TRACTOR NOISE EXPOSURE LEVELS FOR BEAN-BAR RIDERS

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ABSTRACT. *Tractor noise exposure levels were measured for bystanders as described by the Nebraska Tractor Test Laboratory and for bean-bar riders on ground surfaces of concrete, grass, and bean field. The influence of ground configurations, engine speeds, and gear selections on noise exposure levels were determined. The average sound level decreased as the ground cover changed from concrete to grass and then to bean field. An increase of 3 dBA was measured for engine speed changes from 1200 to 1500 rev/min and 1500 to 2000 rev/min. Gear selection was determined not to be significant for bystander exposures but bean-bar exposures increased as gear selection changed from first to fourth. Noise exposure levels experienced at the bean-bar position were, on average, 10 dBA higher than those measured at the bystander position. Results of the noise exposure measurements indicate that a hearing conservation program according to the Occupational Safety and Health Administration Compliance Manual (Petersen, 1979) should be established for bean-bar riders.* ***Keywords.*** *Bean-bar, Bystander, Hearing conservation, Noise exposure.*

The OSHA Compliance Manual (Petersen, 1979) restricts a person working in an environment with a noise level of 90 dBA to an 8-h work day or, with a noise level of 95 dBA to a 4-h work day. Each 5-dBA increase in sound pressure level halves the exposure time allowed in the working environment without use of Environmental Protection Agency (EPA) approved hearing protection. The OSHA noise exposure guidelines are shown in table 1. The sound pressure level is the ratio expressed in decibels of the mean square sound pressure to a reference mean square pressure; this ratio is by convention selected to be equal to the assumed threshold of hearing.

Loss of hearing occurs as a result of the cumulative effect of exposure to sound above a maximum intensity and over a maximum allowable time. The sound energy absorbed during maximum permissible exposure is considered the upper limit of a daily dose that will not produce a disabling loss of hearing in more than 20% of the exposed population. In OSHA's effort to reduce disabling hearing losses, a hearing conservation program was developed in 1984 that covers all employees exposed to an 8-h time-weighted average sound level of 85 dBA, except those employed in agriculture, construction, oil and gas well drilling, and servicing operations (Best, 1990).

The Walsh-Healey Public Contract Act in association with the Occupational Safety and Health Act developed the set of permissible noise exposure levels and time for various sound levels in dBA units shown in table 1. Most sound level meters used in tractor noise measurements are equipped with A, B, and C scale filters, and some have octave band filters. Comparing sound measurements obtained using different weighting curves has proven impractical. Noise measurements performed today are made using the A-weighting scale expressed in dBA (Bruel and Kjaer, 1991). The A-weighting scale allows the sound level meter to respond in relatively the same manner as the human ear, which is much less responsive to low (below 1,000 Hz) and high (above 10,000 Hz) pitched sound

Table 1. OSHA noise exposure guidelines*

Sound Level (decibel A)	Permissible Exposure (hours per day)
80	32
85	16
90	8
95	4
100	2
105	1
110	0.5
115	0.25
120	0.125
125	0.063

* When the daily noise exposure is composed of two or more periods of noise exposure of different levels, the effect of the combined periods should be considered, rather than the individual effect of each. If the sum of the following fractions: $C_1/T_1 + C_2/T_2 + \ldots C_a/T_a$ exceeds unity, then, the mixed exposure should be considered to exceed the limit value. C_a indicates the total time of exposure at a specified noise level, T_a indicates the total time of exposure permitted at that exposure at a specified noise level, and T_a indicates the total time of exposure permitted at that level. Exposure to impulsive or impact noise should not exceed 140 dBA peak sound pressure level (Best, 1990).

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frequencies than to those at intermediate (between 1000 and 10,000 Hz) frequencies (Crocker, 1972).

Tractor Noise Level

Agricultural equipment manufacturers have directed efforts toward reducing sound levels at the operator stations of tractors in recent years. Many manufacturers have designed operator stations for tractors that have noise levels below the safe level of 85 dBA at which hearing loss will not occur after 16 h of exposure. Many operator stations of farm tractors are still characterized by noise levels sufficient to constitute a chronic health hazard (Suggs, 1987).

Splinter et al. (1972) at the Nebraska Tractor Test Laboratory found that of 67 tractors tested for sound levels at 50, 75, and 100% maximum power and at 50% pull and part throttle, only four tractors had noise levels below 85.5 dBA. Research conducted within the last five years indicates that over 500 tractor models still exceed 85 dBA (Leviticus and Morgan, 1973 to 1990). Broste et al. (1989) at the Marshfield Clinic tested 31 tractors for noise at ear elevation in the driver's seat without a cab or with cab windows open, and only one tractor produced less than 85 dBA at full throttle. Results of this research indicate the need for continued application of noise reduction techniques to agricultural tractors.

Noise Levels for Other Farm Activities

While noise level reduction at the operator station continues in tractors, many farm activities today require the use of additional farm workers in cooperation with the tractor operator. Some of these activities include baling hay, detassling corn, and applying chemicals. Whitener (1984) at the Economic Research Service of the United States Department of Agriculture examined the nation's hired farm workforce and found that 28% or 618,800 of the workers range from 16 to 19 years of age as shown in table 2. Reports of research documenting noise exposure levels of workers under these field conditions were unavailable.

Broste et al. (1989), in a study of 12 Wisconsin high schools, determined that hearing loss typically found in older farmers was also detected in students engaged in farming. Students ranging in age from 12 to 19 years of age who participated were divided into four distinct farming exposure groups as described in table 3. The results indicated that students who show evidence of hearing loss in at least one ear at either high (4,000 to 6,000 Hz) or low (500 to 1,000 Hz) frequencies, table 3. Individuals who actively participated in farm work were, on average, 30% more likely to have evidence of hearing loss. The left ear was observed to have a greater hearing loss attributed to looking over the right shoulder.

Values from the Nebraska Test Data from 1973 through 1990 show a trend of reduction in noise levels at the operator station, whereas bystander levels continue to exceed OSHA's 85-dBA safe noise level as illustrated in table 4 (Leviticus and Morgan 1973-90). Noise levels experienced at the operator station before 1977 were typically higher than noise levels experienced at bystander stations at the Nebraska Tractor Test Laboratory. From 1986 to 1990, there was a definite decrease in noise level at the operator station resulting mainly from improved sound protection in cabs. Noise level at the bystander position, however, has remained relatively constant, as illustrated in figure 1, and the ratio of the number of tractors with higher noise levels at the operator station decreased.

Table 2. Percentage of farm workers employed in 1981 by age groups (Whitener, 1984)

Workers Age(years)	Number of Workers	Percentage of Total Workers
16-19	618,800	28
20-24	442,000	20
25-34	508,300	23
35-44	243,100	11
45-54	276,300	8
55 and over	221,100	10
Total	2,210,000	100

Table 3. Farming exposure groups of 12 Wisconsin high schools (Broste et al., 1989)

Group	Description	% With Hearing Loss
A	Individuals who lived on farms and participated in virtually all farming activities.	71
B	Individuals who did not live on farms, but worked on a farm for hire to help either relatives or friends..	74
C	Individuals who lived on farms, but did not participate or had minimal participation in chores and other farming operations.	36
D	Individuals who did not live on farms and had little or no direct involvement with farm work.	46

Table 4. Number of tractors testing above or below 85 dBA for tractor operator and bystander positions (Leviticus and Morgan, 1973 to 1990)

	Tractor Operator Noise Level			Bystander Noise Level		
	@ 100% Load					
	Number of Tractors			Number of Tractors		
Year	Above 85 dBA	Below 85 dBA	Ratio*	Above 85 dBA	Below 85 dBA	Ratio*
1973	63	6	10.5	55	16	3.4
1974	72	16	4.5	69	19	3.6
1975	74	19	3.9	74	19	3.9
1976	87	23	3.8	88	23	3.8
1977	90	34	2.6	95	19	5.0
1986	121	134	0.90	148	45	3.3
1987	119	139	0.86	143	36	4.0
1988	129	144	0.90	152	41	3.7
1989	101	129	0.78	163	42	3.9
1990	99	117	0.85	130	27	4.8

* The ratio of the number of tractors above 85 dBA divided by the number of tractors below 85 dBA.

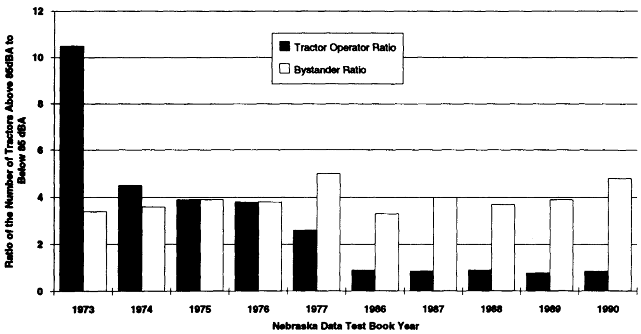

Figure 1–Comparison of the ratio of the number of tractor noise levels above 85 dBA divided by the number of tractor noise levels below 85 dBA between the bystander and tractor operator position.

Bean-bar Riders

Because engineering advances have produced a reduction of noise levels at the tractor operator's work station, additional emphasis should be placed on the bystander position. Today many farming operations require use of farm workers who either ride on or are pulled by tractors as they perform a task. One such operation that requires additional workers is application of chemicals to weeds in soybean fields. One of the most common methods of application is the use of bean-bar riders (who can be regarded as bystanders) to treat weeds with herbicides while riding on a bean-bar. Wintersteen and Fawcett (1989) discuss safety of bean-bar riders, as related to pesticide exposure, but no mention is made of noise exposure hazards.

A bean-bar is an attachment with seats for riders who apply a chemical to weeds. The bean-bar is typically mounted on the front of the tractor and has work stations spaced equally along the bar. Data in table 4 indicate that in 1990, of the 157 tractor test results published in the Nebraska Test Data Book (Leviticus and Morgan 1990), 130 tractors produced noise levels in excess of 85 dBA for the bystander test. Bystander tests performed by the Nebraska Tractor Test Laboratory are recorded by running the tractor past a stationary sound level meter placed 7.5 m (25 ft) from the center line path of the tractor. Bean-bar riders in most conditions are typically less than 3 m (10 ft) from the center of the tractor and therefore could receive exposure rates greater than those recorded at the bystander position by the Nebraska tractor test.

Objective

The objective of this research was to measure the sound level exposure rates for farm workers in bean-bar operations and to develop a model to predict noise level exposure in these conditions based on Nebraska Tractor Test Laboratory Data for a specific tractor.

Equipment and Procedure

Experiments were conducted at the Agronomy-Agricultural Engineering Research Center west of Ames, Iowa. Sound levels were measured over concrete, grass, and bean plant surfaces to determine exposure levels experienced by bean-bar riders. Sound levels were also recorded at bystander, operator station, and bean-bar positions to compare the results of noise levels experienced at different positions on and around the tractor.

Instrumentation

Instrumentation for the tests consisted of two Metrosonics model db-308 simultaneously operated noise dosimeters. Both meters used the A-weighting scale and a slow averaging response rate. Increments of 5 dBA was used to provide sound level readings equivalent to OSHA's permissible noise levels, as shown in table 1. Threshold levels of 80 and 90 dBA were used with a ceiling level of 115 dBA. The dose was set at increments of 8 h with a criterion of 80 dBA for projected dose level to eliminate any risk of hearing damage. The alert threshold of 85 dBA and hazard threshold of 90 dBA are associated with some degree of hearing damage and deafness risk. Each dosimeter was calibrated at the beginning and end of each test with an acoustical calibrator. A 12-mm (1/2-in.) diameter ceramic type pendent microphone was used to record the noise levels. A foam microphone shield was used on all test runs, with the exception of those at the tractor operator station.

Tractor noise exposure levels were measured using a 1990 John Deere tractor Model 2955 with a 6-L, six cylinder diesel, with cab and without front-wheel assist. The tractor was equipped with a two-person front-mounted bean-bar located 107 cm (42 in.) above the ground surface. The two seats were located 107 cm (42 in.) from the center line of the tractor. The bean-bar tank that serves as the liquid chemical reservoir and pump that pressurizes the chemical were located between the two seats. The bean-bar pump was not operated during the noise exposure tests. In addition, the bean-bar had umbrellas located 244 cm (96 in.) above the ground surface (fig. 2).

Bystander Test

The bystander noise exposure tests were performed according to the guidelines established by the Nebraska Tractor Test Laboratory (Splinter et al., 1972). Test courses were constructed on concrete, grass, and bean plant surfaces (fig. 3). The microphone was mounted 7.5 m (25 ft) from the center line path of the tractor and 1.2 m (4 ft) above the ground surface. It was orientated perpendicular to the center line path of the tractor. Tests were performed at engine speeds of 2,000, 1500, and 1200 rev/min, and first, second, third, and fourth gears were used on the concrete and grass surfaces. The Nebraska Test simulation with an engine speed of

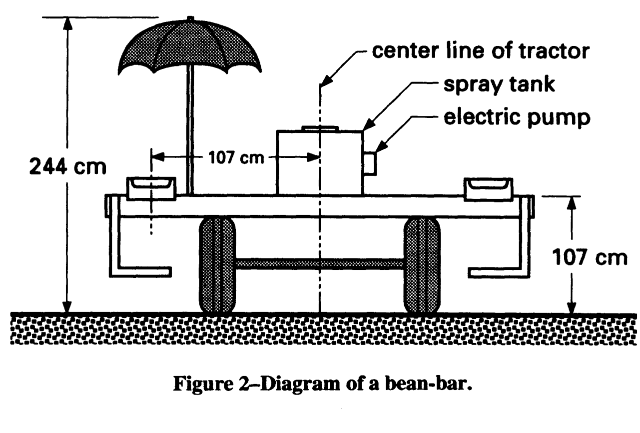

Figure 2–Diagram of a bean-bar.

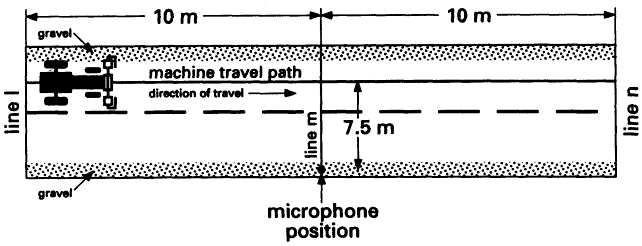

Figure 3–Diagram of a test course used in measuring bystander noise levels.

1200 rev/min and in third gear was performed in the bean field because normal bean-bar spraying conditions typically occur at this speed.

Operator Station Tests

Noise levels recorded at the operator's ear were performed according to the guidelines established in Splinter et al. (1972). The unshielded microphone was mounted on the right shoulder of the operator and pointed in the direction of travel. All cab windows and doors were closed, and vents and air-conditioner were off.

Bean-bar Tests

Noise exposure tests were performed on bean-bar riders for all three ground cover configurations. The concrete ground configuration test was performed using the same course as used for the bystander test. The grass and bean field tests were run for half-hour intervals to obtain an estimated 8-h noise dose value, and the microphone was mounted on the shoulder closest to the center line of the tractor. The microphone was mounted parallel to the center line of the tractor, and pointed in the direction of travel. A separate test was conducted by mounting the microphone on the outermost shoulder to determine effects of microphone location while on the grass surface. The tractor was operated at 1200 rev/min in third gear. The bean plants were 61 to 76 cm (2 to 2.5 ft) high. The grass was approximately 15 cm (6 in.) high with corn plants surrounding the grass field.

The concrete bystander test was performed using two replications at the following engine speeds: 2000, 1500, and 1200 rev/min for first, second, third, and fourth gears. The bystander test in the bean field was performed in third gear at 1200 rev/min with four replications. The bystander test for the grass was performed using the same engine speeds and gear selections as the bystander test for both the concrete and the bean-field surfaces. The bean-bar test on concrete was performed once with engine speeds 2000, 1500, and 1200 rev/min for gears first through fourth, and a second run was performed using only third and fourth gears. Bean-bar tests in the bean field were performed at half-hour intervals with two replications using 1200 rev/min and in third gear. Bean-bar tests on grass were performed in the same manner as in the bean field.

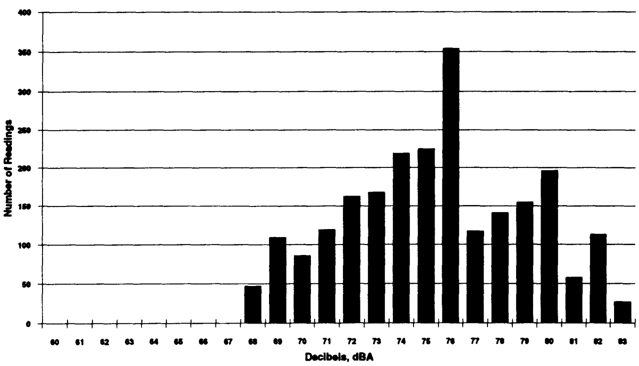

Figure 4–Frequency distribution of decibel readings for the concrete bystander test. (Combined data of 2000, 1500, and 1200 rev/min in first, second, third, and fourth gears).

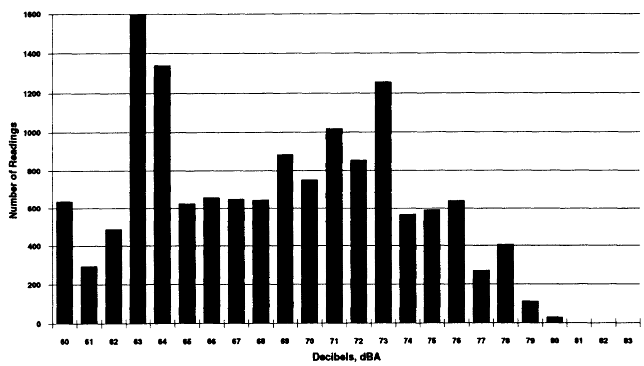

Figure 5–Frequency distribution of decibel readings for the grass bystander test. (Combined data of 2000, 1500, and 1200 rev/min in first, second, third, and fourth gears).

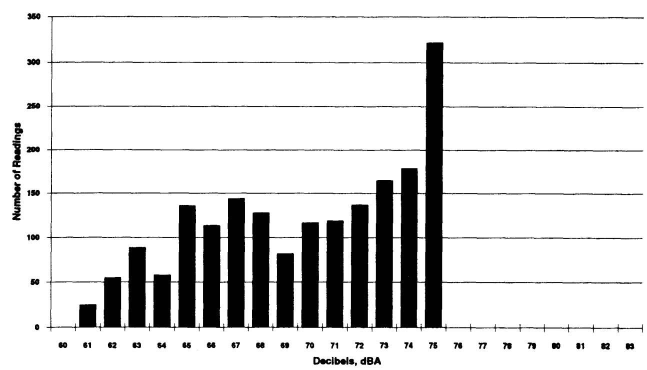

Figure 6–Frequency distribution of decibel readings for the bean field bystander test performed at 1200 rev/min in third gear.

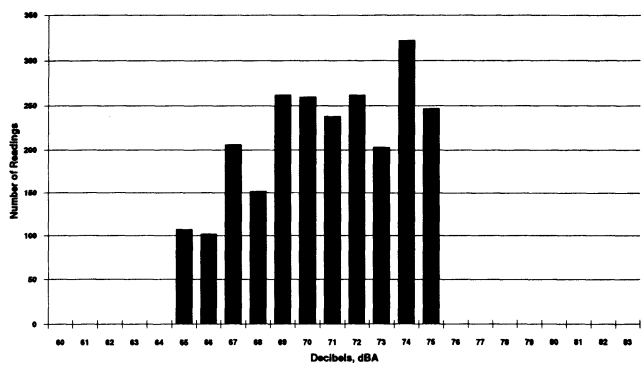

Figure 7–Frequency distribution of decibel readings for the grass bystander test performed at 1200 rev/min in third gear.

Results and Discussion

Effects of Surface

Figures 4 and 5 show the difference in the decibels distribution between the concrete and grass surfaces for the bystander test. The distribution for the concrete surface is a small range of dBA than the grass surface. Figures 6 and 7 indicate that noise levels are typically lower in the bean field than on the grass surface. Figure 6 shows that noise levels in the bean field occur over a wider decibel range, indicating that, as the tractor moves away from the microphone, there is a lower noise level being recorded because of the damping effect of the bean plants. Figure 7 shows that the grass bystander test has noise levels within a relatively small range of dBA. This indicates that the noise levels are relatively constant during the test run. Comparing figures 4, 6, and 7 shows that as surface configurations changed, there was a change in the noise levels recorded. The data indicates that there was a progressive decrease in noise levels as one goes from concrete to grass and bean plant surfaces. The average sound levels for the different surfaces were 77 dBA for concrete, 75.6 dBA for grass, and 75.6 dBA for bean field. The reduction in noise level is a possible result of the damping effect of the surface. Further research is required to determine the effect of different surfaces on the noise levels experienced.

Effects of Engine Speed and Gear

An increase in engine speed from 1200 to 1500 rev/min or from 1500 to 2000 rev/min results in an average 3 dBA increase in noise level for bystander tests performed on concrete (fig. 8). The effect of gear (third or fourth) on noise levels produced at the bystander position was insignificant at the 5% level using the analysis of variance test.

Figures 9 and 10 are plots of sound levels correlating with the number of readings recorded while the tractor was running on concrete and grass surfaces, respectively, at 2000, 1500, and 1200 rev/min. Histograms indicate the average noise levels recorded for the left and right sides with engine speeds of 1200, 1500, and 2000 rev/min, in first, second, third, and fourth gears. The graphs depict a higher noise level being produced for individuals on the left side of the bean-bar as seen from the operator station. Figure 11 shows the maximum noise level recorded for a given gear selection and engine speed. The right and left side noise levels under bean field conditions, as seen from tractor operator seat, are similar with only an average dBA increase on the left side.

Gear selection and engine speed has an effect on bean-bar rider noise levels being recorded (fig. 11). The effect of gear selection on bean-bar noise level for a constant engine speed was significant at the 5% level using an analysis of variance. Moreover, the influence of engine speed on bean-bar rider noise level was significant at the 5% level. Figure 11 shows that with an increase in engine speed from 1200 to 1500 rev/min and from 1500 to 2000 rev/min there was an increase of approximately 3 dBA in the noise level. The difference in the noise level magnitudes between the bystander and the bean-bar tests in the bean field is attributed to the location of the dosimeter. The dosimeter was located 4.5 m farther away from the noise source in the

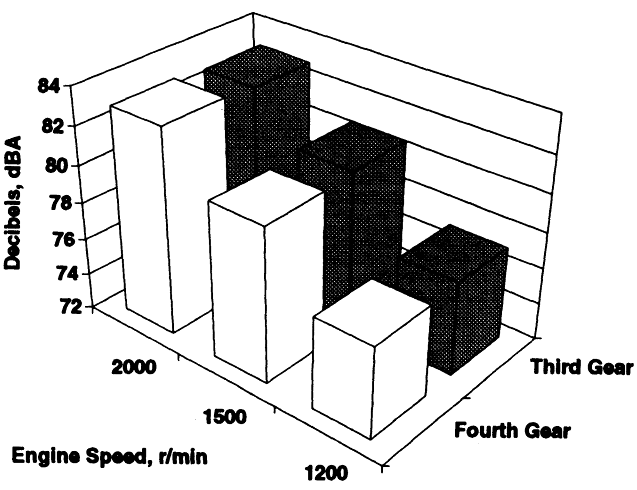

Figure 8–Comparison of the maximum decibel readings as a function of engine speed and gear selection for concrete bystander test.

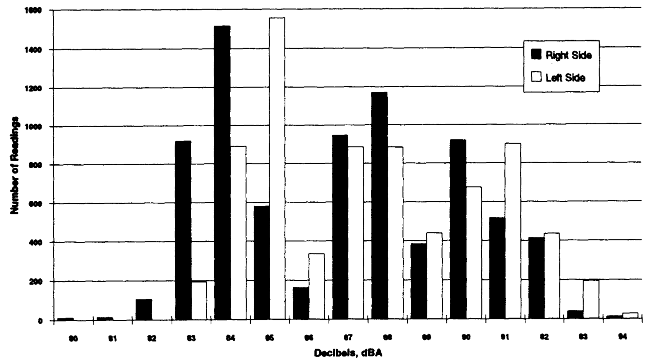

Figure 9–Frequency distribution of decibel readings for the concrete bean-bar test for right and left as seen from the tractor operator's position.

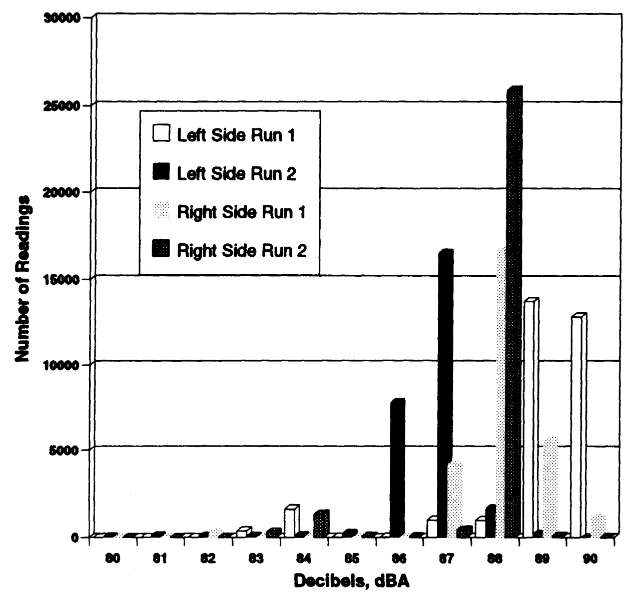

Figure 10–Frequency distribution of decibel readings for the grass bean-bar test for right and left as seen from the tractor operator's position.

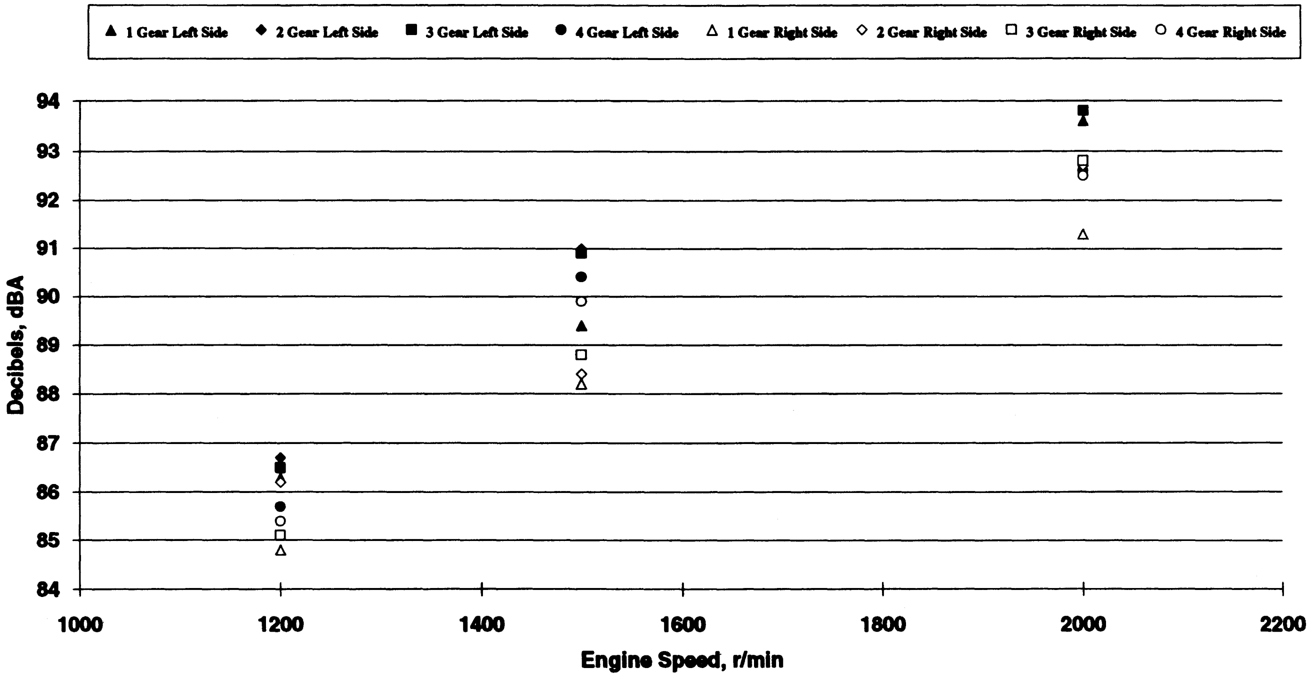

Figure 11–Comparison of maximum decibel readings during the grass bean-bar test for right and left as seen from the tractor operator's position.

bystander test. This added distance could filter out the difference measured at the bean-bar workstation. Unlike the bystander test, gear selection as well as engine speed has a significant effect on noise levels at the bean-bar workstations.

The bystander test values differ from values shown in the Nebraska Test Data Book for a John Deere 2955 (Leviticus and Morgan, 1973 to 1990), values indicating a peak value of 90 dBA for the bystander test. Whereas the simulation bystander tests performed in the bean field, grass, and concrete surfaces resulted in peak values of 75.9, 80.6, and 83.0 dBA, respectively. The differences are due to the load under which tractors were placed when bystander noise levels were recorded in the Nebraska test. Noise levels were recorded in the simulated bystander test for a tractor carrying only a bean-bar and no additional loading.

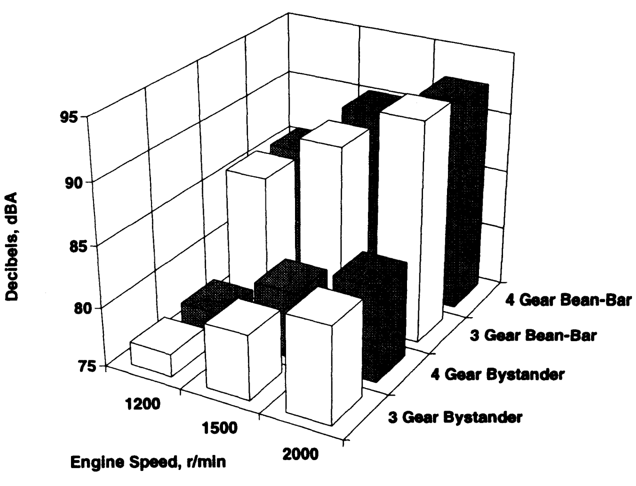

Figure 12–Comparison of the maximum decibel readings for the bean-bar and bystander tests for different gear and engine speed selections.

Bean-bar Riders Exposure Levels

The noise level for individuals riding on a bean-bar was approximately 10 dBA greater than measured for the bystander test regardless of engine speed or gear selection (fig. 12). A 3 dBA increase in sound level was observed for increase in engine speed from 1200 to 1500 rev/min and from 1500 to 2000 rev/min. An increase in noise level was measured as gear selections changed from first to fourth.

Table 5. Equivalent A-weighted sound level for corresponding noise dose values (Thumann, 1990)

Sound Level (dBA)	Noise Dose (%)
85	50
86	57
87	66
88	76
89	87
90	100
91	115
92	131
93	152
94	174
95	200
96	230
97	264
98	283
99	355
100	400

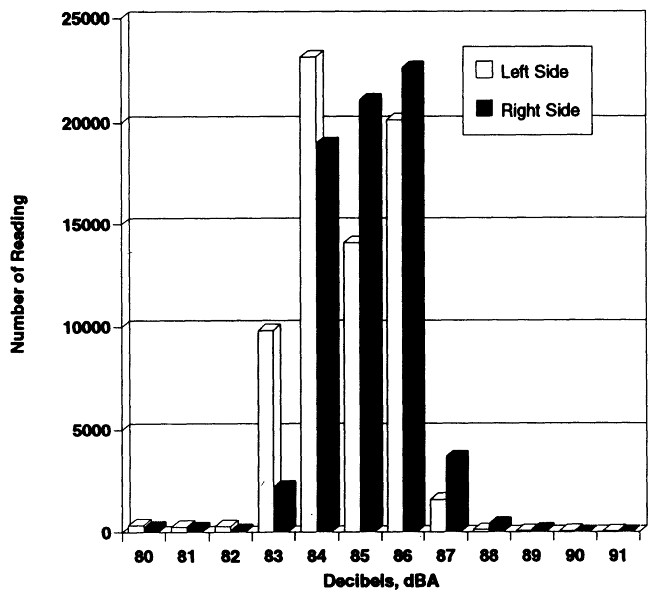

Figure 13–Frequency distribution of the decibel readings between the left and right sides of the bean-bar for concrete bean-bar test performed at 2000, 1500, 1200 rev/min.

A series of 30-min tests on the bean-bar was performed in an open grass field with the umbrella up and by operating the tractor in third gear at 1200 rev/min. The noise data from the 30-min tests was used to determine an expected 8-h noise dose. A projected 8-h noise dose with a cutoff of 80 dBA resulted in a noise dose of 191% for left side bean-bar riders and 164% for right side bean-bar riders. The noise dose is the fraction expressed in percentage of actual exposure time to a sound level divided by the allowable exposure time to the sound level as specified by OSHA. The equivalent A-weighted sound level determined from the noise dose values using table 5 are approximately 95 and 92 dBA for left side and 94 and 93 dBA for right side. The results of the projected 8-h noise dose with the umbrella lowered for the left side resulted in a 157% (93 dBA) and for the right side 135% (92 dBA). Results indicate that a 5-h permissible work day as defined by OSHA (table 1) is approximately the maximum exposure time for these conditions without likely hearing damage.

Figure 13 compares noise exposure for individuals riding on the bean-bar for both left and right sides as seen from the operator seat with umbrella in the down position and microphone mounted on shoulder closest to center line path of tractor. The right side exposure was approximately 1 dBA higher than the left side. The location of the microphone on the shoulder located furthest from the center line path of tractor changes the measured exposure. The average noise exposure level is, on average, 6 dBA lower when the microphone is mounted on the outside shoulder.

The noise exposure experienced by bean-bar riders under actual field conditions with umbrellas in the up position for the projected 8-h dose with an 80 dBA cutoff for the left side was 101% (90 dBA) and 105% (90 dBA) for the right side. The noise dose results indicate that an 8-h workday is permissible by OSHA standards. The noise level tests in the bean field were performed with bean plants larger than normal during bean-bar chemical applications. As discussed earlier in the effect of surfaces, the effects of damping play a key role in the overall average noise levels recorded. Therefore, noise levels recorded may be less than actual noise levels during normal bean-bar operations.

Summary and Conclusions

Noise levels experienced by bean-bar riders are likely to be above OSHA's 85-dBA safe limit. To comply with OSHA regulations, some type of hearing conservation program should be developed to reduce the noise exposure experienced by the riders. Test results on the three ground covers show differences in noise levels experienced at both bystander and bean-bar positions. Further tests should be conducted to determine the relations among different heights of ground cover vegetation. Bystander and bean-bar tests indicate a 10-dBA increase in the noise level experienced on the bean-bar compared with that at a bystander position. More research is needed to develop a database of bean-bars, tractor models, and ages of tractors, so that a hearing conservation program can be developed for farm managers. Based on the results of this study, these conclusions can be drawn:

Ground cover has an influence on the noise exposure levels. The concrete surface produced the highest noise levels followed by grass and then bean plants.

Results of bystander and bean-bar tests showed, on average, a 10 dBA increase in noise levels at the bean-bar position at all engine speeds and ground cover configurations above those at the bystander position.

Engine speeds influence the noise levels at both the bystander and bean-bar positions. On average, there is a 3-dBA increase in sound level from 1200 to 1500 rev/min and another 3-dBA increase from 1500 to 2000 rev/min.

Gear selection in the bystander test does not increase sound levels for a given engine speed, but gear selection in the bean-bar test causes an increase in the noise level as the gears selected changes from first to fourth.

Noise levels experienced on the bean-bar were high enough to require a hearing conservation program according to the OSHA Compliance Manual.

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