Use of a Helmet Endowed with Forced Ventilation and Air Filtration Devices in Greenhouse Application of Agrochemical Treatments Using an Innovative Prototype of Self-Propelled Sprayer Vehicle

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Abstracts

During pesticides spreading operations into greenhouses sited in Mediterranean area many workers don't use all the PPD prescribed by low because the high temperature and humidity.

Recent tests of small self-propelled sprayer vehicles conducted in greenhouses demonstrated a very good efficiency in pesticides distribution. In view of the possible diffusion of such vehicles, this work intends verify if the driver of such vehicle can easily use the prescribed PPD and a full helmet endowed with forced ventilation and air filtration devices, comparing the level of comfort to a traditional personal protection device (PPD). Tests were filmed to analyse repetitive arm movements and calculate the OCRA risk index. Use of vehicles and of a full helmet endowed with forced ventilation and air filtration devices for greenhouse agrochemical application appears to be related to greater comfort and better operator ventilation.

Further testing could address the minimum air flow rate required to operate in warm, humid spaces, like greenhouses, and air flow distribution within the helmet. We use an innovative tracked vehicle manufactured in Sicily.

Keywords

Self-propelled sprayer vehicle, tomatoes, safety, welfare

1. Introduction

Greenhouses crop are characterised by a great amount of pesticides spread periodically over all the life cycle. During pesticides spreading operations into greenhouses sited in Mediterranean area many workers don't use all the PPD prescribed by low because the high temperature and humidity. Recent tests of small self-propelled sprayer vehicles conducted in greenhouses demonstrated a very good efficiency in pesticides distribution. In view of the possible diffusion of such vehicles, this research intends verify if the driver of such vehicle can easily use the prescribed PPD and a full helmet endowed with forced ventilation and air filtration devices, comparing the level of comfort to a traditional personal protection device (PPD).

2. Material and method

As spraying equipment we use a little tracked tractor equipped with a spraying system is at an advanced stage of development thanks to a close cooperation between the Mechanics Section of the Department of Agricultural Engineering (DIA) of the University of Catania and the manufacturer. It is powered by an air cooled, 4-cycle, single cylinder, gasoline engine. Continuous and maximum power are 2.6 and 4.2 kW at 3000 and 4000 rpm, respectively. The main dimensions, including the tank, are: length = 1650 mm, height = 1100 mm, and width = 730 mm. Presently, driver seat of the prototype in not particularly comfortable.

We hope to automatize the vehicle thanks to a cooperation with the Dipartimento di Ingegneria Elettrica Elettronica e dei Sistemi (DIEES) of the University of Catania.

Traditional spraying was conducted by walking along the rows and using spray gun, (1 nozzle), mass 0.25 kg. The linear mass of the pipe was 0.19 kg m^{-1}.

The greenhouse in which we conducted the experimental trials was located in the province of Ragusa (Sicily). The tomato plants, cv *Panarea*, full developed, were arranged in twin rows, with distance between rows of 0.40 m, distance between twin rows of 1.20 m, and row spacing of 0.70 m. The plant density was therefore about 21000 ha^{-1}. The crop was geometrically characterised measuring minimum and maximum height of the foliage to be sprayed.

The greenhouse had a metallic structure, covered with plastic film. The minimum height was 3.5 m, the maximum 5.70 m. A central aisle 3 m wide provided for internal movements of operators during crop activities; half greenhouse has 12 spans, each 38 m long and 9 m wide, so the half surface was some 4100 m^2 and the total one was about 1100 $m^{2.}$ A lateral aisle 1 m wide provided for the movements of the vehicle was obtained by removing some tomatoes plant.

The full-face safety helmet has a mass of 0.7 kg and the flow rate of the fan was not less 180 L min^{-1}; noise was certified lower than 75 dB.

As previous *experimental planning* , ten healthy volunteers (mean age 32.5 ± 4.1 years) were studied as they dispensed agrochemical products in a greenhouse. Their main characteristics are reported in Table 1.

Table 1. Main characteristics of the sample.

Subjects	N=10 (100%)
Gender	Male (100%)
Age – yrs	32.5 ±4.1
Job seniority – yrs	10.6 ±5.4
Smokers	None (100%)
Alcohol consumption – g/day	22.1 ±17.6
Body mass index – BMI (kg/m^2)	24.8 ±3.5

They were asked to refrain from smoking and from consuming caffeine for 12 and 2 hours, respectively, before each trial and before the study all subjects signed an informed consent form.

Trials lasted 20 minutes; each subject performed the test in three conditions: 1) standing and wearing a conventional PPD (mask with filter) (test 1); 2) walking and wearing the helmet (test 2); and 3) driving the vehicle and wearing the helmet (test 3).

A questionnaire was administered to measure the degree of discomfort experienced using each PPD (from 0=comfortable to 4=extremely uncomfortable).

Before each test ad hoc paper pads were accurately weighed and then applied on forehead, chest and back with anti-allergic plaster strips for the qualitative and quantitative analysis of sweat according to Bates and Miller (2008). The devices did not restrict movement and were worn throughout each test; then they were collected, placed in a sterile plastic container and finally delivered to the laboratory, where they were weighed and subjected to atomic absorption spectroscopy analysis for sodium loss.

Medical measures, assessed at baseline and after each test, were tympanic temperature (TT), systolic/diastolic pressure (SBP/DBP), heart rate (HR) and respiratory function parameters: forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1) and peak expiratory volume (PEF). Ventilation parameters were expressed as a proportion of ECSC reference values (1971) and adjusted for age, gender and body weight.

The following equipment was used: a portable spirometer (MIR); a tympanic thermometer (Braun; resolution 0.1°C); and a sphygmomanometer.

Each test was filmed with a camera to analyse repetitive arm movements and calculate the OCRA exposure index (Occhipinti and Colombini, 2007). This is the ratio of the number of repetitive upper limbs actions actually performed by the worker to a maximum recommended frequency of 30 actions/minute; the exposure index is modified as a function of the presence and characteristics of additional risk factors (or multiplier factors), e.g. posture and duration of the recovery period, which are attributed values ranging from 0 to 1. When the potential risk factor corresponds to an optimum condition it is attributed a value of 1, which entails no decrease in the exposure index. The more the risk factor diverges from the ideal condition the more its value diminishes and the value exposure index is reduced.

The values of the exposure index fall into three levels: level 1, ≤2.0 "green area", absent or non-significant occupational risk; level 2, >2.1 ≤3.9 "amber area", mild or borderline risk; and level 3, >4.0 "red area", high occupational risk.

Statistical analyses were conducted with the SSPC-PC program (SPSS, Italia). Between groups differences were subjected to one-way analysis of variance (ANOVA). The level of statistical significance was set at ≤0.05.

Fig. 1

Fig. 2

3. Results

Workers speed during the trials vary from 0.42 and 0.46 m s^{-1} and vehicle speed was about 0.52 m s^{-1}. Trials were conducted from 10.30 to 12 in the morning**,** temperatures were about 38 °C and relative humidity from 41%. Baseline and post-exposure values of physiological measures are reported in table 2.

Values demonstrated greater operator comfort in test 3 (subject driving the vehicle while wearing the helmet) and in test 2 (subject walking while wearing the helmet) compared with test 1, where he was wearing a traditional PPD (mask with filter).

The qualitative and quantitative analysis of pads demonstrated increased sweat rates, and consequently sodium loss, after each test. Comparison of the three sets of pads demonstrated that sweat rates were lower, albeit non significantly so, in the two tests where the operator was wearing the helmet compared with the test where he was equipped with the mask (tests 3 and 2 *vs*. test 1).

Although SBP and DPB were significantly higher after the tests compared with baseline values, their comparison demonstrated a significantly lower increase in test 3 than in tests 1 and 2. HR increased after each test, but did not show significant differences among the three conditions. Similarly, TT increased after each test but differences among tests were not significant.

All respiratory measures decreased significantly after each test. The largest reduction was measured after test 1, where the operator was standing and wearing a traditional PPD (mask with filter). Significantly better values were measured after test 3, where the operator was driving the vehicle and wearing the helmet.

Finally, analysis of the images enabled calculation of the OCRA index. It demonstrated that manual spraying (tests 2 and 3) entailed similar actions and OCRA scores, whereas the exposure index was significantly reduced in test 3 due to a reduction in the biomechanical demands on the upper limbs related to repetitive movements.

Table 2. Baseline and post-exposure values of the physiological measures studied

	Vaseline	**Test 1**	**Test 2**	**Test 3**
Dis/comfort	-	3.2 ±0.6*	2.3 ±0.7*	1.6 ±0.6*
NaCl mmol.L^{-1}	46.4 ±23.1^	48.4 ±26.6	47.7 ±25.2	47.5 ±25.9
SBP mmHg	114.8 ±6.4^	129.3 ±7.8	126.9 ±8.5	123.3 ±8.1*
DBP mmHg	76.3 ±6.1^	83.4± 6.1	81.7 ±7.0	78.2 ±5.7*
HR (beats/min)	74.3 ±5.4^	78.3 ±5.9	76.7 ±6.1	76. 3 ±6.5
TT °C	36.2±0.3^	37.4±0.5	36.9±0.8	36.7±0.9
FVC %	101.4±2.4^	97.6±4.3	97.7±3.7	99.3±4.1*
FEV_1 %	102.7±3.2^	97.4±4.6	98.2±3.4	100.7±3.5*
PEF %	100.5±4.1^	96.8±5.1	97.4±3.3	99.5±3.7*
OCRA index	-	3.3 ±0.3	3.3 ±0.3	1.5 ±0.8*

^baseline *vs*. test; p≤0.05 (ANOVA);
*test *vs*. tests; p≤0.05 (ANOVA).

4. Conclusions and prospects

The trials showed that a modern and well designed full-face light safety helmet provided with a little fan able to cool and to prevent the condensation on the visor can be used with driver liking during pesticides spread mechanised operations.

Moreover, during traditional operations workers prefer the safety helmet vs face mask.

Finally, we also can claim that the use of the spraying developing vehicle allows a great level of safety because the dramatic reduction in terms as pollution on the driver and, moreover, because drivers can willingly use a modern full-face efficient light safety helmet.

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