Effect of Forward Speed, Load and Cabin on Tractor Noise and the Health of Drivers

M. Payandeh[1], M. Behroozi Lar[2], J. Bagheri[3], Z. Khodarahm Poor[4]

[1]M.Sc. Student in Agricultural Mechanization, Islamic Azad University, Shoushtar branch, Shoushtar, Iran. Payandeh.mehrzad@hotmail.com
[2]Department of Agricultural Mechanization, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran. Email: behroozil@yahoo.com
[3]Department of Agricultural Mechanization, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran. Email: moghaddas74@yahoo.com
[4]Department of Agronomy and Plant Breeding, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran. Email: Zahra_khodarahm@yahoo.com

Abstract: Noise has caused hearing problems to many drivers in the world. It has been investigated that 30 percent 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. A MF399 tractor without cabin and a Valtra 170 with open cabin were tested for noise level at the driver as well as the bystander ear for no load and loaded cases. Comparison were made between noise level in different forward speeds for each tractor with no cabin and open window cabin on driver's ear and bystander for no load and loaded cases. Also Comparison between no cabin and open cabin in each forward speed for no load and loaded tractor at driver's ear as well as at bystander. The noise level at 2.9 km/h for no load open cabin as well as for loaded no cabin and open cabin at driver's ear was significantly greatest among the related speed ranges. It looked like the 2.9 km/h speed with one exception was a threshold after which the SPL (Sound Pressure Level) dropped. For no load no cabin case at the driver ear with a mean value of 87.72 dB(A) no significant difference was observed at 1% level for speeds up to 3.7 km/h; but the SPL for 6.1 km/h was significantly higher. The permissible exposure time was calculated as 4 h/day and 1.9 h/day respectively. For no load open cabin case no significant difference in SPL between SPL at speeds 1.9, 2.2 and 6.1 km/h with a mean value 83.1 dB(A). However significant difference was observed between 2.9 km/h and 3.7 km/h speed. For loaded no cabin, no significant difference was observed between SPL of 1.9, 2.9 and 3.7 km/h with mean value 93.5 dB(A) and 1.1 h/day permissible exposure time. For loaded open cabin. No significant difference between SPL for 3.7 and 6.1 km/h with mean 89.2 dB(A) and permissible exposure time of 5.4 h/day. Also no significant difference between the SPL for 1.9 and 2.2 km/h with mean 83.7 dB(A). Bar graph for all exposure times are shown. The same comparisons were made at bystander's ear and between no cabin and open cabin in each forward speed.
[Mehrzad Payandeh, Mansoor Behroozi Lar, Jahangir Bagheri and Zahra Khodarahm Pour. Effect of Forward Speed, Load and Cabin on Tractor Noise and the Health of Drivers. Journal of American Science 2011;7(8):604-609]. (ISSN: 1545-1003). http://www.americanscience.org.

Keyword: sound level, noise measurements, tractors, cabin, driver's ear

1. Introduction

Noise or unwanted sound is one of the major sources of discomfort to the workers which affects human both psychologically and physically. It has caused hearing problems to many drivers in the world. Noise is measured in two ways for OECD tests (Anonymous, 2010): at the operator's ear and from a bystander position, and is measured in decibels [dB(A)]. But to the human ear, a noise that sounds twice (or half) as loud is actually measured at 10 dB(A). Sound measurement is made on the test track in two locations-at the driver's ear and in a location representing "bystander noise. The 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 7.5 m from the centerline of the tractor which is accelerating from a lower speed to full speed in its top gear. The OECD procedure differs. The SAE/ASABE procedure measures sound in only one gear under different load conditions, whereas the OECD procedure measures sound in different gears between High Idle and Rated Engine speed (Larsen, 2002). 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 et al., 2007)

Tractor driver farmer had more often high frequency hearing loss when compared to non tractor driver farmer. The noise levels observed on tractors in different operations were in the range of 90–110 dB (A) (Kumar et al., 2005). Sound levels that cause hearing loss begin at about 85 dB(A). Hearing loss occurs more quickly with louder noise. OSHA Standards consider sound measured at 85 decibels or higher as damaging to the eardrum and therefore a risk to hearing (Anonymous, 2004). It has been investigated (Anonymous 2010) that 30 percent 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. An investigation by Dewangan et al (2005) for determination of SPL on 18.7 and 26.1 kW tractors and 4.6 and 6.7 kW hand tractors during field operations with various implements, revealed that both tractors produced the noise of 92 dB(A) in the working zone of operator. The SPL of the hand tractor was about 2 dB(A) higher than that of the tractor. The SPL during field operations at operator ear level increased with increase in engine speed and forward speed.

Celen and Arm (2003)found that the maximum SLP of 97.1 dB(A) was in exhaust pipe and the minimum of 79.7 dB(A) at the bystander ear. An increase of 3 dB(A) was measured for engine speed changes from 1000 to 2000 rpm. Durgut and Celen (2004) measured an 96.6 dB(A) at the drivers ear but a minimum of 67.7 dB(A) for the surrounding. They also found a 6 dB(A) difference when engine speed changed from 1000 to 2000 rpm. According to Aybek et al (2010), statistical analyses showed that type of operation, type of cabins, and operation x cabin interactions were statistically significant at ($P < 0.01$). The use of original cabins had a greater effect in decreasing average sound pressures and resulted in more efficient noise insulation, especially at higher center frequencies compared to field installed cabins. Sound pressure levels at 4000 Hz center frequency was reduced 2–13 dB and 4–18 dB by using a field-installed cabin and an original cabin, respectively. It was concluded that depending on the cabin types used, the operators could usually work from 4 to 6 h a day without suffering from noise induced inconveniences while 2–3 h is permissible for plowing and forage harvesting on tractors without cabins. In reference Anonymous (2009) it is stated that No Member State may refuse to grant EC (European Council) type-approval or national type-approval of any type of tractor on grounds relating to the driver-perceived noise level if that level is within the following limits: 90 dB(A) in accordance with Annex I, or 86 dB(A) in accordance with Annex II. Individual tasks which exceeded 85 dB(A) TWA-8 (NIOSH) identified by researchers were Tilling/plowing, Planting, other farm activities (Milz, 2006)

Equation (1) is given for safe exposure time to noise,

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

(Anonymous, 1996) where t= hours of exposure per day. An experiment in Croatia by Goglia and 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 with radios off and windows closed (if so equipped) was from 78 to 103 dB(A). Seventy-five percent of tractors without cabs had noise levels in excess of 90 dB, compared to only 18% of tractors with cabs. The use of a radio adds an average of 3.1 dB of noise. A specially selected group of 45 farm tractor drivers were examined in order to estimate the degree of occupational hearing loss (Holt et al., 2006). The drivers, aged 21-50 years, were employed on multi production farms. The study showed that the operators under study had statistically worse hearing within the range of high frequencies (3-6 kHz), especially those aged over 30 years. A study was carried out when a fabricated cab was added to an agricultural tractor (Abd-el-Tawwab et al., 2000). The fabricated cab was selected after a comprehensive series of experimental tests carried out on a variety of cab constructions. The results were discussed from the view point of obtaining the influence of the tractor driving parameters (road speed, gear-shift, engine speed and tractive effort) on the noise measured inside the tractor cab and over the frequency range up to 2000 Hz. 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 (Aybek et al., 2010). In the seasons of the year analyzed, high equivalent exposure values were observed within the range: 5.53-6.61 Pa^2 h (some polish standards). Mean value for this parameter for the whole year reached the value of 4.27 Pa^2 h (standard exceeded 4.3 times). This value is equivalent to a mean exposure level equal to 91.3 dB.

2. Material and Methods

Two types of tractor a 2-wheel drive MF399 with 62 kW PTO power without cabin and a Valtra T170, 184 kW power with cabin were tested. No load and loaded with mouldboard plough were tested for

noise level at different forward speed. The measurements were taken at the driver ear and at a distance 7.5m from centre axis of tractor according to OECD standards(Anonymous 2010). A sound meter of type Lutron SL4013 equipped with capacitance microphone was used. The test course was a plot of 100 m long by 40m wide in open field. Each experiment data was recorded with 9 replicates. Data was analyzed based on factorial experiment with MSTAT-C software.

3. Results

The results are shown in Graphs 1-6 and tables 1-2. Comparison results were as follows:

1. Comparison between noise level in different forward speeds for each tractor with no cabin and open window cabin on driver's ear and bystander for no load and loaded cases

1.1. At driver's ear.

1.1.1. The noise level at 2.9 km/h for no load open cabin (graph 2), loaded no cabin (graph 3) and open cabin (graph 4) was significantly greatest among the related speed ranges as shown in Graph 1 and in third row in table 1. It looks like the 2.9 km/h speed is a threshold after which the SPL (Sound Pressure Level) drops although exception is seen in graph 3. Also although the trend is true for graph 1 but the SPL rises for 6.1 km/h speed. The permissible exposure time were 1.9, 2.5, 0.9 and 1.9 h/day for graphs 1, 2, 3 and 4 respectively as is shown in Graph 5 and in last row in table 1.

1.1.2. No load no cabin case. With a mean value of 87.72 dB(A) no significant difference was observed at 1% level for speeds up to 3.7 km/h; but the SPL for 6.1 km/h was significantly higher. The permissible exposure time was 4 h/day and 1.9 h/day respectively.

1.1.3. No load open cabin case. No significant difference in SPL at speeds 1.9, 2.2 and 6.1 km/h with a mean value 83.1 dB(A). However, significant difference was observed between 2.9 km/h and 3.7 km/h speed. The calculated exposure time for the latter speed was 6 h/day.

1.1.4. Loaded no cabin. No significant difference between SPL of 1.9, 2.9 and 3.7 km/h with mean value 93.5 dB(A) and 1.1 h/day allowed exposure time. Also no significant difference between 2.2 and 6.1 km/h but; a permissible exposure time about 6.3 h/day.

1.1.5. Loaded open cabin. No significant difference between SPL for 3.7 and 6.1 km/h with mean 89.2 dB(A) and permissible exposure time of 5.4 h/day. Also no significant difference between the SPL for 1.9 and 2.2 km/h with mean 83.7 dB(A). Bar graph for all exposure times are shown in Graph 5.

1.2. At bystander's ear.

Results for this case are shown in Graph 2 and columns 4,5,7 and 8 of table1. The graphs 1-4 in Graph 2 shows ups and downs but all SPL are lower than the safe level, 85 dB(A) which is set by NIOSH standards. Therefore, there is no limitation on the bystander's exposure time. For open cabin case, no load and loaded (graphs 2 and 4), the sound level increases up to speed 2.9 km/h but decreases after ward which is the same pattern for the same case at the driver's ear. For no cabin, no load (graph 1), the SPL is almost increasing but up to 3.7 km/h speed which does not resemble with the one at the driver's ear. However, the graph 3 follows the same pattern although with a wide gap with respect to the no load case. Graph 4 shows the bar graph for these cases. Allowable exposure time is shown in Graph 6.

2. Comparison between no cabin and open cabin in each forward speed for no load and loaded at driver's ear as well as at bystander. With reference to table 2:

2.1. At 1.9 km/h forward speed.

2.1.1. There was significant difference between the no cabin and open cabin noise level at the driver's ear (Table 2). Considering the doubling noise for a difference of 3 dB(A) [12], the sound level increases more than double at the driver's ear for no cabin loaded tractor compared to open cabin tractor (fourth column in table2). SPL for all cases was lower for open cabin compared to no cabin.

2.1.2. Significant difference was observed for loaded tractors at the bystander ear but; not so for the no load case.

2.2. At 2.2 km/h forward speed.

Significant difference observed between the SPL for no cabin and open cabin at the driver's ear for no load and loaded tractors. Data for open window were lower than that for no cabin. The SPL at the bystander's ear were not significant in either cases.

2.3. At 2.9 km/h forward speed.

SPL differences were significant for only the no load case at the bystander ear.

2.4. At 3.7 km/h forward speed.

Significant difference for the no load case at the bystander ear and for loaded tractors at the driver ear.

2.5. At 6.1 km/h forward speed.

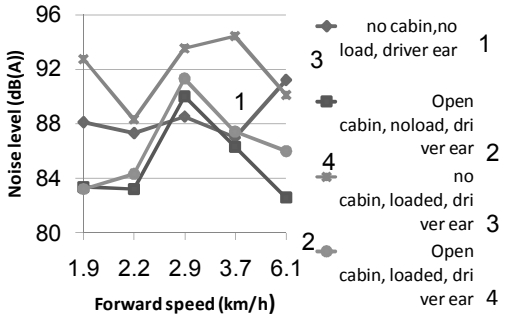
No significant difference for only the loaded case at the bystander ear.

4. Discussion

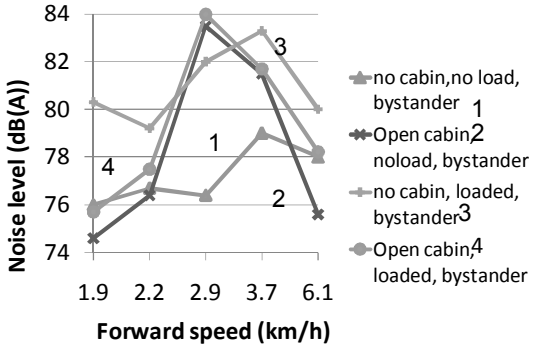
For no cabin and open cabin both, data showed an increasing SPL with increase in forward speed up to 2.9 km/h as it was observed by Dewangan et al (2005) but; it decreased afterwards. One exception was for the no cabin loaded tractor at the driver's ear that the SPL continued rising up to 3.7

km/h and then dropped. The tractors were up shifted from Low 3 to Hi 1 to increase the speed from 3.7 km/h to 6.1 km/h. This shifting could have caused the drop after 3.7 km/h because of decreased torque and relieving the engine. No reason can be thought of for justifying the SPL drop after the 2.7 km/h. More research on this matter is recommended. Another exception was observed for no cabin, no load case at the driver's ear in which the sound level increased after the 3.7 km/h to 6.1 km/h. This may be attributed to inaccuracy in data because it contradicts the results for the other three cases. For the usual ploughing speed of 4.5 km/h to 5, in Iran, the driver, as calculated from equation (1) for 92 dB(A), should not be driving for more than 1.5 hours a day unless putting on some kind of ear protections. The result somehow agrees with Aybek and et al (2010) who allow ploughing for 2-3 hours a day. The maximum data point did not get over 96 dB(A) while Durgut and Celen (2004) reported it as 96.6. However, the noise level was in fact over 85 dB(A) for field operation as said by Solecki (2010). Holt et al (2006) obtained a value of 78 to 103 dB at the driver ear for tractors with closed cabin and with radio off while in this research, with even open cabin, the SPL did not reach 91 dB(A). Celen and Arm (2003) reported a minimum of 79.7 dB(A) noise level at bystander ear which compares well only for the no cabin, loaded case. The minimum here was less than 76 dB(A) for other cases with or without cabin. This might be due to the better make of engines with new technology.

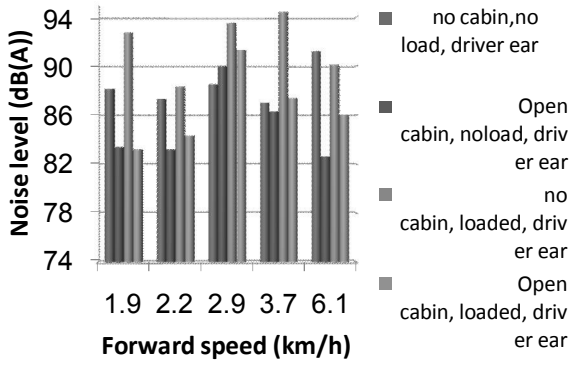
Finally, both the load and speed affects the sound level. While higher speeds over 4 km/h decreases the SPL, higher load on the engine increases it. For usual field operation, no harm at the bystander's ear but the driver at low speeds should either limit the exposure hours or wear some kind of ear protection while driving on no cabin tractor or even with cabin tractor if he is to frequently open the windows. Engines with new technology help in reducing noise.



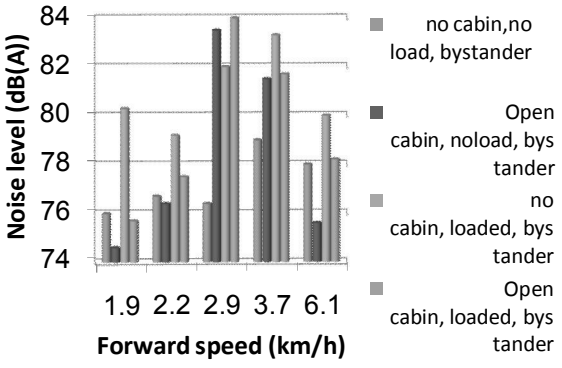
Graph 1: Mean noise level for different forward speeds, at driver ear.



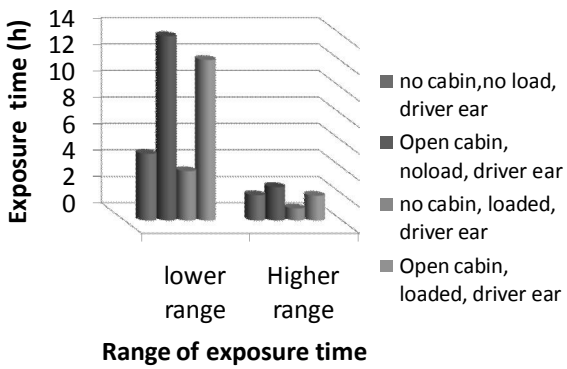
Graph 2: Mean noise level for different forward speeds, at bystander ear.



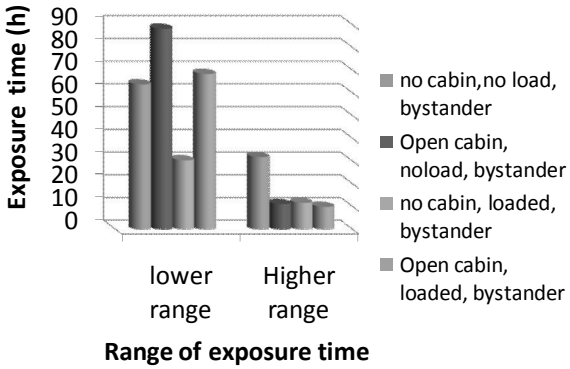
Graph 3: comparison between no cabin and open cabin noise level at driver's ear.



Graph 4: comparison between no cabin and open cabin noise level at bystander's ear.



Graph 5. Allowable exposure time for driver's ear.



Graph 6. Allowable exposure time for bystander's ear.

Table 1. Comparison of noise level in different forward speeds for each tractor with no cabin and open window cabin on driver's ear and bystander for no load and loaded cases.*

Forward speed km/h	Driver ear No load		Bystander ear No load		Driver ear loaded		Bystander ear loaded	
	No cabin	Open cabin	No cabin	Open cabin	No cabin	Open cabin	No cabin	Open cabin
1.9	88.1^{b}	83.4^{c}	76.0^{a}	74.6^{b}	92.7^{a}	83.2^{c}	80.3^{b}	75.7^{c}
2.2	87.3^{b}	83.2^{c}	76.7^{a}	76.4^{b}	88.3^{b}	84.3^{c}	79.2^{b}	77.5^{c}
2.9	88.5^{b}	90.0^{a}	76.4^{a}	83.5^{a}	93.5^{a}	91.3^{a}	82.0^{a}	84.0^{a}
3.7	87.0^{b}	86.3^{b}	79.0^{a}	81.5^{a}	94.4^{a}	87.4^{b}	83.3^{a}	81.7^{b}
6.1	91.2^{a}	82.6^{c}	78.0^{a}	75.6^{b}	90.1^{b}	86.0^{b}	80.0^{b}	78.2^{c}
Min.	87.00	82.60	76.00	74.60	88.30	83.20	79.20	75.70
Max.	91.20	90.00	79.00	83.50	94.40	91.30	83.30	84.00
Mean	88.42	85.1	77.22	78.32	91.8	86.44	80.96	79.42
SD	1.67	3.09	1.25	3.93	2.53	3.15	1.66	3.36
Lower exposure(h)	5.04	13.93	64.00	88.44	3.73	12.13	30.55	68.59
Higher exposure(h)	1.91	2.52	32.00	11.31	0.91	1.87	11.85	10.08

* Means with different letters at different forward speeds in each column are significantly different at 1% probability level.

Table 2. Comparison between no cabin and open cabin in each forward speed for no load and loaded at driver's ear as well as at bystander.*

Forward speed km/h	Driver ear No load		Bystander ear No load		Driver ear loaded		Bystander ear loaded	
	No cabin	Open cabin	No cabin	Open cabin	No cabin	Open cabin	No cabin	Open cabin
1.9	88.1^{a}	83.4^{b}	76.0^{a}	74.6^{a}	92.7^{a}	83.2^{b}	80.3^{a}	75.7^{b}
2.2	87.3^{a}	83.2^{b}	76.7^{a}	76.4^{a}	88.3^{a}	84.3^{b}	79.2^{a}	77.5^{a}
2.9	88.5^{a}	90.0^{a}	76.4^{b}	83.5^{a}	93.5^{a}	91.3^{a}	82.0^{a}	84.0^{a}
3.7	87.0^{a}	86.3^{a}	79.0^{b}	81.5^{a}	94.4^{a}	87.4^{b}	83.3^{a}	81.7^{a}
6.1	91.2^{a}	82.6^{b}	78.0^{a}	75.6^{b}	90.1^{a}	86.0^{b}	80.0^{a}	78.2^{a}

* Means with different letters at different loading and driver ear as well as bystander in each forward speed are significantly different at 1% probability level.

Corresponding Author:
Mehrzad Payandeh. M.Sc. Student in Agricultural Mechanization, Islamic Azad University, Shoushtar branch, Shoushtar, Iran.
E-mail: payandeh.mehrzad@hotmail.com

References

1. Anonymous. 1996. Criteria for a recommended standard occupational noise exposure revised criteria. NIOSH.
2. Annonymous. 2004. Noise Hazards and Hearing Protection. HOSTA. The Pensylvania State University. USA.
3. Anonymous. 2009. Directive 2009/76/EC of the European parliament and of the council. Official Journal of the European Union. Australia.
4. Annonymous. 2010. Farmers risk hearing loss. www. hearinglossweb.Com
5. Anonymous 2010. Standardized Tractor Performance Testing, What It Is - and Isn't. Agriculture and rural development. Alberta, Canada.
6. Anonymous. 2010. OECD Standard code for the official measurement of Noise at the driving position(s) on agricultural and forestry tractors.
7. Abd-el-Tawwab A.M. Abouel-seoud S.A. El-sayed F.M. and H.T.and A. Abd-ell- Hakim 2000. Characteristics of Agriculture Tractor Interior Noise. Journal of low frequency noise, vibration and active control. 2000, Vol.19, No. 2, pp73-81.
8. Aybek A. Kamer H. A. and A. Selçuk. 2010. Personal noise exposures of operators of agricultural tractors. journal homepage: www.elsevier.com/locate/apergo. Applied Ergonomics 41 (2010) 274–281
9. Celen I.H. and S. Arm. 2003. Noise Levels of Agricultural Tractors. Pakistan Journal of Biological Sciences 6(19):1706-17011@2003 Asian Network for Scientific Information.
10. Dewangan K.N, Prasanna Kumar G.V. and V.K. Tewari. 2005. Noise characteristics of tractors and health effect on farmers. www.elsevier.com/locate/apacoust. Applied Acoustics 66 (2005) 1049–1062.
11. Durgut M.R. and I.H.Celen.2004. Noise Levels of Various Agricultural Machineries. Pakistan Journal of Biological Sciences 7(6):895-901@2004 Asian Network for Scientific Information.
12. Goglia V, Beljo R, and D. Gnjilac D.2005. Measurement of the airborne noise and the noise at the operator's position emitted by the ECOTRAC V-1033 F forest tractor. Faculty of Forestry, University of Zagreb, Croatia.
13. Grisso R., Vaughan D.H., Perumpral J. V., Roberson G. T., Pitman R. R. M. Hoy, 2007. Using Tractor Test Data for Selecting Farm Tractors. Virginia Cooperative Extension. USA.
14. Holt JJ, Broste SK, and D.A.Hansen. 2006. Noise exposure in the rural setting. Department of Otolaryngology, Marshfield Clinic, WI 54449.
15. Kumar A., Mathur N.N., Varghese M., Mohan D., Singh J.K. and P. Mahajan. 2005. Effect of tractor driving on hearing loss in farmers in India. Wiley online library. India.
16.Larsen F. Lester. 2002. Sound Measurement. Test 1800: John Deere 8420 Diesel 16-Speed. Tractor Museum, University of Nebraska-Lincoln. USA.
17. Milz A. S. 2006. Total noise exposure assessment of a farm family. Medical University of Ohio. USA.
18. Solecki L. 2006. Characteristics of annual exposure to noise among private farmers on family farms of mixed-production profile. Ann Agric Environ Med. 2006;13(1):113-8. Poland.
19. Solecki L. 2010.Occupational hearing loss among selected farm tractor operators employed on large multi production farms in Poland Ann Agric Environ Med. 2010 Dec;17(2):243-50. Poland.

6/1/2011