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Dust exposures in tractor and combine operations in eastern Mediterranean, Turkey

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Abstract: *The objective of this study was to determine the dust concentrations in selected tractor and combine operations in eastern Mediterranean region in Turkey. Mean dust concentrations were 137.9 mg m^{-3}, 83.6 mg m^{-3}, 80.3 mg m^{-3}, and 88.8 mg m^{-3} respectively for soil packing, furrowing, straw making, and baling on tractors with no cabins whereas 106.9 mg m^{-3} was found in combines without cabins, which are much higher than the limit dust concentration (10 mg m^{-3}) considered hazardous for workers' health. In tractor operations with field-installed cabins, mean dust concentrations were 5.6 mg m^{-3}, 6.6 mg m^{-3}, 6.4 mg m^{-3}, and 3.7 mg m^{-3}, respectively in soil packing, furrowing, straw making, and baling while 4.7 mg m^{-3} was measured in combines with field-installed cabins. Considering unit-manufactured cabins, mean dust concentrations were 1.1 mg m^{-3}, 1.6 mg m^{-3}, 3.2 mg m^{-3}, and 1.4 mg m^{-3} respectively in tractor operations, and 1.4 mg m^{-3} in combine operations. Variance analyses showed that not only the respiration environment of the workers but also the field operation had a significant effect on measured dust concentrations ($p<0.01$). Pearson correlation coefficient was 0.74 (very strong level) between dust concentration and wind speed in soil packing, 0.46 (medium level) between dust concentration and wind speed in baling, and 0.44 (medium level) between dust concentration and ground speed in combining.*

Key words: *Dust exposure, Dust measurements, Tractors, Combines, Turkey*
PDF file of full length paper is available with author

Introduction

Dust is generated as a result of agricultural machine operations in the field mostly by machine-soil and machine-plant interactions. Operators and workers breathe the generated dusts from these interactions. Dust also interacts with human body as the skin is exposed to dust particles.

Dust may cause poisoning and allergy in the respiratory tract (Witney, 1988) and inflammation of the eyes, lungs, and the skin (Matthews and Knight, 1971). Intoxicant dusts in the lower respiratory tract may cause farmers' lung, resulting in labor loss, increased health costs and even death in severe cases (Erkan, 1989; Sabanci, 1999). The disease byssinosis is caused by chronic dust inhalation, from cotton processing for instance, due to high levels of microbial products (Lane *et al.*, 2004).

The effects of pollutants are not limited to human but to all living organisms, water and wildlife (Yilmaz *et al*., 2004). Physiological changes were reported for plants under various forms of pollutions (Nuhoglu, 2005). The flowers exhibit significant differences in their flowering phenology and floral morphology (Chauhan *et al*., 2004). As a result, plants try to develop mechanisms to avoid the adverse effects of pollution resulting from human activity (Mandal, 2006).

For all farmers the relative heart rate increase during working, resulting in increased respiration of dusts in the workplace (Christensen *et al*., 1992). It is, therefore, crucial to reduce repetitive dust exposure of farmers. Thus, the assessment of the effects of different agricultural operations, such as soil management systems, on dust production is important to be able to take complementary actions in maintaining air quality (Baker *et al*., 2005).

Based on a four-year study (Reilly, 1981), respiratory problems were observed in 25% of the agricultural operators. In a study conducted in former Soviet Union, according to Reilly (1981), operators working in agriculture faced allergies four times more as compared to a control group. Respiratory problems turned out to be the second most common diseases that the farmers suffer, and tractor and combine operators experienced bronchioles two times more than other agricultural workers. The severity of the effects of dust in terms of human health depends on the source of dust particles, particle sizes, dust concentration, and exposure time (Witney, 1988).

Dust is described as solid particles ranging from 10^{-3}-10^{3} mm with random shapes and density (Reilly, 1981). Dusts generated in agricultural activities could be classified as inorganic dusts (soil/mineral dusts), organic dusts (plant debris), and biological dusts (animal debris). Dust sizes in the air could vary in the range of 1-30 μm (Alsan, 1998). Dusts larger than 10 μm are considered to be coarse dusts, which are blocked in the upper air passages in the body. Dust particles smaller than 10 μm are fine dusts and can penetrate into lower air passages in the human body (Fig. 1). Some portions of the fine dust are cell penetrating and can reach terminal bronchioles.

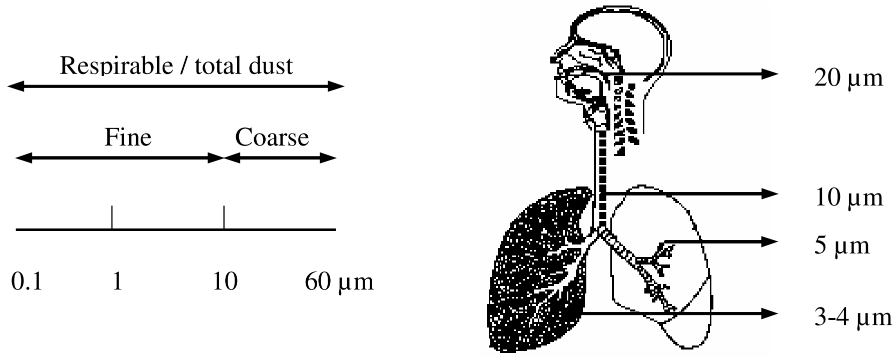

Fig. 1: Dust particle sizes and dust penetration in the respiratory system (Reilly, 1981)

Table - 1: Dust types and threshold dust levels (Gustafsson, 1979; Atiemo *et al.*, 1980)

Dust source	Threshold dust concentration level (mg m^{-3})		
	Sweden	Germany	USA
Mineral	10	8	10
Organic	5	8	10

The upper limit for dust concentration in order to avoid dust originated health problems has not been standardized. Threshold for mineral dusts, for instance, is considered to be 10 mg m^{-3} in Sweden and the United States, and 8 mg m^{-3} in Germany. The threshold for organic dusts, however, is 5 mg m^{-3} in Sweden, 8 mg m^{-3} in Germany, and 10 mg m^{-3} in the United States (Table 1).

In an earlier study in California (Nieuwenhuijsen and Schenker, 1998), the presence of an enclosed cabin, relative humidity, type of field operation, and tractor speeds were found to be the determinants of personal dust exposure during field crop operations. Personal exposures to inorganic dust in manual harvest of citrus and table grapes were also studied (Kiyoung *et al.*, 2004). Exposure to inhalable dust is important not only in field operations in agriculture but also in agri-industrial facilities such as flour mills: In Canada, flour dust concentrations were found to exceed the threshold limit value set for flour mills (Karpinski, 2003).

Chemical and organic dusts endanger human health in the workplace (Sprince *et al.*, 2000). This is why much attention has been directed towards the measurement of dust particle sizes and concentration and reduction/prevention methods of dust propagation in field applications, in animal husbandry facilities, and in agri-industrial plants in developed countries. Nevertheless, in Turkey, this issue has not received enough attention. According to the data provided by State Statistics Institute, in 2001, there were 948,416 agricultural tractors and 12,053 combine harvesters in Turkey. Assuming one operator for each machine, more than 950,000 operators deal with dusts in the country. Furthermore, approximately 40% of the population works in rural areas and/or in the agricultural industry. Determining dust levels in tractor and combine operations in Turkish Republic was considered important in this study due to the effects of personal dust exposure on workers health hence. The objectives of this study were

1) To measure dust concentrations during various tractor and combine operations (soil packing, furrowing, straw making, baling, and combining) in three different respiration environments (no cabins, field-installed cabins, and unit-manufactured cabins),
2) To compare measured dust levels with threshold dust level,
3) To determine whether respiration environment (cabin types), relative humidity, wind speed, and ground speed has an effect on measured dust concentrations.

The findings of the projected study would draw attention to the importance of personal dust exposure in Turkey and could be used to reduce personal dust exposure measured in tractor and combine operations in the country.

Materials and Methods

Dust concentration (mg m^{-3}) was measured using a hand-held real-time aerosol monitor (MIE, Personal DataRAM MODEL). Some technical features of the device are given in Table 2. Wind speed and ambient relative humidity were measured using a thermo-hygro-anemometer. Measurement range and error of the thermo-hygro-anemometer are shown in Table 3.

This study was conducted in Eastern Mediterranean region of Turkey. Medium textured soils prevail in this region.

Tractors and combines used in the study can be seen in Table 4. Tractor and combines with field-installed cabins had fans

Table - 2: Technical specifications for aerosol monitor

Range	0.001 mg m^{-3} - 400 mg m^{-3}
Error	± 5% of the measured quantity
Measurable particle sizes	0.1 µm - 10 µm

Table - 3: Technical specifications for thermo-hygro-anemometer

Feature	Range	Error
Relative humidity (%)	5 - 95	± 2.1%
Wind speed (m/s)	0.3 - 35	± 1%

Table - 4: Brands and models of tractors and combines used in the study

Operation	Tractor/ Combine	Cabin type		
		No cabin	Installed cabin	Original cabin
Soil packing	Tractor	Ford 6600	Fiat 70-56	New Holland M135
Furrowing	Tractor	Fiat 480	Ford 6000	M. Ferguson 6180
Straw making	Tractor	Ford 5000	M. Ferguson 275	New Holland L 95
Baling	Tractor	Fiat 70-56	M. Ferguson 285 S	Tumosan 8280 DT
Harvest	Combine	New Holland 80-55	New Holland 80-50	New Holland TC-56

for ventilation whereas unit-manufactured (original) cabins had air conditioners.

Dust measurements for each field operation were completed in a day between 10 am and 2 pm. Eight measurements were done with four replicates for each field operation. Wind speed, relative humidity, and ground speed were measured once with four replicates. Dust concentrations were determined in three respiration environments, namely in field-installed cabins, in unit-manufactured cabins, and with no cabins on tractor and combines. Measurements were made at the same height as the operators' heads. Wind speed and relative humidity were measured outside the cabins.

The following field operations were evaluated in this study due to higher dust concentration levels compared to other field applications: soil packing, furrowing, baling, straw making, and harvesting.

Variance analyses were done for each field operation to determine the effect of each respiration environment and each field application on dust concentration. Duncan test was used for multiple mean comparisons (Devore, 1993).

Also, the effects of wind speed, relative humidity, and ground speed on dust levels were determined for each operation mentioned above. Data regarding dust levels, wind speed, relative humidity, and ground speed were collected through stratified sampling and evaluated based on Pearson's correlation coefficients (Devore, 1993).

Results and Discussion

Dust concentrations were measured in some tractor and combine operations. Wind speed, relative humidity, and ground speed were also measured to determine the effect of these parameters on dust concentrations in operations without cabins, with field-installed cabins and with unit-manufactured cabins.

The threshold dust concentration was considered to be 10 mg m^{-3} in the evaluations below.

Dust concentrations, air relative humidity, wind speed and ground speed:

Measured dust concentrations, mean wind speed, mean relative humidity, and mean ground speed on tractors and combines with three types of respiration environments for each field operation are shown in Table 5 while mean dust concentrations based on field operations are given in Fig. 2. Table 5 also shows whether mean differences are significant in different field operations and cabin types.

In soil packing, mean dust concentration was 137.95 mg m^{-3} on tractors with no cabins, 5.62 mg m^{-3} in field-installed cabins, 1.10 mg m^{-3} in unit-manufactured cabins. Field operations without cabins resulted in excessive dust concentration compared to the threshold at the operators' head level. Based on a 10 mg m^{-3} upper limit, both field-installed cabins and unit-manufactured cabins functioned satisfactorily. No significant statistical difference was found between field-installed and unit-manufactured cabins. Therefore both cabin types were useful in reducing personal dust exposures to a safe level.

Table - 5: Wind speed, relative speed, ground speed, and Duncan test results* for dust concentrations for each field operation

Operation	Environment	Dust concentration (mg m^{-3})			Mean wind speed ($m\ s^{-1}$)	Mean relative humidity (%)	Mean ground speed ($km\ h^{-1}$)
		Min.	Max.	Average ± SD			
Soil packing	No cabins	61.2	198.4	137.9±45.35^{a}	10.0	14.0	8.0
	Field installed cabins	3.9	9.7	5.6±1.25^{c}	10.0	30.5	8.7
	Unit manufactured cabins	0.5	1.8	1.1±0.32^{c}	19.2	34.7	10.5
Furrowing	No cabins	52.7	10.4	83.6±12.77^{b}	9.7	24.0	7.7
	Field installed cabins	4.9	8.7	6.6±0.99^{c}	16.7	30.5	9.0
	Unit manufactured cabins	0.5	2.9	1.6±0.59^{c}	26.2	26.0	10.0
Straw making	No cabins	65.7	98.6	80.2±9.69^{b}	7.7	32.0	5.2
	Field installed cabins	3.2	9.5	6.3±2.20^{c}	9.5	36.2	5.0
	Unit manufactured cabins	2.7	4.1	3.2±0.47^{c}	11.2	33.5	5.0
Baling	No cabins	38.6	128.9	88.7±23.53^{b}	6.5	34.7	11.2
	Field installed cabins	2.6	5.1	3.7±0.72^{c}	20.0	29.0	7.0
	Unit manufactured cabins	0.4	2.4	1.3±0.58^{c}	23.2	36.0	5.7

*a, b and c refer to significantly different means according to Duncan multiple mean comparisons ($p<0.05$)

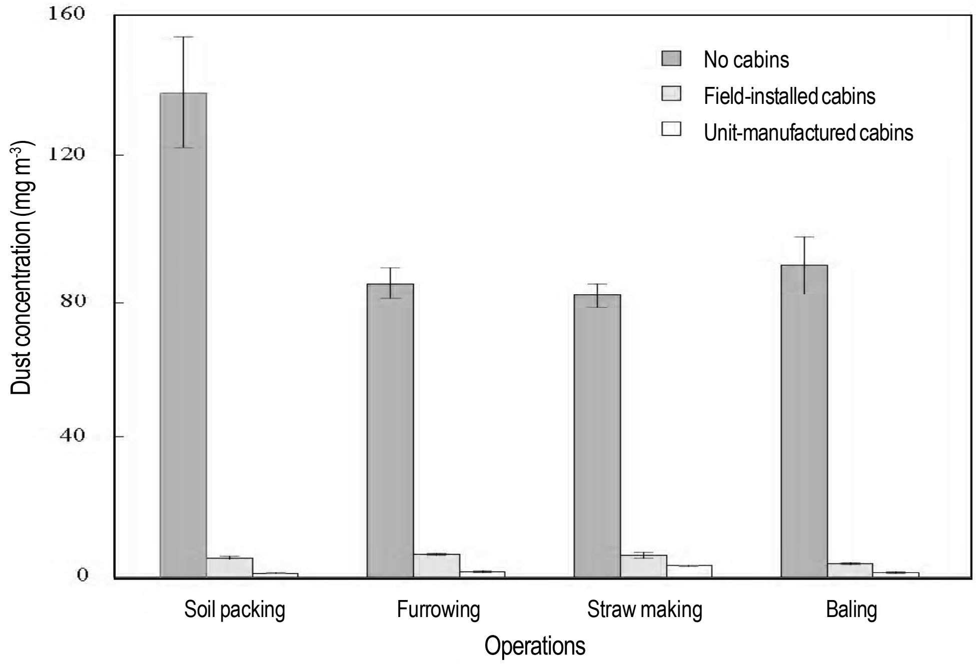

Fig. 2: Mean dust concentrations in tractor operations

Gustafsson and Noren (1979), found a dust concentration range of 2.1-577 mg m^{-3} in soil tilling operations with no cabins. The wide range Gustafsson and Noren found could have resulted due to a wide variety of tilling equipment tested and changing wind direction during data collection might have contributed to the range of dust concentrations measured in their study.

Mean dust concentrations in furrowing were measured to be 83.57, 6.60, and 1.60 mg m^{-3}, respectively for no cabins, field-installed cabins, and unit-manufactured cabins.

In straw making, mean dust concentrations were 80.28 6.38 and 3.23 mg m^{-3} respectively for no cabins, field-installed cabins and unit-manufactured cabins. Atiemo *et al.* (1980) found a range from 0.41 to 0.49 mg m^{-3} in unit-manufactured cabins during straw making.

Personal dust exposures in different cabins in baling followed the same trend as in the other tractor operations. In this study, the mean dust concentration was 1.35 mg m^{-3} while, Atiemo *et al.* (1980) found dust concentrations ranging from 0.07 to 0.08 mg m^{-3} in unit-manufactured cabins. Although, Atiemo *et al.* (1980) measured a lower range as compared to this study. The two studies agree that both types of cabins reduce dust levels below threshold level.

According to variance analyses, the effect of tractor operations (soil packing, furrowing, straw making, baling) and cabin types (no cabins, field-installed cabins, unit-manufactured cabins) on dust concentrations was found to be significant ($p<0.01$).

Duncan test ($p<0.05$) showed that, mean dust concentration in soil packing was statistically higher than the mean dust concentrations in all other operations (Table 5, Fig. 2) while mean dust concentrations for furrowing, straw making, and baling were statistically the same. Although field-installed cabins led to a higher dust concentration level in each operation compared to unit-manufactured cabins (Fig. 2) no significant difference was found between these two types of cabins (Table 6).

Dust concentrations in harvest operations for each respiration environment and Duncan multiple comparisons are given in Table 7 while dust levels are shown in Fig. 3. In harvest operations, dust concentration ranged from 62.40 to 148.50 mg m^{-3} with no cabins, from 3.70 to 6.40 mg m^{-3} in field-installed cabins, and from 0.85 to 2.90 mg m^{-3} in unit-manufactured cabins (Table 6). Gustafsson and Noren (1979) reported a dust concentration of 300 mg m^{-3} in studies conducted in Germany and Netherlands and 22 - 72 mg m^{-3} in Sweden. The results shown in Table 7 and Fig. 3 are lower than the results of studies conducted in Germany and Netherlands, but higher than the results of studies conducted in Sweden.

Atiemo *et al.* (1980) determined dust concentrations in harvest operations to be 0.03-2.63 mg m^{-3} in field-installed cabins and 0.03-0.05 mg m^{-3} in unit-manufactured cabins. The dust concentrations measured in this study are higher than those reported by Atiemo *et al.* (1980).

According to variance analysis, respiration environment had a significant effect on measured dust concentrations in harvest operations ($p<0.01$).

Duncan test ($p<0.05$) showed that the mean dust concentration in combines with no cabins was different from the two cabin types that were tested (Table 6). There was no statistical difference between field-installed and unit-manufactured cabins. Furthermore, both field-installed and unit-manufactured cabins had

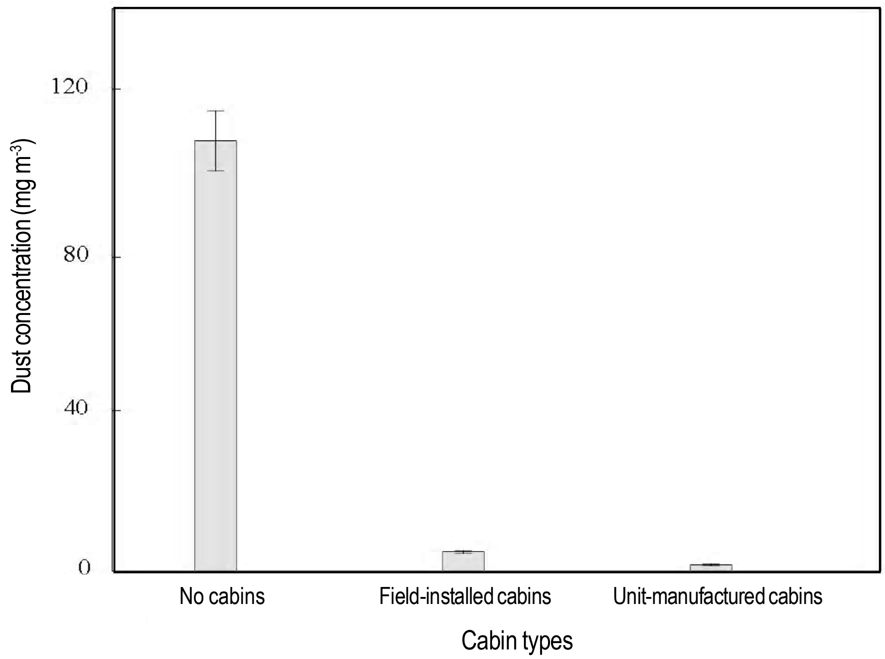

Fig. 3: Mean dust concentrations in harvest operations

lower dust concentrations compared to the threshold whereas combines with no cabins had a mean dust concentration much higher than the threshold (Fig. 3).

As a result, each tractor operation (soil packing, furrowing, straw making, and baling) had a significant effect on measured dust concentrations ($p<0.01$). The respiration environment (no cabin, field-installed cabin, and unit-manufactured cabin) also affected mean dust concentrations in that tractor operations without cabins had significantly higher dust levels compared to either cabin types. Furthermore, variance analyses showed that cabin type in harvesting had significant effect on measured dust levels, too ($p<0.01$).

In Eastern Mediterranean Turkey, operators tend to open the windows of field-installed cabins since this type of cabins do not have air conditioners, resulting in higher dust concentrations compared to unit-manufactured cabins. Other reasons for high dust concentrations in field-installed cabins could be the design and insulation insufficiencies, improper installation, lack of filters in cabins, mismatch of filters with cabin types, and insufficient maintenance.

In a study carried by Atiemo *et al.* (1980), dust concentrations varied from 34 to 195 mg m^{-3} in all field operations. Measured quantities in this study, however, ranged from 80.28 to 137.95 mg m^{-3}. This could have resulted from equipment, wind speed, temperature, relative humidity, soil types and soil relative humidity, and ground speed differences.

In this study, it was concluded that field operations without cabins elevate personal dust exposure levels above threshold and are hazardous for human health. Thus, original cabins are not a must to avoid excessive dust levels since field-installed cabins could also function effectively to reduce dusts in the respiration environment. However, field-installed cabins should be equipped with air conditioners due to hot weather conditions prevailing in the region.

Relations between dust concentrations and relative humidity - wind speed - ground speed: The effect of relative humidity, wind speed, and ground speed on dust concentration for field-installed and unit-manufactured cabins was not investigated as the mean dust concentrations were below 10 mg m^{-3} for these two cabin types. The relationships between dust concentration and relative humidity, dust concentration and wind speed, and dust concentration and ground speed in operations without cabins are shown in Table 7. Very strong correlation was found between wind speed and dust concentration in soil packing ($r=0.74$, $p<0.01$, $n=32$) and medium level correlation was determined between wind speed

Table - 6: Dust concentration levels and Duncan tests results for harvest operations

Operation	Environment	Dust concentration (mg m^{-3})			Mean wind speed (m s^{-1})	Mean relative humidity (%)	Mean ground speed (km h^{-1})
		Min.	Max.	Average ± SD			
Harvesting	No cabins	62.4	148.5	106.9±21.65^{a}	17.5	27.2	4.0
	Field-installed cabins	3.7	6.4	4.7±0.80^{b}	12.5	39.0	4.5
	Unit-manufactured cabins	0.8	2.9	1.4±0.52^{b}	25.0	24.5	4.5

Table - 7: Correlations between dust concentrations and relative humidity-air speed-ground speed

Field operation	Factors	n	r	p
Soil packing	Dust concentration - relative humidity	32	-	-
	Dust concentration – wind speed	32	0.74	0.01
	Dust concentration – ground speed	32	-	-
Furrowing	Dust concentration - relative humidity	32	0.06	-
	Dust concentration – wind speed	32	0.15	-
	Dust concentration – ground speed	32	0.15	-
Straw making	Dust concentration - relative humidity	32	0.08	-
	Dust concentration – wind speed	32	0.39	-
	Dust concentration – ground speed	32	0.29	-
Baling	Dust concentration - relative humidity	32	0.20	-
	Dust concentration – wind speed	32	0.46	0.01
	Dust concentration – ground speed	32	0.31	-
Harvesting	Dust concentration - relative humidity	32	0.22	-
	Dust concentration – wind speed	32	0.34	-
	Dust concentration – ground speed	32	0.44	0.05

n = number of observations, r = pearson correlation coefficient, p = significance level

and dust concentration in baling ($r=0.46$, $p<0.01$, $n=32$). On combining, a medium level correlation was found between ground speed and dust concentration ($r=0.44$, $p<0.05$, $n=32$). The remaining interactions shown in Table 7 did not have significant effect on measured dust concentrations.

It was concluded that the wind direction should be taken into consideration during tractor operations. The vast majority of farmers does not own combine harvesters in the country due to high combine prices. Combines are rented as well as the operators and the payment is made per unit area harvested. As a result, the operators usually opt to speed in order to cover more area to increase their profits. This results not only in increased harvest loss but higher levels of dust concentration in the respiration environment. Therefore, combine operators should be more careful about ground speed during harvest.

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