

Evaluation of the SIS, a new Frost Protection Method Applied in a Citrus Orchard

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ABSTRACT. The new SIS System of frost protection is based in the operation of SIS (Selective Inverted Sink) devices, which selectively drain the coldest air -responsible of frost damage- from the orchard expelling it upwards out of the plantation area, by means of mechanical power. The main innovation of the SIS System is the application of a fluid mechanics property –the selective extraction of a stratified fluid- to the atmosphere under frost conditions. In hilly terrains, cold air flows downhill towards the valleys, due to gravity force. In these low areas, cold air tends to accumulate, explaining the more severe frost damage observed. The SIS devices selectively drain cold air coming from the hillsides, avoiding its accumulation. An experimental evaluation, supported by CONICYT (National Council of Scientific and Technological Research), was conducted in a 432 ha citrus orchard located in Rio Negro, Uruguay. Six SIS devices of 15HP were installed in a 54 ha Valencia orange valley, that belongs to the orchard. One year frost damage records of the protected valley were compared with those obtained at an adjacent unprotected Valencia orange valley, in which historically a slighter damage behaviour was observed. A statistical work was conducted in order to determine the percentage of frost damage observed. Results showed that the average frost damage observed at the lowest areas of the protected valley was 14 %, against the 42 % observed at the lowest areas of the unprotected valley. The average frost damage observed at the hilltop of the orchard was 10 %.

FROST TYPES AND TRADITIONAL FROST PROTECTION METHODS. Frosts are responsible of significant annual losses in the fruit-growing production worldwide, and particularly in the Citrus Industry, where frosts affect citrus leaves, flowers, and fruit in many citrus producing areas of the world.

There are two main types of frost: the advective freeze and the radiation frost (Turrel, 1973; Kalma, 1993). Advective freezes occur as a result of a large-scale incursion of cold air, and are characterised by moderate to strong winds and a well-mixed atmosphere. Radiation frost results from longwave radiation cooling under calm, clear and dry atmospheric conditions. Under radiation frost conditions, major causes of significant horizontal temperature differences in varied terrains are cold air drainage and cold air ponding. Cold air flows downhill towards the valleys, due to gravity force, where tends to accumulate. Thus, valleys and depressions are usually colder than hilltop sites, explaining the observation of a more severe frost damage in these low areas (Kalma, 1993). The damage caused by

the extreme cold in the plant tissue is associated to the temperature to which the tissue is exposed and the duration of such exposure (Ashworth, 1985).

Protection against advective freezes is much more difficult to achieve than protection against radiation frosts. Consequently, most of the methods are practical and effective only under radiation situations (Evans, 2000). Main traditional active methods include irrigation sprinkling systems, mixing of air (wind machines, helicopters) and open air heating.

Latest research on frost protection has focused in the importance of the microclimate study in order to design, evaluate and assess most active frost protection methods (Doesken, 1989; CTIFL, 1992; Evans, 2000).

SIS SYSTEM. The new SIS System of frost protection –internationally patented- is based in the concept of Selective Cold Air Drainage, through the operation of SIS (Selective Inverted Sink) devices, which selectively drain the coldest air -responsible of frost damage- from the orchard, expelling it upwards out of the plantation area, by means of mechanical power (Fig 1). The main innovation of the SIS system is the application of a fluid mechanics property –the selective extraction of a stratified fluid- to the atmosphere under frost conditions. The SIS devices work in a different way depending on the topography type. In undulated topography, SIS devices selectively drain cold air coming from the hillsides, avoiding its accumulation (Fig 2). These cold air fluxes can be calculated in order to design the quantity and location of the SIS devices required in each case. In flat topography, SIS devices are located on the perimeter of the zone to be protected. This perimetral drainage expels cold air from inside the protected area and avoid the cold air entrance from the outside area (Fig. 3) (INIA, 1999).

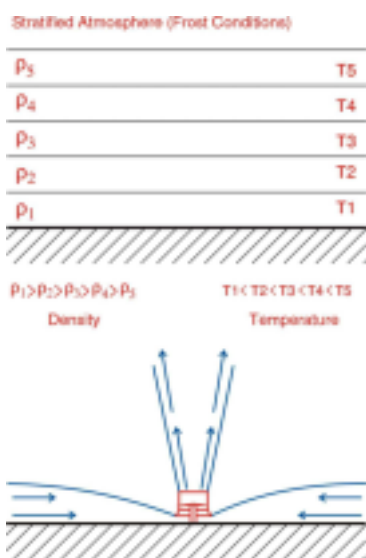


Fig. 1 Selective Cold Air Drainage

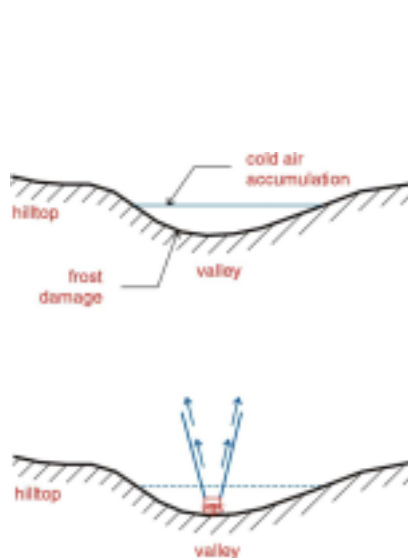


Fig 2. SIS in undulated topography

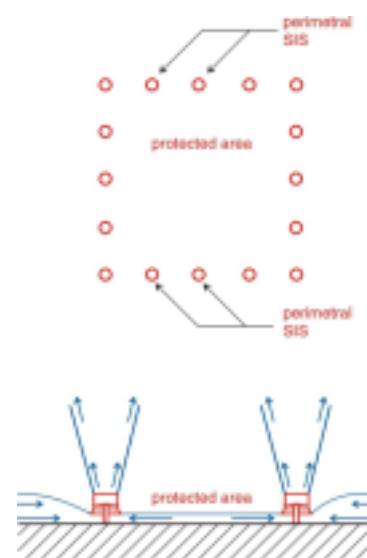


Fig. 3 SIS in flat topography

OBJECTIVE. In the present Study, an Experimental Evaluation of the effectiveness of SIS System in reducing frost damage was conducted in a citrus orchard located in Rio Negro, Uruguay, during the winter of 1995. The Evaluation was supported by CONICYT of Uruguay (National Council of Scientific and Technological Research), financed by BID (Interamerican Development Bank). Six SIS devices of 15 HP were installed in a 54 has –134 acres- Valencia orange valley that belongs to the orchard. One year frost damage records of the protected valley were compared with those obtained at an adjacent unprotected Valencia orange valley, in which historically a slighter damage behaviour was observed. A statistical work was conducted in order to determine the percentage of frost damage observed, aiming to evaluate the effectiveness of the system.

Materials and Methods

SITE SELECTION. Milagro SA is a citrus-growing exporting company of Uruguay that has 7 productive units located in the main citrus-growing regions of Uruguay (littoral of Uruguay River and Southwest part of the country). Annual frost damage existing in Uruguayan citrus-production have been reduced significantly the total amounts of the Country exporting citrus production.

Evaluation was made in Orchard N° 3 of Milagro SA (Mandarines, Oranges and Lemons plantations, total area 432 ha –1068 acres-), located near the city of Young (Rio Negro, Uruguay). The plantation suffered historically a medium to severe annual frost damage that reduced significantly its exportable fruit production. The intensity of the frost damage observed in the orchard varies locally due to the different microclimates generated by the existing hilly topography (average slopes of 2-4 %).

The most severe frost damage historically observed in the orchard is located in a 54 ha -134 acres- valley (valley A, planted with Valencia oranges trees) (Fig. 4). Therefore, it was decided to install the SIS system to protect such valley. For comparison purposes, an adjacent unprotected 45 has -111 acres- valley of the orchard (valley B, planted with Valencia oranges trees, with a historically slighter frost damage records in comparison with valley A) was selected.

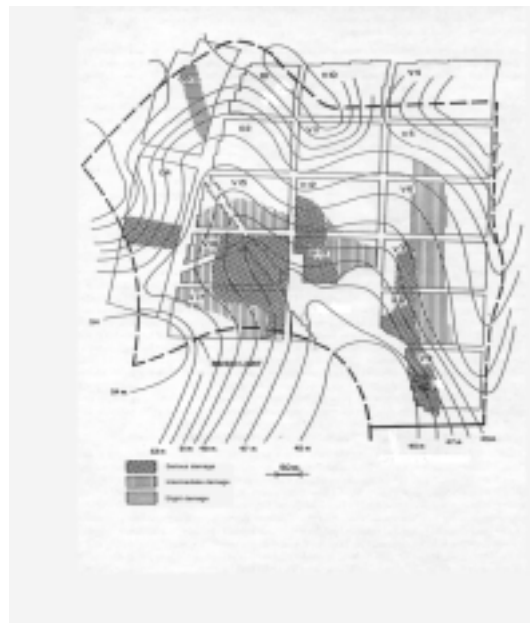


Fig 4 . General topography and localization of the historical frost damage of valley A (before SIS installation)

SIS INSTALLATION. After doing the corresponding cold air fluxes calculations in valley A, six SIS (15 HP each one) were installed (Fig. 5). The SIS devices utilized in the present Evaluation were operated by electric motors. The installation was completed in April 1995, before the beginning of the Winter frost period.

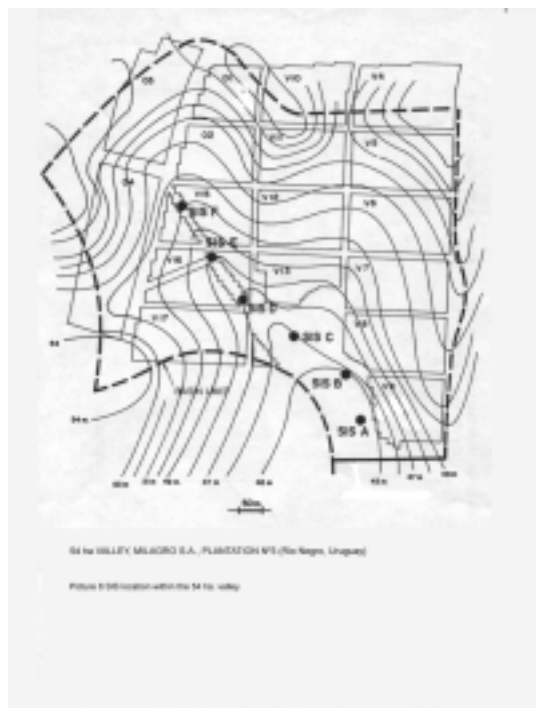


Fig. 5 Placement of 6 SIS of 15 HP in valley A

EVALUATION PROCEDURES. During Winter of 1995, SIS devices were turned on at sunset on each frost night, and turned off in the early morning until temperatures reached 2 ° C (36 ° F). The total number of frosts occurred (between June and September 1995) was of 14. After Winter frost period ending, average frost damage records were obtained through a statistical evaluation at the lowest areas of the protected and unprotected valleys (A and B respectively), and at the hilltop of the orchard.

STATISTICAL EVALUATION CHARACTERISTICS. After Winter frost period ending, representative fruit samples at each evaluation site were taken (low areas of valley A, low areas of valley B and hilltop). This samples were stored for 40 days in cold storage. After that, a statistical work was conducted in order to determine the frost damage rates. For that purpose, two fruit quality levels were determined: exportable level (with no damage at all or a very slight damage) and non exportable quality level -local market, industry or discard- (with slight to serious damage).

Results

Results obtained concerning the damage of the fruit exposed to the frosts during the whole Winter, showed that a damage rate of 14% was observed at the protected valley and of 10% at the hilltop. In the unprotected valley that was used as reference, the average damage caused was of 42%.

Location	Frost Damage Rate
Valley A (Protected with SIS)	14 %
Valley B (Unprotected)	42 %
Hilltop	10 %

Discussion

Taking into account that the valley protected by the SIS had always suffered more damage than the valley used as reference, the result obtained as a consequence of SIS operation is really satisfying because it reduced from 42% to 14 % the frost damage rate in the protected valley. This represents about 600 tons of exportable fruit. Considering fruitgrowing costs, the value of this 600 tons of fruit means 1.5 times the investment made to install the six SIS.

Regarding additional SIS system properties that could be possible to evaluate, the installed system has proved that the total investment was refunded within the first year of its operation. Furthermore, the citrus-growing company Milagro SA, after performing the Evaluation, completed the installation of the SIS protecting the 432 has –1068 acres- of the whole orchard. Another important aspect of the SIS system refers to the environmental sustainability of the method; SIS operation effects a selective drainage of the cold air that damages the crop, on a clean way and without causing any negative impact to the ecosystem to which the protected plantation belongs. Because of that, SIS System is being applied in other types of crops (e.g. vineyards, stone fruit, walnuts, and blueberries). During Spring 2000, 100 has of walnuts were successfully protected in a plantation near Sacramento (California, USA) (Photo. 1). SIS devices (in 2 industrial versions: 15 or 50 HP) are easy to automate and can be adapted to different orchard infrastructures, as it can either work with an electric or explosion engine or by connecting it to a tractor power take-off (Augsburger, 2000).



Photo. 1 - SIS installed in California – USA (2000)

After years of operation, there has been an important increase in the average production as the damage caused by frosts during blossom has been reduced. Thus, SIS action not only reduces significantly the damage caused to the fruit during Winter season, but also it implies an important reduction of the endemic damages caused by frosts during Spring season.

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