devices, and the windrow samples both before and after harvesting were collected to investigate the effects of fan speed on cleanliness of the harvested product. Post harvest samples were carefully collected into large bags as they exited from the discharge chain of the harvester.

Visually, and as measured by opacity and gravimetric methods, effects of fan speed on the observed dust were noticeable, especially at the 715 and 0 rpm settings. Operating the harvester with the fan disconnected (0 rpm) resulted in a significant reduction in dust. Visually, there remained dust produced by the motion of the harvester through the orchard and the operation of the pick up and internal chains and handling of the windrow product. However, the experimental data indicate a virtually complete reduction in dust concentrations within the orchard air. The fan operation at 910 rpm showed significant reduction of TSP and PM_{10} emission compared to 1080 rpm operation. In addition, the dust emission from 910 rpm and 715 rpm operations were similar.

The results from analysis of the harvested material show that suction fan speed has a significant effect on the materials such as leaves, grass, small twigs, and small nuts. These materials must be separated from the nut to maintain harvest quality. The results from the operation with 910 rpm and with 1080 rpm fan speeds show the highest mass fraction of nuts and the least mass fraction of leaves, grass, and small twigs (≤9.4 mm materials. While the operation with fan speeds of 715 rpm and lower results in the highest mass fraction of the waste-product, the operation at 910 rpm fan speed is a considerable alternative for a cleaner harvest operation with maintained harvest quality.

Materials and Methods:

Experiments were conducted in a commercial almond orchard near Arbuckle, CA. The windrows were prepared using a standard sweeping practice for the local area and grower. A standard harvester (Model 850, Flory Industries, Salida, CA) was operated at a constant ground speed of 3.2 mi/hr. Typically, the normal operating speed of the harvester fan is 1080 rpm (at a tractor PTO speed of 540 rpm). That typical speed, 1080 rpm, was tested along with experimental operational speeds of 910, 715 and 0 rpm. The slower fan speeds were achieved by replacement of the drive belts and sheaves. The 0 rpm (no fan) speed was achieved by disconnecting the drive shaft from the fan. During all tests, all other components (chains, etc.) on the harvester were operated at normal speeds (at 540 tractor PTO speed). Dust discharge was measured using opacity and gravimetric devices, and the windrow samples both before and after harvesting were collected to investigate the effects of fan speed on cleanliness of the harvested product. Post harvest samples were carefully collected into large bags as they fell from the discharge chain of the harvester. In addition, an opacity device, which uses laser light to measure the intensity of dust within the air, was located 1 row, 2 rows, and 3 rows away from the row being harvested. Moreover, gravimetric devices (filter-based air samplers) were located 1 row and 2 rows away from the row being harvested.

Post-harvesting windrow samples were collected from the outlet of the nut harvester while it was being operated with the selected suction fan speed (i.e. 0 rpm, 715 rpm, 910 rpm, or 1080 rpm); 250 grams of each sample were taken for sieve analysis. The sample was placed in a sieve series **(Figure 1)**, which was then mechanically shaken at 1,450 rpm using the Ro-Tap Testing Sieve Shaker for 15 minutes. The suitable sieving size and time for almond windrow materials have been determined in previous sieve analysis. The Ro-Tap Testing Sieve Shaker **(Figure 2**) reproduces the circular and tapping motion given testing sieves in hand-sieving, but with a uniform, mechanical action, producing dependable sizing tests [W.S. Tyler Company, 1943]. Retained materials on sieves were collected and measured by weighing them.

Figure 1. Sieve series

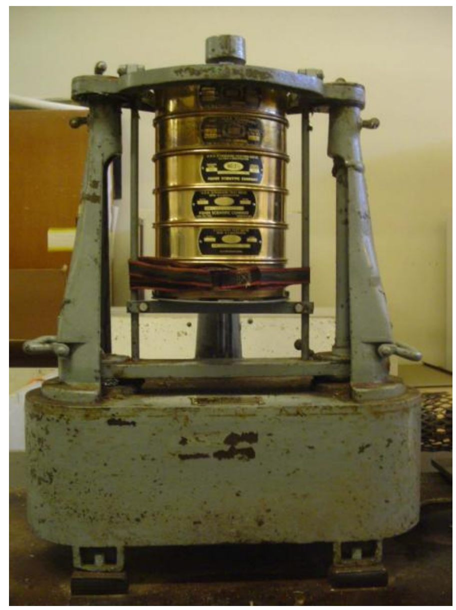

Figure 2. Testing sieves on the Ro-Tap Testing Sieve Shaker

Results and Discussion:

Visually, effects of fan speed on the observed dust were noticeable, especially at the 715 and 0 rpm settings **(Figures 3-6)**. An additional observation, which has also been made in previous testing seasons, is that the air jet becomes dustier once it impacts the orchard floor and entrains dust from the floor. The effect of this is that the air leaving the fan outlet is sometimes less dusty than the air in motion one row over. This may suggest that orientation of the blower outlet may be another grower-controlled means to reduce dust, provided that discharge of dust into the trees does not create other production problems.

Figure 3. 1080 rpm fan operation

Figure 4. 910 rpm fan operation

Figure 5. 715 rpm fan operation

Figure 6. 0 rpm (no fan) operation

The quantitative results are shown in **Table 1**. These results show that fan speed does have a significant effect on the duration of the dust cloud, the intensity (opacity) of the visible dust moving within the orchard and also on the mass of dust collected on air samplers. The effect of air jet impacting the orchard floor was also detected in the data as the second row over was the location of the greatest dust load in most experiments.

Table 1: Average results for gravimetric mass, peak opacity and time signature for dust discharge measurements as a function of fan speed.

Fan speed (rpm)	Time span (s)			Peak opacity (%)			TSP and PM10 mass (mg)		
	Row 1	Row 2	Row 3	Row 1	Row 2	Row 3	TSP Row 1	TSP Row 2	PM10 Row 3
1080	31.75	46.50	66.75	2.83	11.73	7.20	0.68	1.14	0.35
910	35.25	25.50	38.00	3.03	7.63	3.75	0.38	0.43	0.08
715	51.75	26.25	33.25	2.70	3.18	3.63	0.37	0.39	0.11
0	n/a	n/a	n/a	0.20	0.08	0.20	0.04	0.04	0.01

Operating the harvester with the fan disconnected resulted in a significant reduction in dust. Visually, there remained dust produced by the motion of the harvester through the orchard and the operation of the pick up and internal chains and handling of the windrow product. However, the experimental data indicate a virtually complete reduction in dust concentrations within the orchard air.

Examples of the visual assessment of the sieved harvester discharged product are shown in **Figures 7 – 12** as follows. Analysis of the collected material revealed the expected trends in fan speed effects, i.e., lower fan speeds resulted in more undesired material in the harvested product **(Figure 13)**.

Figure 7. Sieve-1 (opening 18.850mm) contains mostly nuts and twigs

Figure 8. Sieve-2 (opening 9.423mm) contains small nuts, leaves, and small twigs

Figure 9. Sieve-3 (mesh #3.5, opening 5.6mm) contains mostly leaves and grass

Figure 10. Sieve-4 (mesh#10, opening 2mm) contains mostly grass

Figure 11. Sieve-5 (mesh#20, opening 0.850mm) contains mostly grass.

Figure 12. Bottom tray collects the remaining fine particles

Figure 13. Sieve analysis of example replicate (1) windrow samples from Arbuckle on August 18th-19th 2008. From left to right: particle size ≥ 18.850 mm, 9.423 mm ≤ particle size ≤ 18.850 mm, 5.6 mm ≤ particle size ≤ 9.423 mm, 2 mm ≤ particle size ≤ 5.6 mm, particle size ≤ 2 mm.

The overall results show that suction fan speed has a significant effect on the materials such as leaves, grass, small twigs, and small nuts. These materials (except nuts) must be separated from the nuts to maintain product quality. The results from the operation with 910 rpm and with 1080 fan speeds show the highest mass fraction of nuts (>9.423mm materials). Moreover, they also show the least mass fraction of leaves, grass, and small twigs. While the operations with suction fan speed of 715 rpm and lower results in the highest mass fraction of the waste product, the operation at 910 rpm fan speed is a considerable alternative for a cleaner harvest operation with maintained harvest quality. This is especially interesting when viewed in the light of the orchard dust results that found the 910 rpm speed to provide notably reduced dust discharged when compared to the 1080 rpm operation but only a small improvement over operation at 715 rpm.