Dust Exposure for Workers During Hazelnut Harvesting

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Abstract

A research has been carried out to assess the dust exposure for workers during mechanized harvesting of hazelnuts. The survey has been performed in the years 2006 and 2007 in four farms in Piemonte (Italy) in the province of Cuneo in the typical area of the cultivar "Tonda Gentile of Langhe". The samplings of the dust have been performed for workers during mechanized harvesting of hazelnut (four towed self-propelled vacuum machines and a towed picker-up). The results have been compared with ACGIH (American Conference of Governmental Industry Hygienist) threshold limit value (TLV), usually adopted as reference value for risk evaluation.

The results of the samplings highlighted an average exposure, for the year 2006, of 27.71 mg/m^3 and for 2007 of 2.58 mg/m^3. During 2006, 85.7 % of the analyzed samples exceeded the referring value advised by the ACGIH (3 mg/m^3) for respirable dusts. Analyzing the data for every type of harvesting machine employed it appears that the biggest concentrations were found in 2006 for the towed picker-up, with maximum value of 77.80 mg/m^3, while lower values were registered for towed and self moving vacuum machines. Analysing the swathing with backpack blowers it appears that, even in unfavourable conditions as in 2006, the average values of exposure are inferior as to machines and equal to 4.14 mg/m^3 for 2006 and 1.25 mg/m^3 for 2007. Finally, even if the harvesting is limited to few days, to avoid the onset of diseases to the respiratory system, it is advisable for workers employed with harvesting machines and blowers to use the right individual protection devices.

Keywords: dust, hazelnut harvesting, work hygiene

Introduction

The laws in safety and work hygiene subjects impose the assessment of the risks which the operators are exposed and the realization of prevention and protection's measures to improve the working conditions. Besides, the whole process of prevention, from the identification of the dangers to the measures of improvement, must be based on the consultation and the share of all the working subjects in the work place.

The aim of this survey is to analyze one of the main risk factors derived by the mechanized activity of harvest of the hazelnuts as the workers' exposure to the inorganic respirable particles spread in the air (Biondi et al., 1992; Monarca et al., 2005).

This survey refers to dusts that are absorbed during the respiration and that are not expelled through cough or secretion of mucous, which are particles that are not intercepted by the first respiratory ways and which, therefore, reach the bronchial and pulmonary hollow.

The nature of airborne can be the most varied: silicon, zinc oxide, carbonaceous particles, combustion smokes, radioactive substances, asbestos, insecticides, organic substances as well as those that derive from the cereals, etc. The word "concentration" means the quantity of particles in suspension in one cubic meter of air: it is generally expressed in mg/m^3, in μg/m^3 or in ppm (parts per million: volume of the contained particles in 10^6 volume unit).

The granulometry points out the dimensions of the particles: a diameter *d* is defined, expressed as the arithmetic average of the three dimensions of the particle (length *l*, width *b* and thickness *s*).

In the study of the dangerousness for inhalation, great importance however has the subdivision between respirable dusts and non-respirable dusts, depending on their aerodynamic diameter. This represents the diameter of a sphere of unitary density (1 g/cm^3) that has the same terminal sedimentation speed of the particle in examination. The PM10 (particulate matter, with an aerodynamic diameter inferior to 10 μm) represents the dusts able to penetrate into the superior part of the respiratory apparatus; while the PM 2.5 represents the dusts able to penetrate into the inferior part of the respiratory apparatus (pulmonary alveolus).

These last ones are the most dangerous because they are able to deposit themselves in the pulmonary system provoking inflammations, fibrosis and cancer.

The dusts with pathological action in humans are classified in two categories: pneumoconiogen dusts and non-pneumoconiogen dusts (Monarca and Zoppello, 1993). The first ones are those that expound their action to the level of the respiratory apparatus provoking pneumoconiosis which consists of an accumulation of dusts in the lungs and consequent reaction of the pulmonary tissue.

The pneumoconiogen dusts can be divided in "inactive" and "fibrogenic" dusts. The first ones don't alter the structure of the respiratory apparatus; the second ones can provoke more serious alterations modifying the structure of the alveolus and provoking a fibrogenic reaction of the tissue (Biondi et al., 1993).

These pathologies are subject to further worsening, even after the exposure, up to the appearance of illnesses as silicosis (provoked by dusts of silicon dioxide), asbestosis (provoked by asbestos dusts) and byssinosis (provoked by cotton dusts).

The non-pneumoconiogen dusts however can result as harmful because they bring particular substances or active principals able to pass into the circulation of the organism through the emo-lymphatic system. Given the dangerousness of the aforesaid dusts, in the last years (and it is predictable also for the next ones) there has been an increase of studies, researches, normative with the purpose to avoid, to prevent or to reduce the harmful effects on the health and on the environment.

The ACGIH identifies specific limits for coal dust, dust of cereals, dust of glass fibers, wood dust and cotton dusts. Other dusts are gathered under the name "(insoluble) particles not otherwise classified" (P.N.O.C.) and for these the ACGIH nowadays speaks of "guidelines", rather than of TLV; in the past, TLVs fixed for the P.N.O.Cs have been used wrongly and applied to any non available particle in the lists.

The ACGIH, today, specifies that the recommended limits for the P.N.O.Cs are applied to particles that: haven't a specific applicable TLV; are insoluble or poorly soluble in water (or, preferably, in the pulmonary fluids if available data have been given); have low toxicity. For the aforesaid particles (in 2009) limits of aerial concentrations of 3 mg/m^3 in the case of the respirable particles are recommended.

Material and methods

The survey has been performed in the years 2006 and 2007 in four farms in Piemonte in the province of Cuneo in the typical area of the cultivar "Tonda Gentile of Langhe":

- Cravanzana: altitude 585 m above sea level (min 369; max 716) – latitude 44° 34'32"52N;
- Torre Bormida: altitude 391 m a.s.l. (min 269; max 680) – latitude 44° 33'49"32N;
- Bosia: altitude 484 m a.s.l. (min 340; max 700) – latitude 44° 36'12"24N;
- Feisoglio: altitude 706 m a.s.l. (min 475; max 823) – latitude 44° 32'40"92N.

During the two years two campaign of measurements were carried out: the first one during the main harvesting (last decade of August); the second one during the first decade of September. In every orchard samples of soil were collected. These samples were analyzed at the "Coldiretti" Lab in Cuneo, obtaining data of soil humidity.
The harvesters used during the campaign of measurements are reported in table 1.

Table 1. Harvesters used during tests

Farm	Machine	Harvesting technique	Displacement	Working capacity (kg/h)
Moscone	Rivmec Smart 1800	Picking	Tractor-mounted	n.d.
Busca	Facma Cimina 300T	Aspirating	Pulled	600
Bertone	Facma Cimina 300S	Aspirating	Self-propelled	1000
La Ferrera	Facma Cimina 300S	Aspirating	Self-propelled	1000
"	Facma Cimina 380S	Aspirating	Self-propelled	1400

The pulled harvester Cimina 300T was equipped with one lateral aspirating device. Samplings were carried out also during the use of same blowers.

The samplings of dust have been effected using personal samplers built by SKC (SKC Inc. 863 Valley View Road, Eighty Four, PA 15330 U.S.A.): particularly the model Airchek® 52 has been used to constant course during the sampling (figure 1) (pump set to a course of 1,9 l/minute through a bubble flowmeter) and a cyclone SKC (figure 2) for the selection of the respirable convention as defined by the EN 481 standard "Workplace atmospheres. Size fraction definitions for measurement of airborne particles".

The cyclone is realized in conductive plastics and it exploits a system of removable and reusable cassette sampling; inside the cassette the filter is supported on a homogeneous grilled surface, to exploit in a uniform way the filtering surface and at the same time to facilitate the manipulation of the filter before and after the sampling.

Filters (figure 3) have been employed in cellulose nitrate with a porosity of 0,8 μm and a diameter of 25 mm. The filters have been weighted, before and after the sampling, through an analytical balance Sartorius (Sartorius Mechatronics India Pvt. Ltd. #10, 3rd Phase, Peenya 6th Main, KIADB Industrial Area Bangalore - 560 058 INDIA) mod. BL 2105, with precision equal to 0,1 mg and a maximum of 120 g (figure 4).

Before weightings, for every filter a conditioning of 24 hours in a checked environment has been anticipated.

The samplers have been submitted to the workers during the normal harvesting job, positioning the orifice of entrance of the sampler parallel to the body and at the same height of the respiratory zone.

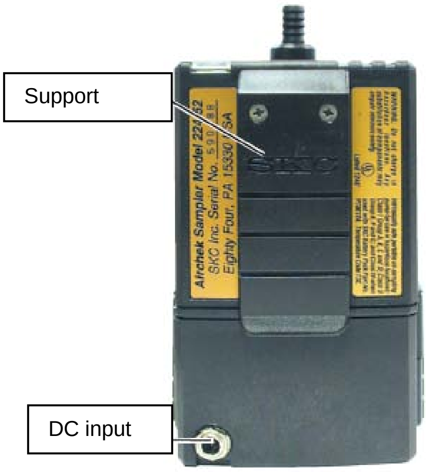


Figure 1. SKC Pump™

Figure 2. SKC cyclone for respirable fraction

Figure 3. SKC MCE filters

Figure 4. Analytical balance Sartorius

The sampling times have been timed and verified with the times pointed out by the counter in endowment to the pump. The choice of the samplings duration is founded on the observation of the filtering membranes: particularly the sampling was concluded when on the membranes a light visible layer of dust resulted, without reaching excessive accumulations of particles that during the transport of the filters would have been able to cause a loss of part of the samples and consequent under-estimation of the values of concentration.

For the transport of the samples a stuffed handbag has been used, to guarantee an elevated protection against the bumps that would have been able to provoke the separation of the particles sampled by the membranes (events that would have distorted the results of the tests); the handbag was manoeuvred with particular attention.

Given the sampling time t_c (min), the volume flow rate of sampling Q (m^3/min), the initial mass of the filter M_i (mg) and the mass of the dust-filled filter M_f (mg) (values gotten after the conditioning of the membranes) the value of the dust concentration Ct_c is obtained through the formula (CEN, 2005):

$$Ct_c = \frac{(M_f - M_i)}{Q \times t_c} \qquad (\text{mg/m}^3) \qquad (1)$$

Regarding the times of exposure (to dusts) of the workers employed in the harvest, a fundamental factor for the evaluation of the risk, it's necessary to underline that these are influenced by the dimensions of the surfaces to be harvested, the orographic characteristics from the conditions of the ground and from the plant distances.

Nevertheless in all the examined firms an exposure time practically coincident with the whole working shift is noticed, (equal to the 8 daily hours). This has allowed to be able to directly compare the average values of concentration noticed with the limits defined by the ACGIH.

Results

Tests in both seasons occurred in the absence of rainfall, so facilitating the harvesting, but also the development of dust during operations. The orchards in Alta Langa are not watered, and are generally not turfed: this contributes negatively to the dust production.

The visual feedback on the airborne particles was found misleading and it has not confirmed by exposure data for operators. In fact, the self-propelled Cimina 380 S showed much lower exposure than the picking machine Smart 1800, a sign of careful design of flows for removing dust from the operator area.

Tables 2 and 4 show relative humidity data of soil samples and the RH of the field obtained as the average of data.

Table 2. Relative humidity of sampled soils (2006)

Nr.	Sampling date	Farm	RH (%)	Av. RH (%)	Nr.	Sampling date	Farm	RH (%)	Av. RH (%)
1	30/08/2006	Bertone	10.16		1	11/09/2006	Bertone	7.56	
2	30/08/2006	″	8.33	10.46	2	11/09/2006	″	4.38	6.03
3	30/08/2006	″	12.89		3	11/09/2006	″	6.14	
1	30/08/2006	Moscone	8.06		1	11/09/2006	Moscone	6.37	
2	30/08/2006	″	6.70	7.89	2	11/09/2006	″	4.66	5.12
3	30/08/2006	″	8.92		3	11/09/2006	″	4.32	
1	31/08/2006	La Ferrera	10.85		1	11/09/2006	La Ferrera	4.87	4.54
2	31/08/2006	″	4.90	7.88	2	11/09/2006	″	4.91	
3	31/08/2006	″	7.89		3	11/09/2006	″	3.85	
1	29/08/2006	Busca	4.11						
2	29/08/2006	″	7.35	5.83	*(Busca didn't made second harvesting)*				
3	29/08/2006	″	6.02						

Data in table 2 show, for August and September 2006, a low value of relative humidity due to scarcity of rainfall (between late August and early September there were no rainfalls – table 3). This situation favored the development of dust during harvest, leading to higher values of dust concentrations than in 2007.

Table 3. Weather during the sampling days (2006) (Source: Sistema Piemonte)

Date	T min (°C)	T max (°C)	Av. T (°C)	RH min (%)	RH max (%)	Av RH (%)	Rain (mm)
26/08/2006	11.2	25.2	18	44	94	75	0.2
27/08/2006	12.8	26.9	19.1	29	93	69	0
28/08/2006	10.9	22.8	16.6	55	94	79	0.2
29/08/2006	12	23.8	17.7	40	94	75	0
30/08/2006	9.2	25.5	16.9	18	92	52	0
31/08/2006	6.7	24.5	16	21	77	45	0

Table 4. Relative humidity of sampled soils (2007)

Nr.	Sampling date	Farm	RH (%)	Av. RH (%)
1	24/08/2007	Busca	20.23	
2	24/08/2007	″	19.95	20.44
3	24/08/2007	″	21.15	
1	24/08/2007	Moscone	18.29	
2	24/08/2007	″	17.55	18.41
3	24/08/2007	″	19.39	
1	24/08/2007	Bertone	19.51	
2	24/08/2007	″	16.99	17.78
3	24/08/2007	″	16.83	
1	25/08/2007	La Ferrera	22.12	
2	25/08/2007	″	23.4	24.05
3	25/08/2007	″	26.62	

Table 5. Weather during the sampling days (2007) (Source: Sistema Piemonte)

Date	T min (°C)	T max (°C)	Av. T (°C)	RH min (%)	RH max (%)	Av. RH (%)	Rain (mm)
20/08/2007	12.7	20.6	15.8	66	92	85	8.4
21/08/2007	12.6	18.9	14.4	61	93	85	8.8
22/08/2007	12.3	18	14.7	65	92	84	1.0
23/08/2007	10.2	22.6	15.5	47	93	79	0.2
24/08/2007	11.7	24.1	17.4	45	93	74	0.2
25/08/2007	13.0	28	22.8	46	93	77	0

In total, during the two seasons, 18 samples were collected:

- nr. 7 during the swathing with blowers (6 with backpack blowers and 1 with blower connected to the tractor);
- nr. 2 were collected on workers who have performed the swathing and the harvesting;
- nr. 9 during the harvesting.

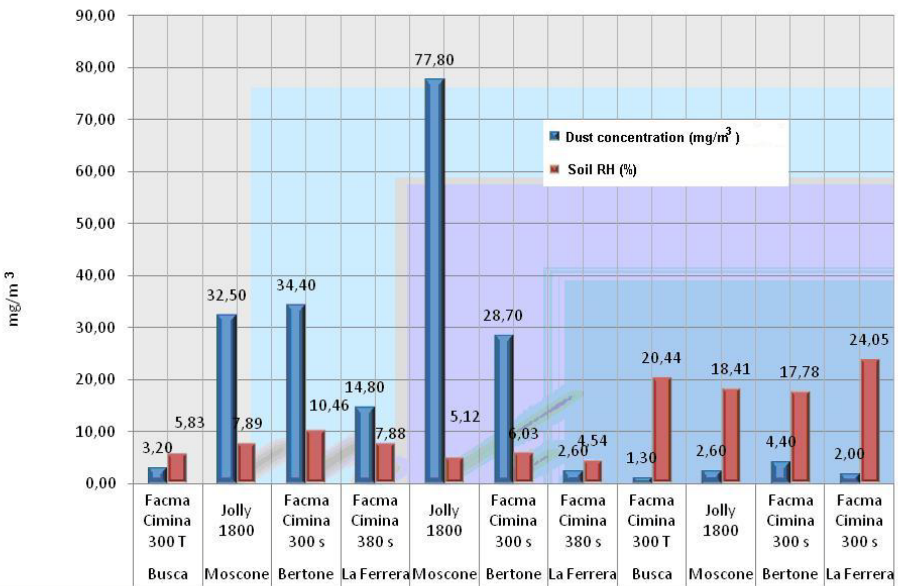
11 samplings were collected during harvesting:

- nr. 3 on the tractor mounted Rivmec Smart 1800;
- nr. 2 on the pulled aspirating Facma Cimina 300 T;
- nr. 6 on the self propelled aspirating Facma Cimina 300 and 380.

Table 6 shows results of all the tests in chronological order. Graphs in figures 5 and 6 show the exposure levels respectively for workers on harvesters and those involved in the swathing, reporting also levels of soil relative humidity.

Tabella 6. Tests results

Date	Farm	Operation	Machine	Sampling time (min)	Aspirated volume (l)	Dust weight (mg)	Soil RH (%)	Dust concentration (mg/m^3)
29/08/2006	Busca	blowing+harvesting	Facma Cimina 300 T	25	47.50	0.15	5.83	3.20
29/08/2006	Busca	blowing	-	9	17.10	0.10	5.83	5.80
30/08/2006	Moscone	harvesting	Rivmec Smart 1800	34	64.60	2.10	7.89	32.50
30/08/2006	Bertone	blowing+harvesting	Facma Cimina 300 s	107	203.30	7.00	10.46	34.40
30/08/2006	Bertone	blowing	-	65	123.50	6.00	10.46	4.90
31/08/2006	La Ferrera	harvesting	Facma Cimina 380 s	64	121.60	1.80	7.88	14.80
31/08/2006	La Ferrera	blowing	-	78	148.20	0.30	7.88	2.00
11/09/2006	Moscone	harvesting	Rivmec Smart 1800	23	43.70	3.40	5.12	77.80
11/09/2006	Bertone	blowing	-	30	57.00	0.20	6.03	3.50
11/09/2006	Bertone	harvesting	Facma Cimina 300 s	45	85.50	2.45	6.03	28.70
11/09/2006	La Ferrera	blowing	-	35	66.50	0.30	4.54	4.50
11/09/2006	La Ferrera	harvesting	Facma Cimina 380 s	50	95.00	2.15	4.54	2.60
24/08/2007	Busca	harvesting	Facma Cimina 300 T	80	152.00	0.20	20.44	1.30
24/08/2007	Moscone	harvesting	Rivmec Smart 1800	40	76.00	0.20	18.41	2.60
24/08/2007	Bertone	blowing	-	58	110.20	0.10	17.78	0.90
24/08/2007	Bertone	harvesting	Facma Cimina 300 s	30	57.00	0.25	17.78	4.40
25/08/2007	La Ferrera	harvesting	Facma Cimina 300 s	80	152.00	0.30	24.05	2.00
25/08/2007	La Ferrera	blowing	-	80	152.00	0.25	24.05	1.60



	Facma Cimina 300 T Busca	Jolly 1800 Moscone	Facma Cimina 300 s Bertone	Facma Cimina 380 s La Ferrera	Jolly 1800 Moscone	Facma Cimina 300 s Bertone	Facma Cimina 380 s La Ferrera	Facma Cimina 300 T Busca	Jolly 1800 Moscone	Facma Cimina 300 s Bertone	Facma Cimina 300 s La Ferrera
Dust concentration (mg/m^3)	3,20	32,50	34,40	14,80	77,80	28,70	2,60	1,30	2,60	4,40	2,00
Soil RH (%)	5,83	7,89	10,46	7,88	5,12	6,03	4,54	20,44	18,41	17,78	24,05

Figure 5. Dust concentration during hazelnut harvesting

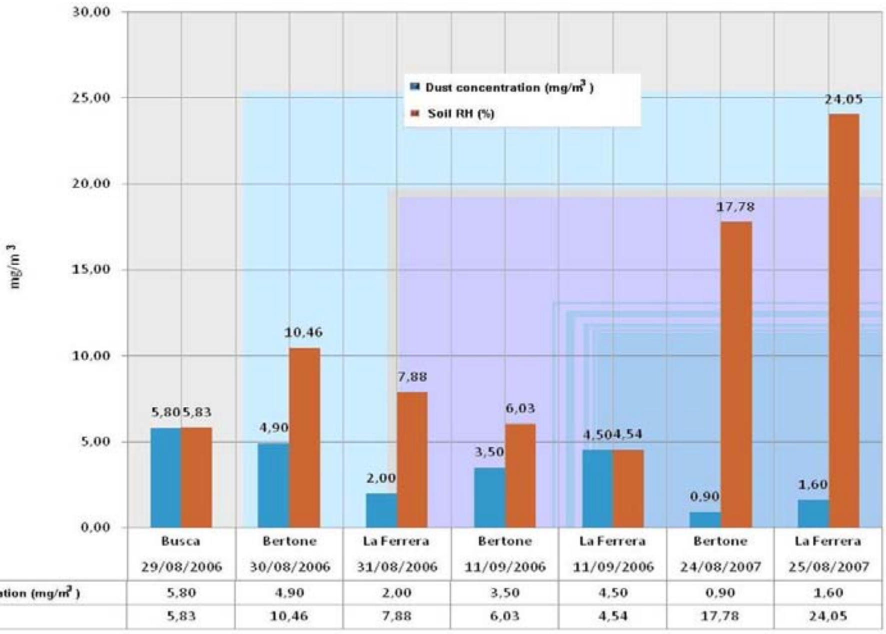


Figure 6. Dust concentration during hazelnut swathing with blowers

Discussion

Data analysis shows values of dust exposure, for workers involved in hazelnut harvesting and blowing, very variable between the years 2006 and 2007.

The exposure for workers during harvesting ranged from a minimum of 1.30 mg/m^3 to a maximum of 77.80 mg/m^3, depending on the machines used and the conditions of soil (humidity, influenced by rainfall).

The overcaming of the level set by ACGIH to 3 mg/m^3 (respirable dust), occurred in 7 out of 11 samples (63.6%). The highest values, as has been found in previous tests (Monarca et al., 2008), are those recorded on the picking machine Smart 1800 in 2006.

The analysis of aggregate data for different types of machines (table 7) confirms the higher values attributed to the picking machines. Among the aspirating machines, the self-propelled Facma Cimina 380S, although has no cyclones, shown exposure values often less than the 300S model: this could be due to a system for dust removing from the driver's area.

Table 7. Average dust concentration during harvesting with different type of harvesters

Type of harvester	Average (mg/m^3)	St. Dev. (mg/m^3)
Aspirating with cyclons	12.33	15.03
Aspirating without cyclons	8.70	8.63
Picking	37.63	37.86

As for dust exposure of workers involved in the swathing, the data show that 4 out of 7 samples exceeded the reference value of 3 mg/m^3.

The demonstration of the importance of the soil RH and therefore the relationship with the dust concentrations is demonstrated by the sample data. Those for the year 2006, showing high levels of exposure to dust, are related to very low levels of soil RH ranging from 4.54% to 10.46%. In 2007, significantly lower levels of exposure are related to humidity levels much higher with values between 17.78% and 24.05%. The meteorological conditions during 2007 was caracterized by more rainfall than during 2006. Furthermore, data about regional weather station in Cravanzana recorded few days before the start of testing (24 and 25 August), a value of 17.2 mm of rain fell on 20 and 21 August.

Another factor which may have influenced the persistence of dust in the worksite and then the workers exposure is the difference in vegetative development of orchards. The orchards of "La Ferrera", featuring the latest plantation, regular plant distances and farming conditions suitable to allow the movement of air in rows, have found lower levels of dust exposure than other older plants.

Particularly in orchards of farms "Bertone" and "Moscone", with 30 years and more old plants characterized by a dense vegetative growth with low movement of air between the plants, especially in the year 2006 have presented higher values of dust exposure for workers.

Conclusions

From the data shown in table 6 and figures 5 and 6, a constant overcaming of the limit values defined by the ACGIH is deduced, in the case of the harvest of the hazelnuts, although the technologies used for the mechanized harvest of this product result to be characterized by a high degree of innovation (ACGIH, 2009).

The average concentration of dusts found in the tests during harvesting is equal to 18.6 mg/m^3 (with a great standard deviation, in comparison to the results, equal to 23,6 mg/m^3), against a value defined by the "guidelines" recommended by the ACGIH equal to 3 mg/m^3. During blowing tests show an average dust concentration equal to 3.3 mg/m^3 (st. dev. 1,85 mg/m^3).

The research has also analyzed the importance of the variables involved during a typical harvest: particularly it assumes notable influence the soil humidity, while other variables as the planting distances, the dimension of the fields, the organization of the work, primarily engraves on the times of exposure to the specific agent of risk.

During hazelnuts harvesting, to avoid the onset of possible illnesses of the respiratory apparatus of the workers the use of individual protection devices (IPD) for the protection of the respiratory ways, is fundamental.

Figure 7. A nut harvester with cab (courtesy of Asquini)

However, for the reduction of the risks it seems evident the benefits brought by solutions like for instance: the substitution of the technique of the worked ground with that of the grass covered ground, the reduction of the number of employees (with passage from the traditional system with hauled machines and three or four employees to the harvest, to the self moving ones usable by a single operator), while the employment of picking machines rather than vacuum machines doesn't appear as an evident system of prevention anymore (Biondi et al., 1994; Cecchini et al., 2005).

More drastic solutions to the problem such as the adoption of semi-cab machines, even though desirable, result difficult as an application for the peculiarities of the work (necessity to pick up under the tree). However first models of harvesters with cab are nowadays on the market (figure 7).

References

ACGIH (2009), Valori limite di soglia. Indici Biologici di Esposizione, ACGIH 2009. Giornale degli Igienisti Industriali, AIDII, Milano, aprile 2009.

Biondi P., Monarca D., Zoppello G. (1992), Il problema delle polveri nella raccolta delle nocciole con macchine aspiratrici. Rivista di Ingegneria Agraria 23 (4), 228-236.

Biondi P., Monarca D., Zoppello G. (1993), Il problema delle polveri nella raccolta delle nocciole. Macchine e Motori agricoli, 50 (4), 63-69.

Biondi P., Monarca D., Zoppello G. (1994), Dust control in hazel harvesting with vacuum harvesters. Atti III International Congress on Hazelnut, Alba 14-18 settembre 1992. Acta Horticulturae, gennaio, 351, 513-519.

Cecchini M., Monarca D., Biondi P., Colantoni A., Panaro A. (2005), Il rischio da esposizione a polveri per gli addetti alla raccolta delle nocciole. Convegno AIIA2005: l'ingegneria agraria per lo sviluppo sostenibile dell'area mediterranea. Catania, 27-30 giugno 2005.

CEN (2005), EN 529:2005 "Respiratory protective devices - Recommendations for selection, use, care and maintenance - Guidance document"

Monarca D, Biondi P, Cecchini M., Santi M, Guerrieri M, Colantoni A (2008). Evaluation of respirable dust exposure during hazelnut and chestnut mechanized harvesting. In: Innovation Technology to Empower Safety, Health and Welfare in Agriculture and Agro-food Systems. Ragusa, 15-17 settembre 2008.

Monarca D., Cecchini M., Antonelli D. (2005). Innovations in harvesting machines. Acta Horticulturae. vol. 686, pp. 343-350 ISSN: 0567-7572.

Monarca D., Zoppello G. (1993), Il problema delle polveri e dei rumori in ambiente agricolo. Atti del V Convegno nazionale AIGR. Maratea 7-11 giugno 1993, (4) 383-390.

The contribution to the programming and executing of this research must be equally divided by the authors.