Personal Protective Equipment Design and Ergonomic Work Analysis: Protecting Farm Pineapple Growers

Roberto F. Abrahão (roberto@feagri.unicamp.br)¹, Maria C. Gonzaga (gonzaga@fundacentro.gov.br)¹, Frederico R.C. Queiróz (Frederico.queiroz@feagri.unicamp.br)¹
Mauro J.A. Tereso (mauro@feagri.unicamp.br)¹

¹Faculty of Agricultural Engineering, University of Campinas, São Paulo

ABSTRACT

Pineapple growing is one of the most aggressive agricultural activities and worker protection is a considerable technical challenge. Previous studies point to the lack of efficacy of personal protective equipment (PPE) usually used by workers to protect themselves against accidents with poisonous animals and punctures by pointed leaves, particularly on harvesting activities. In view of these results, this study proposes a two-phase approach. First, a set of PPEs commonly used by rural workers was experimentally evaluated for its effectiveness in protecting workers against real venomous snake attacks. Four sets of PPEs were tested, including shoes and protective gloves, leggings and over sleeves, each set with three different models. The PPE that passed the real attack tests were then evaluated by a group of workers in real use situations, according to qualitative criteria, including comfort and usability. The results of the experimental evaluation showed that only 5 models were effective in protecting the workers against snake attacks, including one shoe model, two models of leggings and two models of gloves. The usability analysis of these PPE revealed that some of them were considered uncomfortable, not effective and obstructive. The next phase of this study relies on the results of the first phase and aims the conception, design and fabrication of a PPE set for the activity of growing pineapples. To generate the design parameters, it will be used an approach based on ergonomic work analysis and conventional design methods, with an emphasis on the QFD method. It is expected that the new set of PPEs will effectively protect the workers and facilitate, or at least not interfere adversely with task execution.

Keywords: Personal protective equipment, snake attack, ergonomic work analysis, pineapple

1. Introduction

The agricultural sector employs an estimated 1.3 billion workers worldwide and, along with construction and mining, is one of the three most hazardous sectors of activity (ILO, 2017). Several epidemiological studies have shown consistently the occurrence of a great number of accidents and work related diseases among agricultural workers (Kirkhorn and Schenker, 2002; Earle-Richardson at al., 2003). The most common injuries are musculoskeletal disorders, due mainly to manual handling of loads, the permanence in extreme postures and repetitive hand movements (Fathallah, 2010).

Pineapple growing is one of the most aggressive agricultural activities and worker protection is a considerable technical challenge. The production process is divided into 4 phases: land preparation, planting, cultivation and harvesting. These phases are divided into various manually executed agricultural operations that make up the production cycle of the crop, which can last from 18 to 24 months.

Previous studies (Adissi and Almeida, 2002; Gonzaga, 2012; Gonzaga et al, 2014) showed the ergonomic and safety problems of pineapple growing in Brazil, including socioeconomic issues - mainly precarious labor relations and work conditions. The workers are exposed to a considerable number of risk factors in all production phases, including the exposure to agrochemicals, skin perforations by pointed leaves and attack of poisonous snakes. The studies pointed out that the ordinary Personal Protective Equipment (PPE) used by the workers (a typical set includes protective shoes and gloves, leggings and over sleeves), besides being uncomfortable and cumbersome, do not effectively protect them from the risk factors.

Snake attacks, besides the danger that it represents, are a major stress factor for pineapple workers. In Brazil, between 2007 and 2013, more than 700.000 accidents with poisonous animals have been notified by the
ministry of health. Particularly in Guaracai, the largest pineapple producer municipality of the state of Sao Paulo, 67 accidents with rural workers were reported, mostly caused by snakes of the Bothrops species, commonly called jaracaras, cotiaras and urutas.

One way to generate design parameters from real work situations and taking into account worker’s requests and needs is to use the Ergonomic Work Analysis method (EWA) as proposed by Guerin et al. (2001). EWA consists of three major stages (demand analysis, task analysis and activity analysis) and could be linked to a conventional design method, like Quality Function Deployment (QFD) to outline attributes and technical specifications of the PPEs (Figure 1).

From these facts, this study aims to evaluate a set of PPEs available on the Brazilian market according to its capacity to resist real snake attacks. The PPEs that were not perforated by the snake attacks will later be evaluated according to usability criteria. The project is part of a broader effort that seeks to design a new set of PPEs suitable for work in pineapple cultivation in accordance with the identified risk factors and according to usability criteria.

2. Method

The snake attack tests were performed at the Foundation Ezequiel Dias - FUNED of Belo Horizonte (MG), in September 2015, with the following PPE: 4 models of protective footwear (B1 to B4 - manufactured according to ISO 20345); 3 models of protective gloves (P1 to P3 - manufactured according to the EN388 2003); 3 models of leggings (L1 to L3 - manufactured according to ISO 11611) and one model of a protective shirt sleeve (M - manufactured according to AT 388). The PPE set, donated by ANIMASEG (National Industry Association of PPE manufactures), was identified by codes to preserve the identity of their manufacturers.

The snakes used in the experiments running the attacks were 4 female healthy adult individuals, belonging to the following species: Bothrops jararacussu (Jararacuçu) and Crotalus durissus terrificus (Rattlesnake). The biometric data of the snakes used in the test (size, weight and the size of the fang) were recorded, as well as the height of the attacks.

The experiment was done in a room at a temperature of 25 °C and humidity equal to 60%. To highlight the results of the attacks – to verify if the PPE were perforated or not – two experimental sets were used (Figure2): the PPE were adjusted in anatomical parts of mannequins (set 1) and filled with air-filled bladders (set 2). With the aid of a
suitable hook, each assembly was approximated at about 30 cm from the snakes in order to stimulate the attacks. Each type of PPE was subjected to three attacks of each species of snake (rattlesnake and jaracuçu) for each experimental arrangement, so that each PPE underwent a total of 12 attacks.

To evaluate the usability of the PPEs that were not perforated, a field study was conducted, with nine workers using the PPEs in various operations and responding to a semi-structured interview.

![Figure 2](image1.png)

**Figure 2.** The experimental set up for the PPEs evaluation

### 3. Results

Figure 3 shows a snake attack from the experimental arrangement with anatomical parts of mannequins and Table 1 summarizes the test results on the basis of the experimental arrangement and snake species. Only 5 models of the PPE set evaluated resisted all of the snake attacks: the protective footwear B3, leggings P2 and P3 and protective gloves L2 and L3.

The main characteristics of PPE that resisted the snake attacks (Figure 4) are presented below. These descriptions are taken from the PPE approval certificates issued by the Secretary of Labor Inspection of the Brazilian Ministry of Labor and Employment.

**Protective footwear B3:** protective boot manufactured according to the standard ISO 20347: 2008. A side zipper closes the boot, made of microfiber (micro-filaments polaramide, polyester and viscose, with heat bonded wires and finished in polyurethane) in black, lining upper in non-woven in gray, insole made of synthetic material in white, outsole polyurethane bidensity in black, injected directly into the leather, resistant to fuel oil, for use in places where there is electricity; approved for protection against risks of lightweight nature, against abrasive and scuffing agents and against electrical shock.

![Figure 3](image2.png)

**Figure 3.** Snake attack on a protective footwear.

<table>
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<tr>
<th>PPE</th>
<th>Botroops Jararacussu (Mannequin)</th>
<th>Botroops Jararacussu (Air Bladder)</th>
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<th>Crotalus terrificus (Air Bladder)</th>
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![Figure 4](image3.png)

**Figure 4.** PPEs that were not perforated.
therefore, great demand for PPEs specifically designed for other purposes, according to the specificities of agricultural work, which ministry of health. Particularly in Guaraçá, the largest

PPEs to protect rural workers should be designed like industrial work. There is, Bothrops urutus. Adjusted in anatomical parts of mannequins – 25 °C and humidity equal to 60%. To highlight the result attacks. Crotalus durissus terrificus followin

were 4 female healthy adult individuals, belonging to the -analysis method (EWA) This work was funded by grants from Fapesp (São Paulo Agency for scientific research promotion) (Grant-#20015/12907-6).

4. Conclusion

Only a small part of the evaluated PPEs supported the snake attacks and most of them were considered obstructive to task execution. These results highlight the need for the conception of PPEs especially designed for agricultural work, with its specificities and particular risk factors.

Acknowledgements

This work was funded by grants from Fapesp (São Paulo Agency for scientific research promotion) (Grant-#20015/12907-6).

References


Legging P2: made of waterproofed leather, finishing in fatty, front closure in elastic and velcro, nylon collar, internal lining with polyester filament, hydrophilic treatment of rapid moisture dispersion lining weft knitted fibers in long molecular chains produced from poly-terephthalamide paraphenylene, highly resistant to cut (manufacturer information - EPI has no certificate of approval).

Legging P3: made of two layers of synthetic material, three batters in front PVC fixed by soldering, closing the edges through bias with soldering; passed to protect the legs against abrasive and scuffing agents, and heat from welding and similar processes.

Protective glove L2: manufactured according to standards EN 388 (2003) and EN 420 (2003); made of leather scrapes, internal reinforcement in the palmar and dorsal regions, external reinforcement strip on the thumb, scrapes and velcro strip on the handle for adjustments, handle 15 cm, mitten model of two fingers; passed to protect hands against abrasive, scuffing and sharps agents.

Protective glove L3: manufactured according to standards EN 388 (2003) and EN 420 (2003); made of treated leather on the back, palm and wrist; reinforcement strip in the palm, thermal lining on the palm and back; lined handle and stitched with aramid yarn, is 41 cm long arm; lined with fabric.

The snakes from the species Bothrops Jararacussu were the most efficient, managing to perforate the PPE in 55.9% of the attacks, against 17.6% of Crotalus terrificus specie. The attacks were remarkably consistent between repetitions, always perforanting or not perforating the same PPE model.

A preliminary analysis of the PPEs performance shows that those perforated in all attacks are made of low thickness (less than 2 mm) single layer synthetic material (thermoplastic polymer), while the ones that resisted all attacks from both species are made of synthetic material with more than one layer and more than 2 mm thickness (P2 and P3) or made of waterproof leather tanned in chromium with 1,3 mm thickness (B3) or scrap leather with 1,6 mm thickness (L3).

The PPEs’ usability evaluation showed that, although some of them were considered comfortable and effective, all of them hindered task execution.