A SIMPLE METHOD FOR SAVING WATER IN AGRICULTURE BASED ON THE USE OF PHOTO-SELECTIVE MULCH FILM

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ABSTRACT

In the panorama of agricultural mulches photo-reflective films represent a valuable support for both spring and summer cultivations, both in open field and under greenhouse. In fact, thanks to the high reflectivity of these films, thermal aggressions, that cause serious problems to plants mainly in the transplant phase when traditional black mulch films are used, are avoided. Yellow or silver colored photo-reflective mulch films, thanks to their optical properties, protect plants from damages, assure the mulching effect, give a valid support to Integrated Pest Management (IPM) and, according to our recent experimental trials, greatly contribute in saving water. This further advantage is determined by the high water condensation under the mulch film, which gives rise to the reduction of irrigation. Water saving means also energy saving for electric system providing water circulation. Trials performed at different environmental and geographical contexts confirm that the use of photo-reflective mulch films during the hot season helps to save water up to 30%, respect to the traditional black mulches, with very small, simple and cheap changes in the agronomical practice.

In this paper, we analyze the optical properties of photo-reflective mulch films and we demonstrate their contribution for saving water in agriculture. In this context, the use of thermography allowed us to monitor the stress states of plants induced by the water scarcity, but also to study more advanced techniques, based on IR imaging, able to manage in the best way possible the use of water in agriculture.

Keywords: saving water, agriculture, photo-selective mulch films

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INTRODUCTION

The concept of selecting the solar radiation that passes through an agricultural plastic film to determine the more advantageous physical conditions for the crops development and protection is well known as "Photoselective effect" and it is recently gaining a wide range of interest (Cerny *et Al*, 2003, Mormile *et Al*, 2013, De Salvador *et Al*, 2008). Thanks to photoselective films it is possible i) to exploit the solar energy to heat or “cool” the soil, ii) to improve the climatic conditions in the greenhouse, iii) to obtain an high solarizing effect of the soil, iv) to reduce the presence of harmful insects and v) to obtain a remarkable water saving according to the type of film employed.

The traditional black films used for mulching guarantee the mulching effect, thanks to the solar radiation blocking, including the part of Photosynthetically Active Radiation (PAR) that prevents weeds growth. Contrarily to the black mulch, photoselective films block only the PAR, by exploiting the part of solar radiation useful to heat or “cool” the soil, according to the optical properties of each film. These films have optical characteristics able to select both incoming electromagnetic radiation (solar radiation) and outgoing radiation (radiation emitted from the ground). In particular, heating films, blocking the PAR, permit on one hand the transmission of the "warm" part of the solar radiation (near Infra-Red and part of the Middle IR commonly known as SW - short wave) and, on the other, they reduce the passage of radiation emitted from the soil, after it has been heated.

The films with these features are present on the market with various colours such as brown, red or green and they are used for winter transplants up to May, depending on the thermal state of the soil and on the climatic conditions.

Another type of photoselective film works to cool the soil thanks to their high reflectivity to heat solar radiation, in addition to mulch. This property allows to avoid thermal damage during the transplants warm period. In this paper we studied the optical properties of photo-reflective (PR) mulch films and their performances at work in view of saving water in agriculture, giving an estimation of percentage of saved water respect to the traditional mulches.
In order to demonstrate this hypothesis, we performed some trials in different sites at different geographic conditions.

The main goal of our trials was aimed to demonstrate that photo-reflective films (yellow, silver and white) give the possibility to save water in agriculture. The trial was performed in greenhouse and several films (two PR mulches and a black one as reference) were tested using an automatic system for the irrigation in each parcel, according to the water content in the soil. This system allows also the acquisition of data, in order to calculate day by day the water

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consumption for each line covered with different mulch films. In order to monitor also the plants physiological state, we employed the thermography as an excellent tool to control the behaviour of plants before, during and after irrigation. This approach could be useful to study also times and modes of irrigation in terms of both quality and quantity with the aim to optimize the irrigation practices according to the vegetative state of a crop.

Recently the photo-reflective plastic films have been subject of a major consideration from the world of research and the most current literature shows very convincing results and performances that confirm the significant contribution to agriculture in terms of quality and quantity of crops (AMI, 2014, Espi *et Al*, 2006, Mormile *et Al*, 2013, 2016, Cerny *et Al*, 2003, Schettini *et Al*., 2011).

The critical phase of transplant, due to stress induced by border conditions like type of soil and its temperature and the temperature around the baby-leafs, is overcome thanks to the high reflecting action of solar radiation that reduces the temperature on the mulch film surface. Furthermore, the temperature variation between film and soil gives rise to the water condensation which is the basis of saving water. This means that, after irrigation, due to the condensation effect, the water remains in the upper layer of soil so that it is exploited totally by the plant root. In the case of black mulch, the situation is completely the opposite. It means that there is no water condensation that goes down for gravity in the soil, far from plant roots. In figure 1, it is shown a schematic representation of such as mechanism that mainly affects the water saving.

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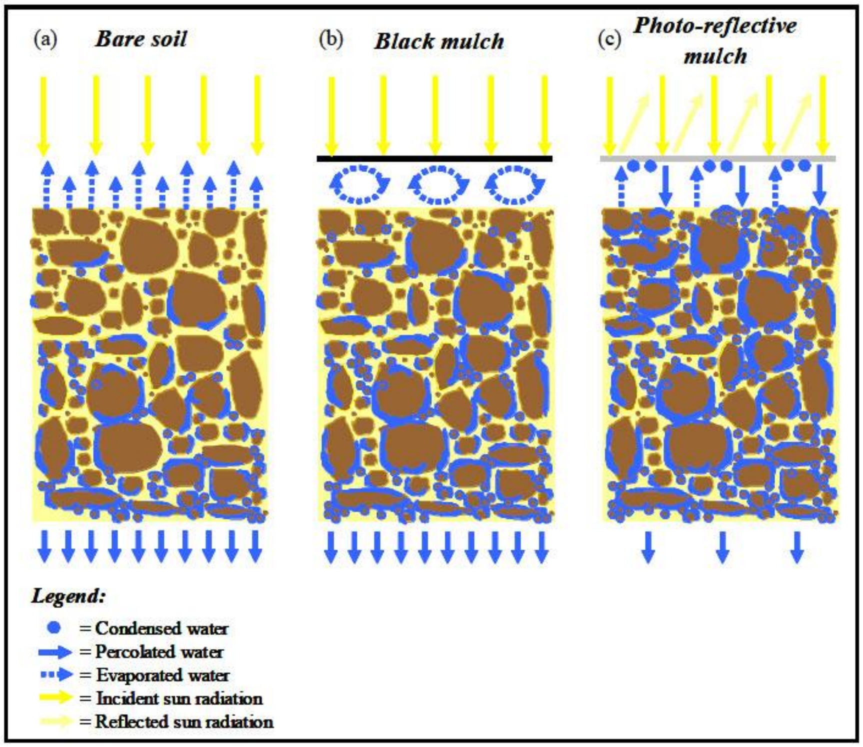
Fig 1: Schematic representation of the water state in the soil according to the different situations



Here, we present our approach to the water sources problem and we report the experimental results of trials that confirm that it is possible to save water with a very simple method (Mormile *et Al*., 2015).

MATERIALS AND METHODS

The optical characteristics of photo-reflective films show a block at PAR (this guarantees the mulching action) and a high reflectivity in the NIR. As an example of spectrum of this type of mulch film, figure 2 (A-B) shows the transmissivity as a function of wavelength of the yellow one.

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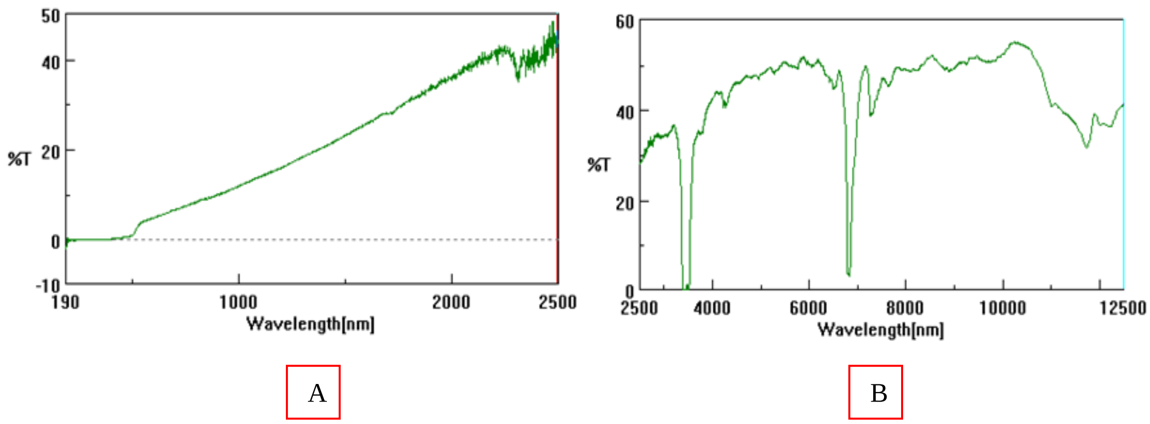
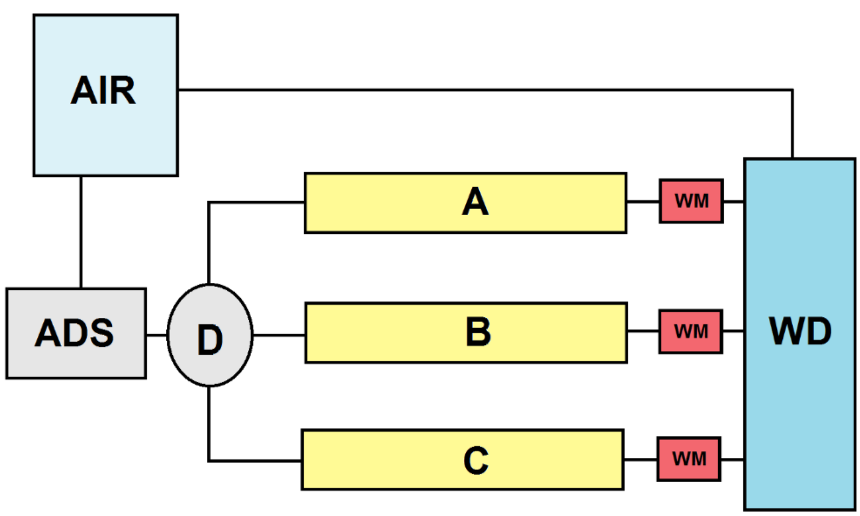
Fig 2: Optical spectra of a photo-reflective mulch film used for spring and summer transplants in UV-Vis-NIR region (A) and IR region (B)



For each trial we adopted the same experimental setup (Fig. 3), based on the use of tensiometers to monitor the soil humidity near the roots.

Fig 3: Experimental setup adopted for trials. A: bare soil; B: black mulch; C: photo-reflective yellow mulch; D: driver: ADS: acquisition data system; AIS: automatic irrigation system; WD: water distributor; WM: water meter



We considered three different parcels: one is bare soil (A), another one is covered with a black traditional mulch film (B) and the last one is mulched with a Yellow PR film.

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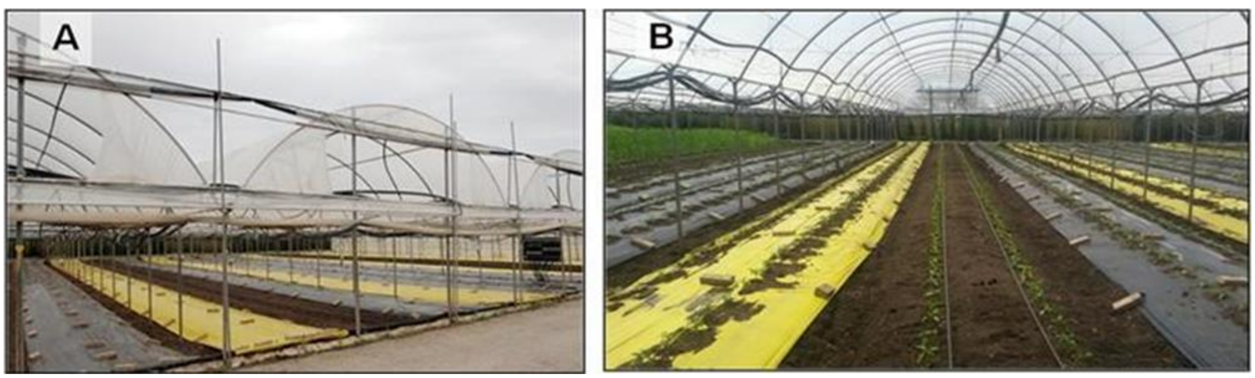
The automatic irrigation system is independent for each parcel, it means that (the irrigation process is totally run by output data from tensiometers) water is supplied according to the output signal from tensiometers placed on each parcel. In other words, the water needs for each parcel is monitored through the tensiometers.

When the humidity in the soil decreases below a threshold value, the output tensiometer signal (soil water tension) enables the irrigation system for each parcel, and the water meter measures the supplied water quantity until the soil moisture tension returns to the reference value. At this stage the water pump is switched off and the water quantity is automatically registered.

Figure 4 (A and B) shows one of the trials, arranged in greenhouse.

Fig 4: Examples of parcel distribution adopted for the trials



RESULTS AND DISCUSSION

The experimental activity was aimed to demonstrate that photo-reflective films (yellow, silver and white) give the possibility to save water in agriculture and to assess the percentage respect to the traditional approach, based on the use of black mulch films. The trials were performed in greenhouse (Fig. 4) and several films were tested using an automatic system for the irrigation in each line, according to the water content in the soil. This system allows also the acquisition data, in order to calculate, hour by hour, the water consumption for each line covered with different mulch films.

We tested five crops (kohlrabi, lettuce, pepper, tomato and melon) in three different farms and monitored the water consumption for each parcel with the described system for the whole vegetal cycle. Day by day, the data of water consumption were stored for A, B and C parcels mulched with the PR films (A) (yellow), with the black one (B) and bare soil (C).

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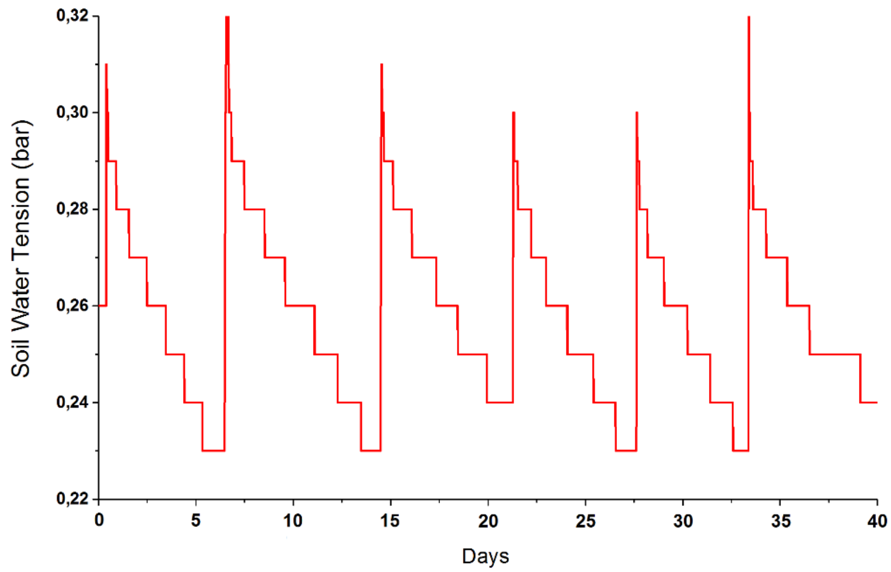
In Figure 5, as an example, it is shown the soil water tension as a function of the time for a few days during a trial. The minima of the curve indicate the threshold value at which the irrigation system (including the measurement system of the water quantity employed) starts to work. In such a way, it is possible to monitor hour by hour the water consumption for each parcel.

Fig 5: Soil water tension as a function of the time



We collected the data for each parcel and calculated a theoretical consumption for one hectare in the case of bare soil, yellow film and black one. This estimation is reported in Table 1, in which the data are expressed in m^3 of water for hectare, BS: bare soil; YM: yellow mulch; BM: black mulch; S: save water (%).

Table 1: Experimental data related to five crops, on water consumption (m^3/hectare) for each parcel with water saved (%).

Product	**BS** (m^3/h)	**YM** (m^3/h)	**BM** (m^3/h)	**S (%)**
Kohlrabi	3134	2390	2103	12
Lettuce	432	180	148	18
Pepper	5790	2513	1960	22
Tomato	8463	1607	1173	27
Melon	2314	1514	986	35

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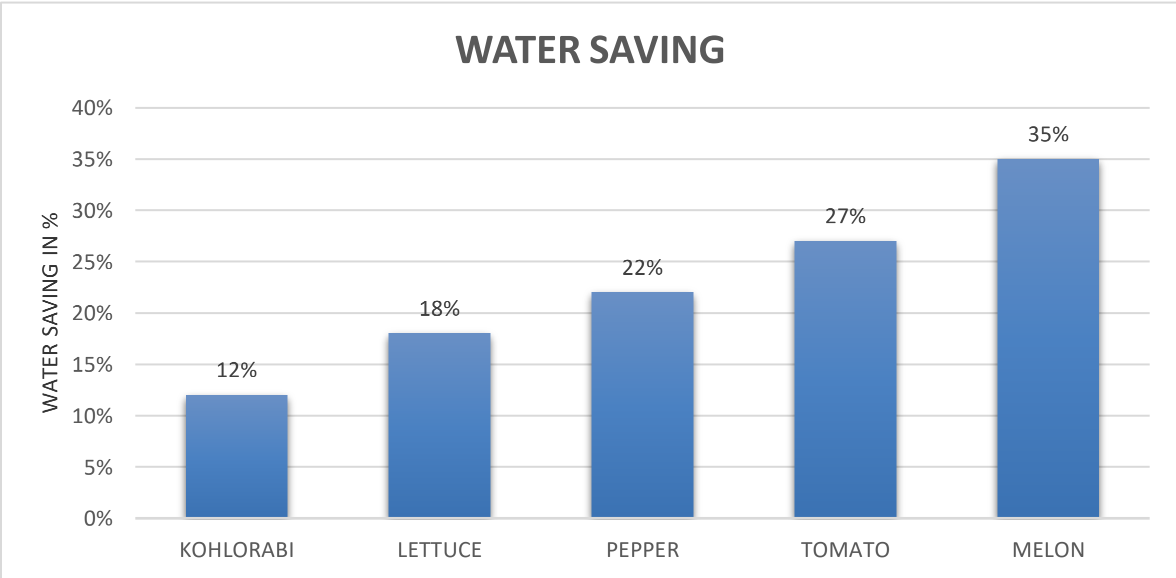
The data, concerning the save water for the five tests arranged, are plotted in figure 6. The values are referred to the percentage of water saved using photo-reflective mulch films instead of the traditional ones.

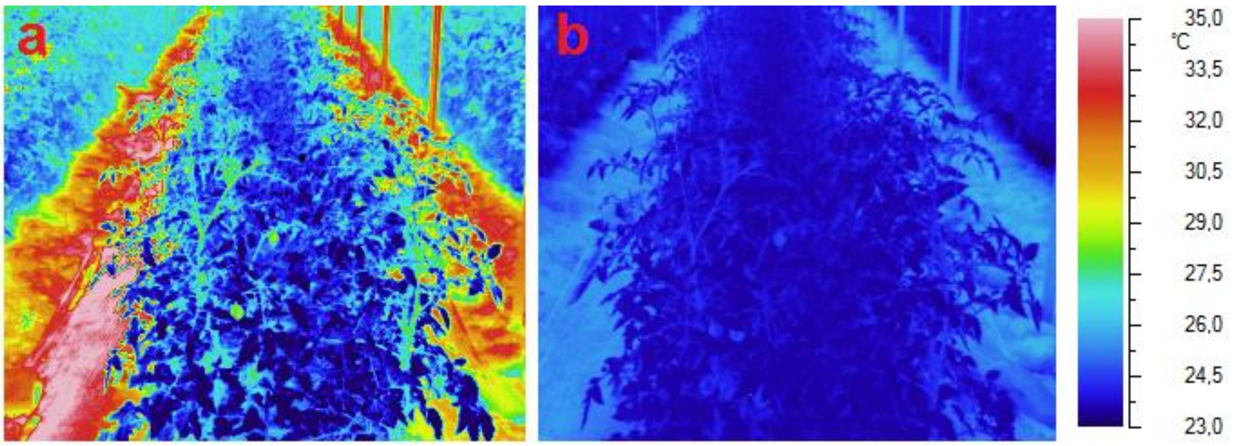
Fig 6: Save water obtained for five crops



In order to confirm, from a qualitative point of view, our technical approach to the contribution of PR mulch films for saving water respect to the use of black mulch, we employed a thermal camera to collect and analyse IR images of the different parcels during trials.

Thermography is a very interesting tool to analyse the thermal state of the single parcel, mainly at the transient (the minima in the graph reported in figure 5). It reports the situations before and after irrigation, when the plants pass from a “stress” state to those where the vegetative activity is more active. The comparison between the two states, through IR images, exhibits a strong variation of plants temperatures (Fig. 7). This approach allows the analysis simultaneously of a wide area of the crop giving information on the water need of plants, on their thermal status and on eventual diseases or pathogens attack. This represents a huge advantage because it is possible to obtain, at the same time, more information on all plants under greenhouse or in open field, while the use of a tensiometer gives just local information on an area of a few square centimetres. This approach, based on simultaneous analysis of a wide zone, could be a future gauge to monitor and manage the irrigation through the thermal state of plants that take into account, not only the need of water, but also their physiological state that depends on different factors such as: development, canopy, eventual diseases, pathogens presence, right light and fruit quantity.

Fig 7: IR imaging showing the switch of the thermal state of plants before (a) and after (b) irrigation



CONCLUSIONS

In this paper, we report the experimental results of different trials, performed to demonstrate that PR mulch films are very useful for saving water in agriculture. The main goal of our study was to introduce in agriculture a simple and very cheap method, based on the use of PR mulch films. Even if this kind of mulching film has been on the market since two decades, its use is generally aimed to create, apart from mulching effect, better thermal conditions near the plants during the hot months, and IPM action. Many farmers, according to their experience, based on daily practice, declared that they saved water using PR mulch films (yellow, silver or white).

Our work confirms and demonstrates that the use of PR mulch films allow to reduce water consumption and it gives, for the first time to the best of our knowledge, an estimation (in percentage) on the quantity of water saved in the case of five different crops. We believe that the experimental results of our work indicate concretely the possibility to save water in agriculture up to about the 35%, with a huge save of energy, money and chemical agents, in the frame of an Agriculture that pay more attention to the crop quality and more respectful to environment. Finally, we introduced a new methodological approach, based on the use of IR imaging, to analyse simultaneously large area of a crop, in comparison with the tensiometer technique that allows to measure just local parameters of crops under inspection. Our preliminary experimental results encourage to proceed on this new investigation even if IR imaging merits a further improvement aimed to provide information on vegetative status of crops in real time. This study is in progress.

ACKNOWLEDGEMENTS

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CONFLICTS OF INTEREST

The Authors have no conflicts of interest to declare.

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