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“APR SYSTEM”, A NEW DESIGN TO INCREASE WORKERS SAFETY IN GREENHOUSES MAINTENANCE OPERATIONS

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ABSTRACT The present communication tries to show the important safety deficiencies of greenhouses roof maintenance operations, because these operations have to be carried out by workers at 4-5 meters height. A technical solution called APR System which eliminates or reduces those risks have been designed and tested. This investigation began with the study of the state-of-the-art maintenance operations for greenhouses roof, including scientific publications and patents, and simultaneously, an evaluation of the film cover renovation works in two multispans greenhouses was carried out. The collected data in these two greenhouses was used to make an evaluation of labor risks following the methodology proposed by the National Institute of Labor Safety and Health in Spain (INSHT), classifying the risk levels for each of the identified dangers. Finally, a technical solution was designed to guarantee the safety in these operations. The literature reviewed revealed at the moment that advances in this area of greenhouses construction are few, with no methods or designs that facilitate the accomplishment of these operations in a safe way. Nevertheless, the means and procedures used in the maintenance operations show great safety deficiencies, verifying that, in the majority of cases, the legal measures proposed to avoid or to reduce these risks are not applied. In this communication, design and operation of a new safety element named "APR System" has been described. This element has been tested and it is demonstrated that it improves the working conditions by avoiding risks of fall from height to which the worker are exposed.

Keywords: greenhouses construction, safety.

INTRODUCTION There are many authors that define the agricultural works as the most dangerous. Pickett et al. (1999) includes agricultural works into a group of four defined as the most dangerous in Canada, at the same level as mining, forestry and building. Rautiainen and Reynolds (2002) consider that agricultural activity is one of the most dangerous in USA. In Spain, agriculture is the fourth activity with more industrial risks after services, industry and building, with an incidence index of 35 per 1000 workers (Ponce, 2008).

In agricultural sector, it is remarkable the greenhouse horticulture because its inputs use and its intensive production. Researches in this area are very little, mentioning a series of articles about this topic written by Lundqvist (1982, 1985 y 1992) in Sweden. This author

connect usual accident causes with produced injuries, identifying greenhouses maintenance operations as one of the most dangerous. With similar conclusions, Gomez (2004) evidences the high accident rate in these operations, remarking that new prevention measures are needed.

In Spain, a specific working group in this safety area (greenhouse commission) tries to study the state of prevention in greenhouses maintenance operations. Its last reports (Ponce, 2005) evidence huge deficiencies in this area, including regulations, resources and training.

In that country, accidents occurred inside greenhouses during agricultural activities as planting, harvesting and other growing operations will be registered in an official statistical database in agricultural sector of activity, meanwhile accidents occurred during greenhouses construction and maintenance operations will be registered in the statistical construction sector. The accident reports are registered in a database called *delt@* by sectors of activity, including construction, but the data on labour accidents registered in *delt@* for the different subsectors of construction (among them greenhouse construction) are not separable.

Some authors have classified the different causes of injuries occurred in the greenhouses construction subsector. In this way, Carreño (2005) determined that main causes of accidents in greenhouses construction are due to cuts and punctures (31%), followed by workers falls from height (19%), over efforts (18%), and worker slides from the same level (16%). Similar results were obtained by Miranda y Martínez (2007) using a similar methodology.

These researches evidence that greenhouses construction and maintenance suffer a high accident rate, with an Incidence Index of 121 (Carreño, 2005), being this level very similar to Spanish construction sector in general (Pérez, 2009).

In this context, Spain is the country with the greatest surface area of plastic-covered greenhouses (Von Elsner *et al.*, 2000), reaching 45,000 ha (Castilla *et al.*, 2005), with the greatest concentration situated in SE Spain, particularly in the province of Almería, with 25,983 ha (San Juan, 2007). Here, intensified agriculture specializes in greenhouse-grown vegetables, with high input and yield, which generates the greenhouse-construction industry, employing hundreds of workers.

METODOLOGY The research starts with the study of the greenhouses construction and maintenance state of the art, searching in data bases as “JOURNAL CITATION REPORTS”, “WEB OF SCIENCE“, “SCOPUS”, “INVENES and ESPACENET” (Spanish Office of Patents and Marks), “DERWENT” (European office of Patents), “PATENTSCOPE” (Web of Knowledge) and “PUBMED” (World organization of Industrial Property).

Simultaneously, an evaluation of roof plastic film setting in two multispan greenhouses was carried out. These two greenhouses were located in Almería (Spain) and one of them was composed by 3 tunnels with 6.5m span and 40m length, and the other one was composed by 8 tunnels with 8m span and 105m length. With the collected datafield, a labour risks evaluation was carried out following the methodology proposed by the

Instituto Nacional de Seguridad e Higiene en el Trabajo (INSHT) from Spain, classifying all the risks level identified. The research ends with the design of a technical solution to increase workers safety in those operations.

RESULTS

State of the art Searching carried out in databases as “JOURNAL CITATION REPORTS”, “WEB OF SCIENCE“ and “SCOPUS” reports that there is no scientist publications related to greenhouses maintenance.

In other hand, searching carried out in patents databases as INVENES, ESPACENET, DERWENT, PATENTSCOPE and PUBMED reports that there is few patents in this area (see table 1).

Table 1. Spanish Patents and internationals Patents related to greenhouses maintenance operations.

Number	INVENCIÓN TITLE
Spanish Patent	
P200001428	Maquina para tendido de cubiertas de invernadero y correspondiente método de instalación de cubierta
U0183194	Estructura móvil para cubiertas de invernaderos
international Patent	
JP2003199440	Machine for laying out greenhouse covers and corresponding method for cover installation
US4318514	Netting applicator
FR2390089	Abri plein champ mobile et mecanisable
PL114708U	Machine for blanking plastic film on mineral wool greenhouse mats
KR950005264	Apparatus for cover of greenhouses
KR890000304	Lifting device of retaining cover of greenhouse
JP11289811	Lift for plastic greenhouse maintenance working machine

Actual Methodology used to setting greenhouse roof plastic film This labour begins with the plastic reel rising to the greenhouse roof. There is no a specific machine to do this operation, been typical the use of power shovel, mechanical loader and rising platforms. (fig. 1)

Next step will be spread out the plastic film on the greenhouse roof. For this purpose, two workers hold both film corners and start to walk over the gutter. Often, it is usually that one or more workers help them acting directly on the reel.



Figure 1: actual methodology: rising the plastic reel

While the process progress, the plastic begin to bend due to its length, and increasing the possibility to get hooked up with the structural elements of the greenhouse. At this point, two more workers are needed, one more on each gutter (figure 2).



Figure 2: actual methodology: spread out the plastic film

The process goes on till the reach the opposite side of the greenhouse (figure 3). At this point must made the most efforts in order to guarantee the correct film tightness, avoiding folds and getting ready for the next step: the fixing.



Figure 3: actual methodology: tighten phase

During tighten phase, fallen risks are increased due to the great efforts made to avoid folds in the film. Once concluded this labour, begin the film fixing phase (figure 4). For this operation, it is needed to do a better tightness just in the point to be fixed with plastic elements that will be fitted by hammering on. This process will be repeat several times until the end of the fixing phase. Obviously, the number of workers needed depends on the greenhouse length.



Figure 4: actual methodology: fixing phase

Risks evaluation according to INSHT method. In order to complete the study, a risk evaluation of the different labours have been carried out (table 2) according to the Spanish Safety and Health Institute (INSHT) method.

Table 2. Maintenance operations risks evaluation (INSHT).

RISKS IDENTIFICATION	DAMAGE IMPORTANCE	PROB.	RISK LEVEL
Workers fall from height	During this operation, workers may fall from 6 meters high. Extremely harmful	Medium	Important
Tools and materials falls from	During this operation, hammers	Medium	Important

height	and plastic pieces may fall from up to 6 meters high and hit workers below. Extremely harmful		
Risks on tighten phase	Efforts may be done by workers in order to reach the correct film tightness, so workers unbalance may occur and consequently fallen from height. Extremely harmful	Medium	Important
Dangerous energy (ie: electricity, radiations, noise and vibrations)	If electrical wires exists. Extremely harmful	Low	Medium
Inadequate thermal environment	Sun overexposure. Harmful	High	Important

DISCUSSION

Scientist and Technical Advances The review carried out shows that most advances in this construction area are registered as patents instead of scientist articles due to its technical nature. In the area of greenhouses construction and maintenance operations, the vast majority of inventions are related to plastic film change, so it evidences the importance of this operation.

Some important documents in this area are: patent number P200001428 (with international number JP2003199440) and the patent P0380619, both with similar basic essentials, consisting on a structure which runs over the greenhouse gutter, carrying the plastic reel on it. These structures have been not extensive incorporated to commercial application due to their high weight, which is too much for the standard Mediterranean greenhouses structures to support.

The utility model U0183194 and patent KR890000304 may be a solution to improve safety in greenhouses maintenance operations due to the capability to raise and descend the greenhouse roof. However, it is difficult to apply this system in a commercial way due to the high cost.

Risks evaluation according to INSHT method Risk evaluation carried out can identify that workers and tools fall from height, group work in height during tighten phase and extreme environmental conditions, as the most risk level. In other hand, the presence of dangerous energy has been identified as risk, for example the presence of electricity pylon over or near the greenhouse, been its risk level as medium.

Among all these risks, attending to seriousness of the injuries, stand out workers fall from height, agree with results obtained by Carreño (2005) and Miranda y Martínez (2007).

APR System, the new technical solution. There are many authors that consider design as the key to avoid or reduce labour risks (Van Gorp, 2007; Gambatese, 2008; Toole, 2008). In this way, a new procedure and structure to carry out all the greenhouses maintenance operations have been design and tested.

This invention (figure 5) consists on the simultaneous use of a sliding platform and a film changer machine.

The platform has been design to rise the film changer machine to the greenhouse roof and slide over a rail to move from one greenhouse tunnel to other. Also, this platform permits supply the roof from some materials as plastic film or lime. In the other hand, the film changer machine consists on a double curve structure adapted to the greenhouse shape and joined between then with bars like a stepladder. This machine ends on both extremes with a pair of wheels which runs over the gutters. This machine will be used as support to realize all the maintenance operations and permits to attach workers harnesses.

The simultaneous use of these equipments involves a new working method to carry out these operations. First of all, to change the plastic film, it is necessary carry the film to the changer machine and after this, drives this to the opposite end of the greenhouse while the spread out the film have been done. Next step will be tighten phase and fixing the film to the structure. For the rest of maintenance operations (shadowing with lime, film repairing, film cleaning, etc.), the equipment will be used as a safety base to work.

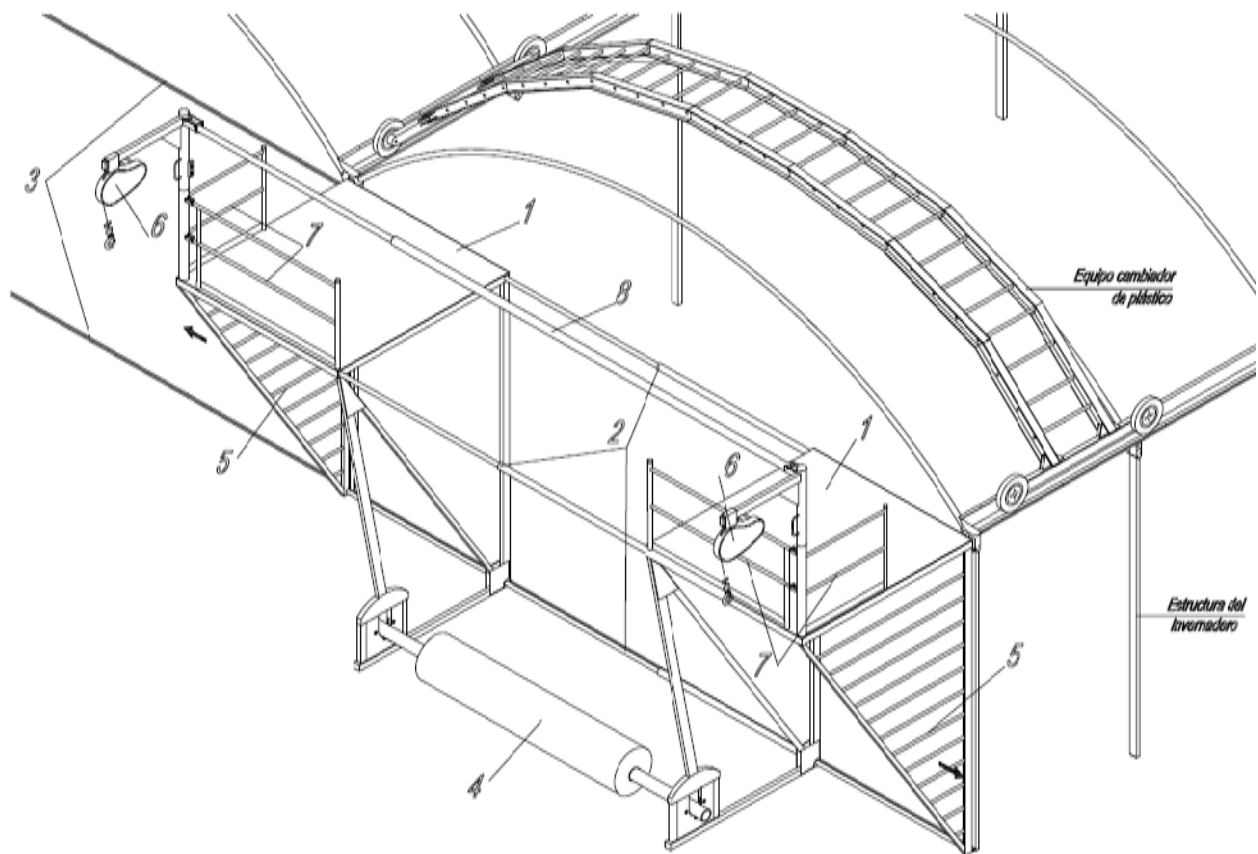


Figure 5: Technical solution proposed

1. *Steel plate*
2. *Extending bar*
3. *Lower and upper sliding bar*
4. *Plastic film reel*
5. *ladder*

6. *winch*
7. *safety railing*
8. *spread out extending bar*

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