

Full Length Research Paper

Comparison of noise level of tractors with cab and without in different gears on driver ear and bystander

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Tractor operator comfort is affected by how much noise tractor produces during continuous operation. Noise at work in agriculture or horticulture can cause hearing loss. A tractor without cabin and one with cabin (closed window and open window) loaded with mounted moldboard plow and disk harrow were tested for noise level in different gears at the driver's ear and bystander ear. The permissible exposure time for safe hearing effect was calculated. The sound level trend versus gears was also shown. Results showed that the Sound Pressure Level (SPL) at the driver ear for the tractor without cab in all gears ranging from a low of 91 dB(A) to a high of 93 dB(A) were more than National Institute for Occupational Safety and Health (NIOSH) allowable 85 dB(A) criteria for eight hour of operation. All domestically manufactured in Iran are without cabin. The SPL of the tractor with open windows cab with a range of 86 to 88 dB(A) was also higher than the standards, but lower than that for the tractor without cab. Loading with moldboard and disk did show significant effect at Hi 1 gear for no cabin and open window cabin. The SPL for closed cabin in all cases stayed below 82 dB(A). It was concluded that the driver should either stay on driving for less than 2 h with tractors without cabin and open window cabin or the only best way, the tractors should be equipped with factory made cabins. Using some kind of ear protection is another alternative. Even with the cabin type of tractors, drivers should avoid opening the window very often for say checking the operation of the machinery behind the tractor or in case the air conditioner malfunctions. Using some kind ear protection can be used for the safety but this may increase farm related injuries. Therefore it is recommended that homemade tractors are to be equipped with factory made cabins.

Key word: Sound pressure level (SPL), tractors, cabin, gears, driver's ear and bystander ear, loaded.

INTRODUCTION

Noise at work in agriculture or horticulture can cause hearing loss. There are many different sources of noise on farms, such as tractors, chainsaws, livestock, grain dryers and guns. Noise can also be a safety hazard at work, interfering with communication and making warnings harder to hear (Baker, 2002). According to a recent University of Iowa study of 904 farmers, those who wore hearing aids had twice as many farm-related injuries as those who had retained good hearing and didn't need one (Day, 2008). OSHA standards consider sound measured at 85 decibels or higher as damaging

to the eardrum and therefore a risk to hearing (Anonymous, 2004). It is stated (Anonymous, 2010) that 30% of Sweden's farmers suffer from hearing loss. Similar results to those from Sweden were found in a study conducted by University of Iowa in the United States, indicating that American farm workers are faced with the same noise problems in their daily work. Consider 90 decibels (dB) a limit for continuous operation without ear protection. An increase of 10 dB roughly doubles the noise level sensed by the ear (Downs and Hansen, 1998; Murphy et al., 2007). Abd-el-Tawwab et al. (2000) found that the driving parameters such as road speed, gear shift, engine speed and tractive efficiency affect the noise inside the tractor cabin. Emmanuel (2006) developed a software and hardware for data acquisition to evaluate the vibration and noise imposed

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on the operator and tire deflection of agricultural tractor working with varying tire inflation at constant engine speed. The booming noise (sound level spikes) was in the 100 to 110 Hz frequency range with sound levels increasing in extreme examples as much as 8 dB(A) while driving at speeds greater than 48 km/h on hard flat road surfaces (John, 2010). In a research to identify the source of noise in tractor (Schlegel, 2011), Valtra company found that there was a combination of structural resonances excited by a larger than expected transmission error instigated by gear misalignment. Many of the new tractor cabs, for example, can reduce an operator's noise exposure by at least 10 to 15 dB (Baker, 2011). At all the driving speeds, the noise level with SST tyres fitted was substantially quieter than with the conventional tyres. With the rear window closed, the average difference was 2.4 dB(A) and with a maximum of 3.6 dB(A) occurring at 46 km/h. The difference was slightly less with the rear window open 2.0 and 2.8 dB(A), respectively, the bigger margin occurring at 48/49 km/h (Hill, 2010). Sound measurement is made on the test track in two locations-at the driver's ear and in a location representing "bystander noise". Tests at the driver's ear are performed in several gears and under a number of conditions but; only the maximum level is reported. The "bystander sound" test is performed with the microphone located at 25 ft (7.5 m) from the centerline of the tractor which is accelerating from a lower speed to full speed in its top gear (Tractor Museum, 2002). PAMI (2011) compared the average specific fuel consumption at rated rpm (hph/gal.) for six of the most common 100 hp tractors sold in Canada in the years 1975 and 1995 with respective sound level in dB(A). The fuel consumption in 1995 reduced from 14.93 hph/gal in 1975 to 17.40 hph/gal while the noise level decreased from 88.36 to 78.4 dB(A) respectively. Sound levels are recorded using the "A" scale in the sound-level meter and are expressed in terms of decibels (A) or dB(A). The A scale is a filter that responds like a human ear. A 3 dB(A) increase in sound level doubles the sound-pressure level. Therefore, for every 5 dB(A) increase in sound level, the permissible exposure time is cut in half. In other words, at 95 dB(A), the allowable exposure time is only four hours. It is not uncommon to have tractor sound-level reaching 95 dB(A) (Grisso, 2007). The noise levels observed on tractors in different operations were in the range of 90 to 110 dB (A) (Kumar et al. 2005). Individual tasks which exceeded 85 dB(A) TWA-8 (NIOSH) identified by researchers were Tilling/plowing, Planting, and other farm activities (Milz, 2006). Equation (1) is given for safe exposure time to noise:

$$t = \frac{8}{\frac{\text{SPL}-85}{2^3}} \quad (1)$$

where t = hours of exposure per day (Anonymous, 1996).

An experiment in Croatia by Goglia et al. (2005) showed that by ISO 4872, 6393 and 362 standards, the noise level did not exceed the limit values. However, the noise level at the operator's position at full load and at nominal load exceeded the limits. Noise levels of 155 tractors on 36 farms were studied (Holt et al, 2006). The range of noise levels at the driver's ear level with radios off and windows closed (if so equipped) was from 78 to 103 dB. Seventy-five percent of tractors without cabs had noise levels in excess of 90 dB, compared to only 18% of tractors with cabs. When some cab windows are open and the radio is on, an average of 4.2 dB is added to the cab noise. In April, however, the occurrence of high total exposure values was due to intensive field activities (plowing, harrowing, sowing), and prolonged exposure to this factor (Solecki, 2006).

MATERIALS AND METHODS

Two types of tractor a 2-wheel drive MF399 with 82 kW power without cabin and a Valtra T170, 135 kW power with closed window and open window cabin were tested. No load and loaded with moldboard plough and disk harrow were tested for noise level at different gears. The gears were low 1, low 2, low 3 and Hi1. The measurements were taken at the driver ear and at a distance 7.5 m from centre axis of tractor at the bystander ear, according to OECD standards. A sound meter of type Lutron SL4013 equipped with capacitance microphone was used. The OECD testing standards were observed. The test course was a plot of 100 m long by 40 m wide in open field. Each experiment data was recorded with 9 replicates. Data was analyzed based on factorial experiment with MSTAT-C software.

RESULTS

Statistical analysis of the results is show in graphs of Figures 1 to 3 and Tables 1 to 3. Results showed that the Sound Pressure Level (SPL) at the driver ear for the tractor without cab loaded with plough or disk harrow in all gears ranging from a low of 89.30 dB(A) to a high of 93.45 dB(A) (numbers 1 and 4 in Figure 1 and rows 1 and 2 in Table 1) were more than NIOSH allowable 85 dB(A) criteria for eight hour of operation. Loading with plough or disk harrow did not have significant effect on sound level at the driver's ear in low gears although the SPL for both increases. At Hi1 gear, however the SPL decreases for both loading but there is significant difference between plough and harrow loading. The latter is higher (numbers 4 and 1 in Figure 1 and row 1 and 2 in column Hi1 in Table 2). No significant difference on the bystander ear for either loading and the SPL did not go over 83 dB(A) which is a safe measure according to NIOSH standard. For closed cabin tractor, neither gear position nor type of loads had any effect at the driver's ear and the SPL was hardly over 77 dB(A); a quite safe level for driver's ear. The same results were obtained at the bystander's ear although the SPL for disk loading reached a high of 81.80 dB(A) and 80.55 dB(A) for

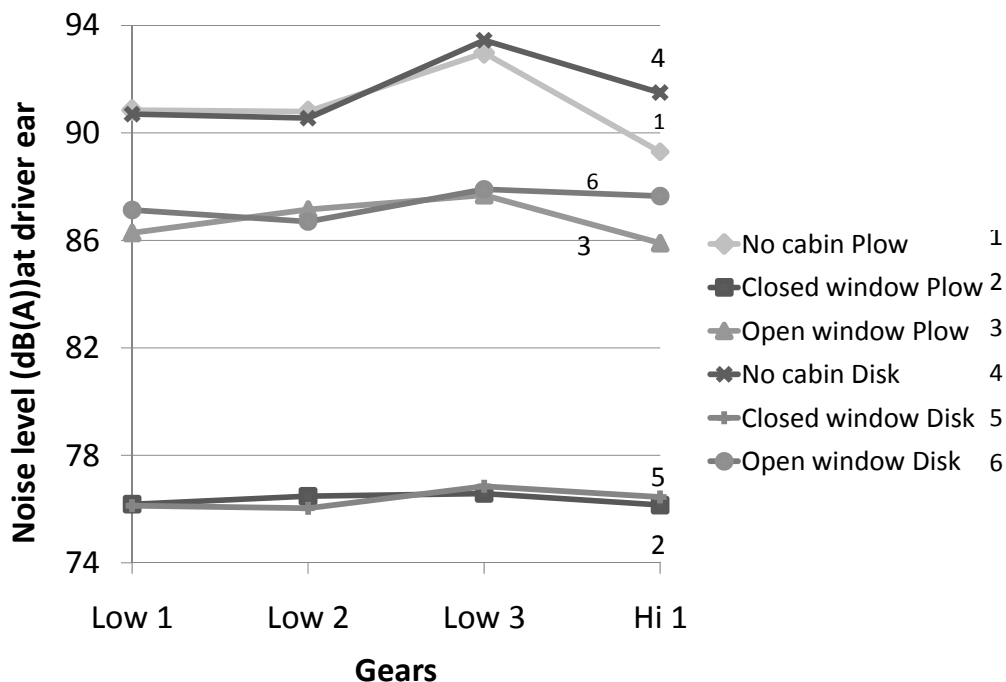


Figure 1. Noise level at driver's ear.

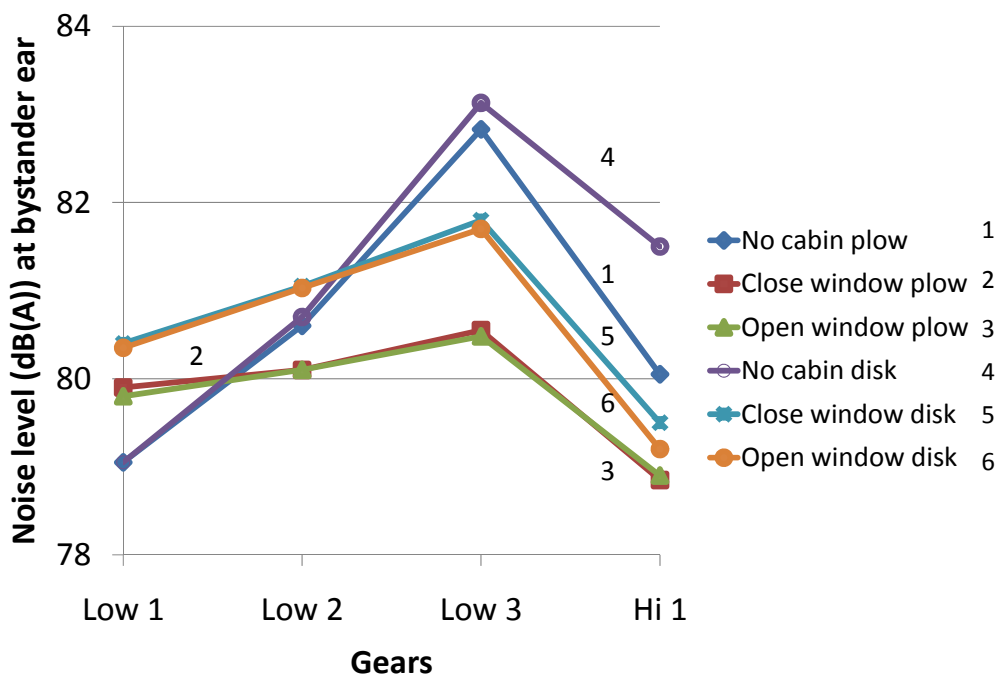


Figure 2. Noise level at bystander's ear.

plough (numbers 2 and 5 in Figure 2 and column under Low 3 in Table 2). The cabined tractor with open window showed a response somehow between the no cabin and closed window. Looking at numbers 3 and 6 in Figure 1

shows that the SPL increases up to Low 3 gear just like the no cabin tractor but at a lower level as much as 88 dB(A). The trend slopes down for Hi1 gear at faster rate for plough loading rather than for disk harrow. The type of

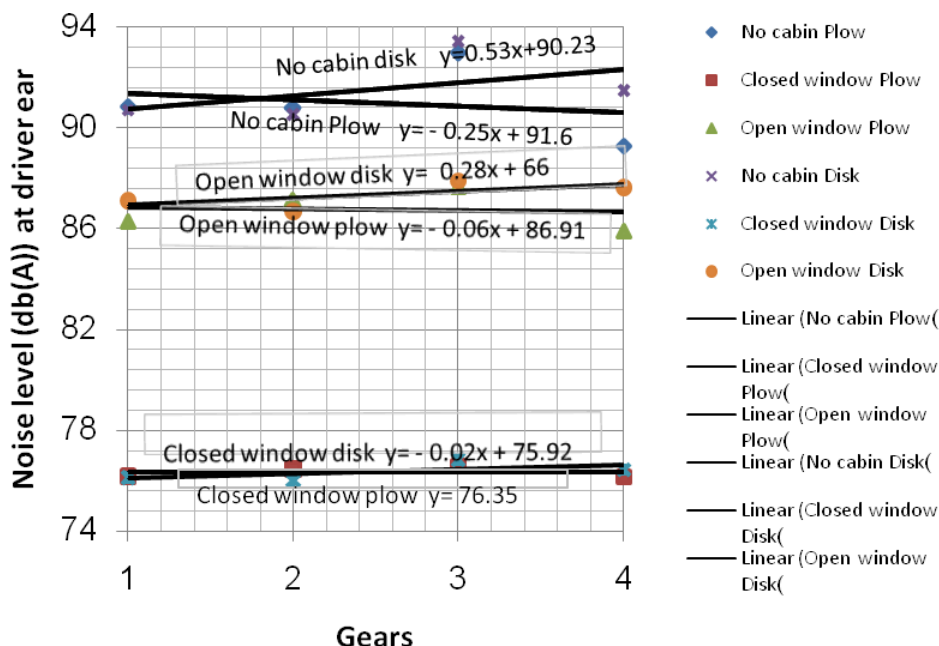


Figure 3. Noise level trend at driver's ear.

Table 1. Means noise level comparison between gears.

Case	Hi1	Low3	Low2	Low1
No cabin plow loaded driver ear	89.30 ^b	92.98 ^a	90.80 ^a	90.85 ^a
No cabin disk loaded driver ear	91.50 ^a	93.45 ^a	90.55 ^a	90.70 ^a
No cabin plow loaded bystander ear	80.05 ^b	82.83 ^a	80.60 ^b	79.05 ^b
No cabin disk loaded bystander ear	81.50 ^b	83.13 ^a	80.70 ^b	80.70 ^b
Closed window cabin plow loaded driver ear	76.15 ^a	76.58 ^a	76.48 ^a	76.10 ^a
Closed window cabin disk loaded driver ear	76.45 ^a	76.85 ^a	76.03 ^a	76.13 ^a
Closed window cabin plow loaded bystander ear	78.85 ^a	80.55 ^a	80.10 ^a	79.90 ^a
Closed window cabin disk loaded bystander ear	79.50 ^a	81.80 ^a	81.05 ^a	80.40 ^a
Open window cabin plow loaded driver ear	85.90 ^b	87.68 ^a	87.15 ^a	86.28 ^a
Open window cabin disk loaded driver ear	87.65 ^a	87.90 ^a	86.70 ^a	87.13 ^a
Open window cabin plow loaded bystander ear	78.90 ^a	80.48 ^a	80.10 ^a	79.80 ^a
Open window cabin disk loaded bystander ear	79.20 ^b	81.70 ^a	81.03 ^a	80.35 ^a

*Figures with different letters in rows are significantly different at 1% level.

loading did not show significant difference on the noise up to Low 3 gear but it did so at high gear as shown in Table 2. The loading did not show significant difference at bystander's ear although the SPL for them both, rises up to 80.48 dB(A) for plough and 81.70 for disk harrow but; then down to 78.90 and 79.20 dB(A) respectively as shown in the last two rows of Table 2. Table 3 reveals that there are significant difference in SPL between the no cabin and open window cabin for either plough or disk harrow loading and at driver's ear. At bystander ear, no significant difference was observed except for Low 3 gear with plough loading and for Hi1 gear for harrow disk.

Permissible exposure time in h/day for the type of loading and different gears for no cabin and open window cabin was calculated from Equation 1 and showed in Table 4. None will allow 8 h/day exposure to the SPL at the driver's ear.

DISCUSSION

The sound level does increase when in low gears but drops when shifting to high gear. This trend is beneficial because for saving energy, it is better to drive in lowest

Table 2. Means noise level comparison between loading.

Case	Hi1	Low3	Low2	Low1
No cabin plow loaded driver ear	89.30 ^b	92.98 ^a	90.80 ^a	90.85 ^a
No cabin disk loaded driver ear	91.50 ^a	93.45 ^a	90.55 ^a	90.70 ^a
No cabin plow loaded bystander ear	80.05 ^a	82.83 ^a	80.60 ^a	79.05 ^a
No cabin disk loaded bystander ear	81.50 ^a	83.13 ^a	80.70 ^a	75.05 ^a
Closed window cabin plow loaded driver ear	76.15 ^a	76.58 ^a	76.48 ^a	76.10 ^a
Closed window cabin disk loaded driver ear	76.45 ^a	76.85 ^a	76.03 ^a	76.13 ^a
Closed window cabin plow loaded bystander ear	78.85 ^a	80.55 ^a	80.10 ^a	79.90 ^a
Closed window cabin disk loaded bystander ear	79.50 ^a	81.80 ^a	81.05 ^a	80.40 ^a
Open window cabin plow loaded driver ear	85.90 ^b	87.68 ^a	87.15 ^a	86.28 ^a
Open window cabin disk loaded driver ear	87.65 ^a	87.90 ^a	86.70 ^a	87.13 ^a
Open window cabin plow loaded bystander ear	78.90 ^a	80.48 ^a	80.10 ^a	79.80 ^a
Open window cabin disk loaded bystander ear	79.20 ^a	81.70 ^a	81.03 ^a	80.35 ^a

*Figures with different letters in columns are significantly different at 1% level.

Table 3. Means noise level comparison between no cabin and open window cabin in every gear.

Driver ear plow loaded open window cabin	85.90 ^b	87.68 ^b	87.15 ^b	86.20 ^b
Driver ear disk loaded No cabin	91.50 ^a	93.45 ^a	90.55 ^a	90.70 ^a
Driver ear disk loaded open window cabin	87.65 ^b	87.90 ^b	86.70 ^b	87.13 ^b
Bystander ear plow loaded No cabin	80.05 ^a	82.83 ^a	80.60 ^a	79.05 ^a
Bystander ear plow loaded open window cabin	78.90 ^a	80.48 ^b	80.10 ^a	79.80 ^a
Bystander ear disk loaded No cabin	81.50 ^a	83.13 ^a	80.70 ^a	79.05 ^a
Bystander ear disk loaded open window cabin	79.20 ^b	81.70 ^a	81.03 ^a	80.35 ^a

Table 4. Permissible exposure time (h/day).

Load	No cabin				Open window cabin			
	Low1	Low2	Low3	Hi1	Low1	Low2	Low3	Hi1
Plow loaded	2.07	2.09	1.27	2.96	5.95	4.87	4.31	6.50
Disk loaded	2.14	2.22	1.14	1.78	4.89	5.40	4.09	4.34

high gear rather than in low gear. The SPL drop in high gear may be attributed to higher speed in this gear. Linear trend of SPL in Figure 3 shows an ever increasing for disk harrow and decreasing for plough which does not follow the data. A trend other than linear and rather a curvilinear should be developed. The result of this investigation with a highest SPL of about 77 dB(A) did not agree with the findings in reference Holt et al (2006), which stated that the SPL for closed window cabin reached up to 103 dB(A). Allowable exposure for 95 dB(A) is stated as four hours in reference 11 while by equation (1) it is calculated to be less an hour and that is how it is calculated in Table 4.

Conclusion

1. According to the findings of Day (2008), it is

recommended that tractors produced in Iran should better be equipped with factory made cabin;
 2. Limit exposure time to the noise (Baker, 2002). If this is not avoidable, some kind of wear earmuffs or rated ear plugs should be used (Jackson, 2011);
 3. Try to arrange work schedules to let farm workers exchange work activities so that no one person is exposed to the noise for more than permissible hours in one day.

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