PRECISION IRRIGATION IN GRAPEVINES: WETTING PATTERN ANALYSIS (WPA ©), A NOVEL SOFTWARE TOOL TO VISUALISE REAL TIME SOIL WETTING PATTERNS.

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Summary

Quantitative assessment of spatial and temporal variation of soil moisture close to the root-zone is a critical factor to be considered in irrigation scheduling for Grapevines under RDI (Regulated Deficit Irrigation) and PRD (Partial Root-zone Drying). RDI and PRD manipulate soil wetting patterns (SWP) to modify the physiology of the vine (i.e. reducing stomatal conductance) to obtain desirable increments in water use efficiency and grape quality. A novel software tool is under development, called Wetting Pattern Analyser (WPA©). This software can be used to generate 3D real time animations of SWP, which can be correlated with plant water status to achieve accurate irrigation scheduling strategies for grapevines under RDI and PRD.

Introduction

The major challenge for irrigation technology in many countries is water scarcity, irregular distribution and the inadequate technology used for water collection, and application in the field. These difficulties make it imperative to adopt new technologies to optimise irrigation design and execution. New technologies permit an adequate mechanisation and automation of agricultural operations, improving water use and energy efficiency, making this process compatible with environmental protection objectives.

Accurate control of grapevine irrigation management is a critical factor in obtaining quality produce. It is well known that wine quality decreases with excessive irrigation, which also has a direct impact on the increment of vegetative growth. Regulated Deficit Irrigation (RDI) and Partial Root-zone Drying (PRD) are relatively new irrigation techniques that have been used to tackle two of the most important issues in the grapevine industry: water scarcity and grape quality. The main objective of these techniques is to manage spatial and temporal distribution of moisture in the soil profile close to the root-zone. These techniques generate “controlled” soil patches of dry and wet zones in the grapevine root-zone resulting in a hormonal signal (probably abscisic acid or ABA) produced in roots on dry soil and transported via xylem to shoots. This produces a partial stomatal closure and therefore an increment in water use efficiency (Davies *et al*., 2002).

As irrigators, we are confronted with maintaining precision management of non-uniform wetting patterns in field conditions using these techniques. So, in this sense we cannot possibly rely on numerical models to represent soil wetting patterns (SWP) in different soil types, which may or may not accurately represent the shape and dimension of real SWP (Reid and Huck, 1990). Additionally, numerical models are less practical because of their complexity, cost and the difficulty of reproducing spatial variability of the wetting front in the field (Lafolie *et al*., 1989).

To address the above mentioned issues, a software tool to monitor SWP has been developed as a result of a PhD thesis at the Centre of Horticulture and Plant Sciences (CHAPS) from the University of Western Sydney. This software allows the visualisation of 3D SWP in real time. Therefore, dimensions and soil moisture content of the wet bulb can be estimated and correlated with plant water status. This software has the potential to assist irrigators, instantly check the effects of different irrigation scheduling practices in the field or compare the performance of irrigation systems in a specific soil type.

Irrigation Scheduling using RDI or PRD. The probe location dilemma.

Soil moisture monitoring is commonly used to schedule irrigation of grapevines under RDI and PRD. However, irrigation scheduling has become more challenging when using these techniques, which have created narrow soil moisture and plant stress thresholds. When modifying spatial and temporal soil moisture distribution at the root-zone, using either RDI or PRD, there is a modification of the vine physiology due to a chemical signalling (root-to-shoot) from the roots in dry soil. We cannot possibly detect these key physiological changes in the plant by just monitoring soil moisture and climatic variables (evapotranspiration). It is therefore imperative to monitor the plant water status, when applying RDI and PRD, to achieve accurate irrigation scheduling programs.

When purchasing soil moisture monitoring equipment, many irrigators are confronted with the dilemma of where to locate the probes. To overcome this problem, irrigators are required to focus on the spatial and temporal distribution of water according to their specific agro climatic conditions, irrigation system and plant water status. This procedure is now possible using a novel software called WPA©, which it has been developed by Sigfredo Fuentes (Soil and Plant Science) and Carlos Camus (Code writing).

WPA © Development

WPA © was developed using capacitance probes (Easy Ags, Sentek Pty. Ltd.). These types of sensors were chosen due to accuracy of measurement, relatively small area of measurement (10cm of soil from sensor) and small diameter of tubes (25mm), which cause minimal soil disruption. To achieve the data sets required by the software, it is necessary to install a set of probes with sensors at different depths in the field close to the plant and water source (Fig. 1). This arrangement has been tested for grapevines (cv. Shiraz) under normal drip irrigation and sub-surface drip irrigation using probes with 4 sensors each at 10, 20, 30 and 50cm depth in a sandy-loam soil (Richmond NSW). A radial distribution of probes allows a 3D visualisation of the wetting patterns and the continuous recording of data every 10 minutes and processing permits real time assessment of SWP.

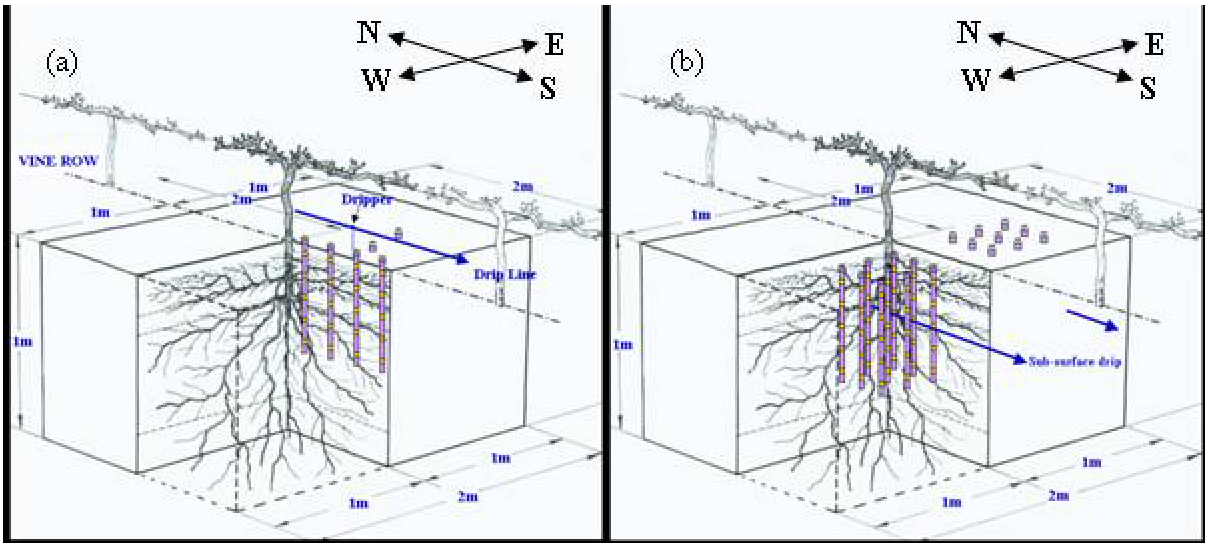

Fig. 1. *Distribution of capacitance probes in a quarter of the area designated to the vine (cv. Shiraz) for normal drip (a) and sub-surface PRD, Richmond NSW Australia (Seasons 2002-03 and 2003-04).*

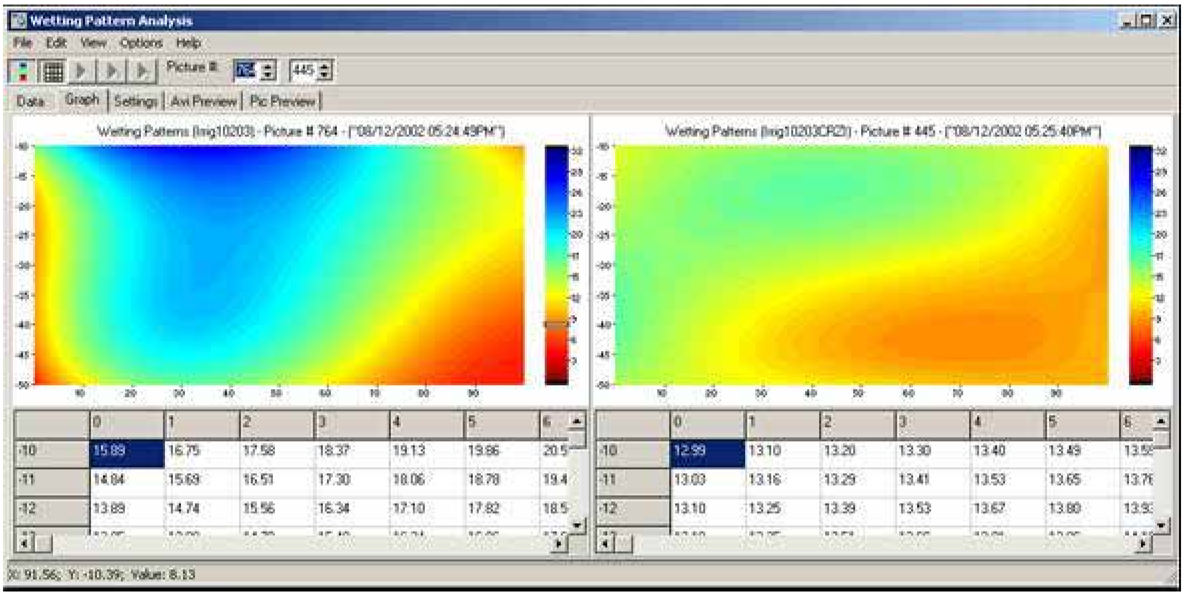

Fig.2. *WPA© output window. Comparison between two irrigation systems: normal drip (left) and sub-surface drip (right). Y-axis is depth (cm); X-axis is distance from plant in the row. Images obtained from probes orientated N-S. (See Fig.1).*

The output window (Fig. 2) shows the soil wetting pattern images obtained through interpolation methods, which can be scanned with the mouse pointer to a minimal range of 1cm^2. Two or more data sets can also be compared. This allows assessing different irrigation timings or the effects of pulse irrigations in the lateral movement of water in the soil profile. Single pictures, set of pictures, matrix of data and "avi" videos files can be exported to excel or media player softwares for further analysis.

Soil moisture sensor calibration. Is it really necessary?

The calibration of soil moisture sensors is considered to be a tedious, time consuming and expensive practice, which most growers are not willing to perform and is more commonly found in scientific researches. However, more important than the calibration of soil moisture sensors, is the assessment of spatial and temporal distribution of water in the soil profile, which plays a key role in the plant water status.

To perform an accurate plant water status assessment it is essential to know the stem water potential (Ψ_X) at different times in irrigation events. This assessment can be performed using a Sholander bomb (Sholander *et al*., 1964) and Ψ_X measurement protocol (available from the authors). Figure 3 shows one of these assessments, monitoring the shape and dimensions of wetting patterns, which allows the calculation of Total Available Water (TAW) in litres. This value can be correlated with the plant water status (Ψ_X) measured at different times in the irrigation event (Fuentes *et al*., 2003)

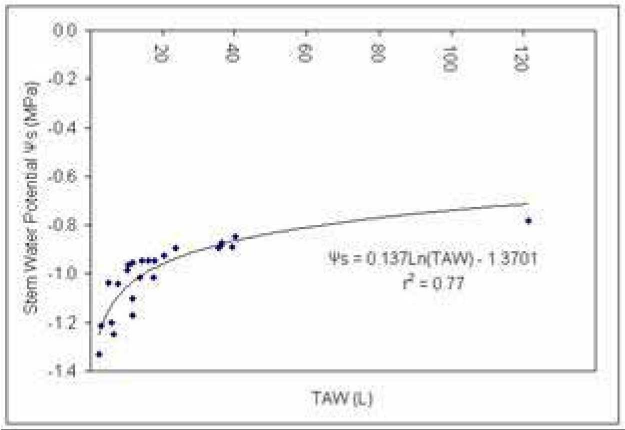

Fig.3. *Relationship between stem water potential (Ψ_X) and total available water (TAW) in a single irrigation event. Talca – Chile. Season 2002-03. Grapevine cv. Cabernet Sauvignon.*

By carrying out this assessment we can obtain the adequate irrigation timing to prevent application of excessive irrigation. The optimum irrigation time can be obtained when the curve has reached its plateau, which in this specific case was close to –0.75MPa. Using this simple procedure, we can adjust irrigation timings according to the plant response, which for growers is a more sensible practice than tedious calibrations to "improve" reading accuracy.

In this way, performing periodic midday stem water potential measurements and using WPA© for SWP analysis, we can answer the two main irrigation questions, which are: when to irrigate? and how much to irrigate?, respectively. The thresholds for midday Ψ_X will be determined according to the production objective and irrigation practice to be performed at determined stages of the grapevine phenological cycle.

Comparison between normal drip and sub-surface drip irrigation systems on grapevines cv. Shiraz using WPA©.

A comparison between normal drip irrigation and sub-surface irrigation systems using a novel drip-line called Safe T-Flo ® was performed using the soil moisture probe distribution (Fig. 1) and WPA© software. The results show that by using this new drip-line there is an initial upward capillarity movement of water, as promoted by the manufacturer (Irrigation and Water Technologies). The effect is achieved due to the drip-line construction characteristics, which consist of a drip-line with a poli-texture film to improve capillarity and lateral movement and a plastic film above and underneath the drip-line to avoid tunnelling and percolation respectively. (Fig. 4).

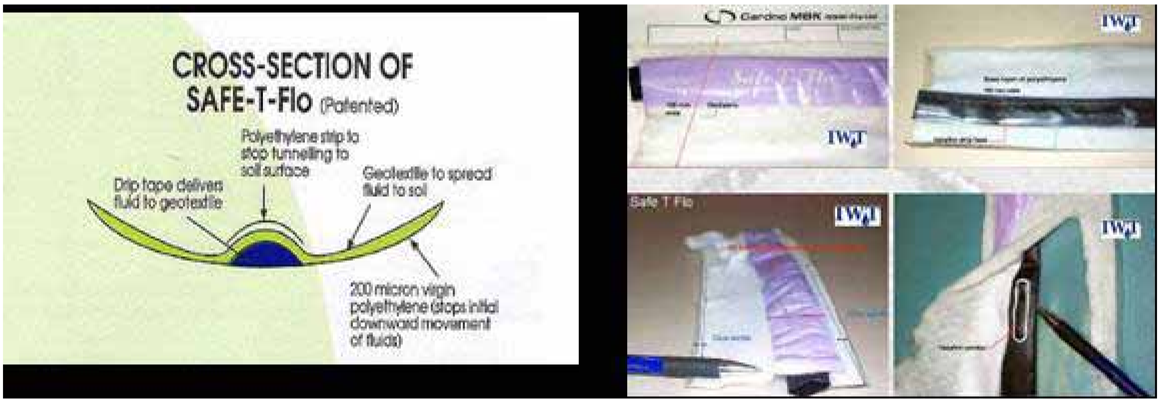

Fig.4. *Safe-T-Flo®. Diagram and pictures showing its construction materials.*

Some key results from animations of wetting patterns using WPA© comparing normal drip and sub-surface drip can be outlined as follows:

Normal drip:

- Water can be quickly incorporated into the soil profile (soil texture sandy-loam).
- Plant water status improves quickly. Improvements can be observed after the first hour of irrigation with a maximum of –0.6 MPa in the fourth hour. (Fig. 5a).
- A continuum column of water is created from the surface, with a paraboloid shape (Fig.6a), which allows a quick evaporation of water from the wetted bulb after the end of irrigations.
- An average of 6 days elapsed between the end of irrigations to refill point (obtained from midday Ψ_X values) at the peak of the irrigation season.

Safe T-Flow sub-surface drip:

- Incorporates water slowly into the soil profile (sandy-loam soil).
- There is a noticeable capillarity movement of water to the surface. The lateral movement of water from the emitter is also improved. The shape of the wetting patterns was sausage-like (Fig 6b), with a more homogeneous water distribution at the root zone.
- Plant water status is noticeable improved after the third hour of irrigation. Then it reaches the same maximum value than drip in the forth hour (–0.57 MPa) (Fig. 5b). After the fourth hour, loses of water to deeper layers were visualised (data not shown).
- Maintaining a dry layer at the surface (5cm) increased soil resistance to water evaporation.
- An average of 15 days elapsed between the end of irrigation to refill point (obtained from midday Ψ_X values) at the peak of the irrigation season.

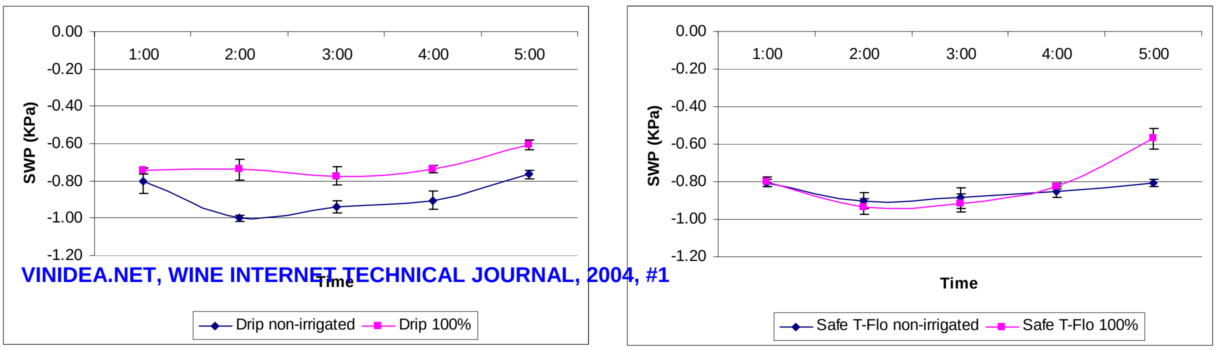

Fig. 5. *Changes in grapevine plant water status (cv. Shiraz) using normal drip (a) and sub-surface drip (b) for a single irrigation event.*

Further WPA© developments

Thanks to an ARC Linkage project recently won by the authors, further research will be done using soil moisture and salinity probes newly developed by Sentek Pty. Ltd. (TriScan®). These probes have a dual measurement ability, which allows simultaneous measurement of volumetric soil moisture and soil electric conductivity. The ARC Linkage project entitled: “Unravelling the links between plant transpiration, soil water and nitrate movement: impact of high atmospheric CO_2 and irrigation strategy” aims to study the links between plant transpiration rates (using sap flow probes) and the 3D real time movement of water and nitrate (NO_3^-) in soils of irrigated grapevines using conventional drip and PRD. WPA© will be improved to visualise wetting patterns and nitrate movement patterns in the soil, which can be correlated with transpiration rates to assess mass flow through the continuum soil-plant-atmosphere. The research will lead to a better understanding of this process and improved irrigation and fertigation practices.

Conclusions

The two main questions in irrigation scheduling of grapevines under RDI and PRD can be answered using a combination of techniques (grapevine water status and soil wetting pattern assessments). “When to irrigate” can be answered by monitoring plant water status (Ψ_X), and ‘how much to irrigate” by using the soil wetting pattern technique described in this article. Soil wetting pattern and volumetric water content measurements are accurate indicators of available water in the soil, which can be correlated with plant water status to achieve accurate irrigation scheduling. The distribution of soil moisture probes in the field and WPA© can be practical and powerful tools to visualise complex SWP shapes at each irrigation event or to characterise the patterns in different soil types to assess the best positioning of a single probe. The use of this technique could prevent water losses to layers outside the root-zone, in this way maximising water application and plant uptake efficiency.

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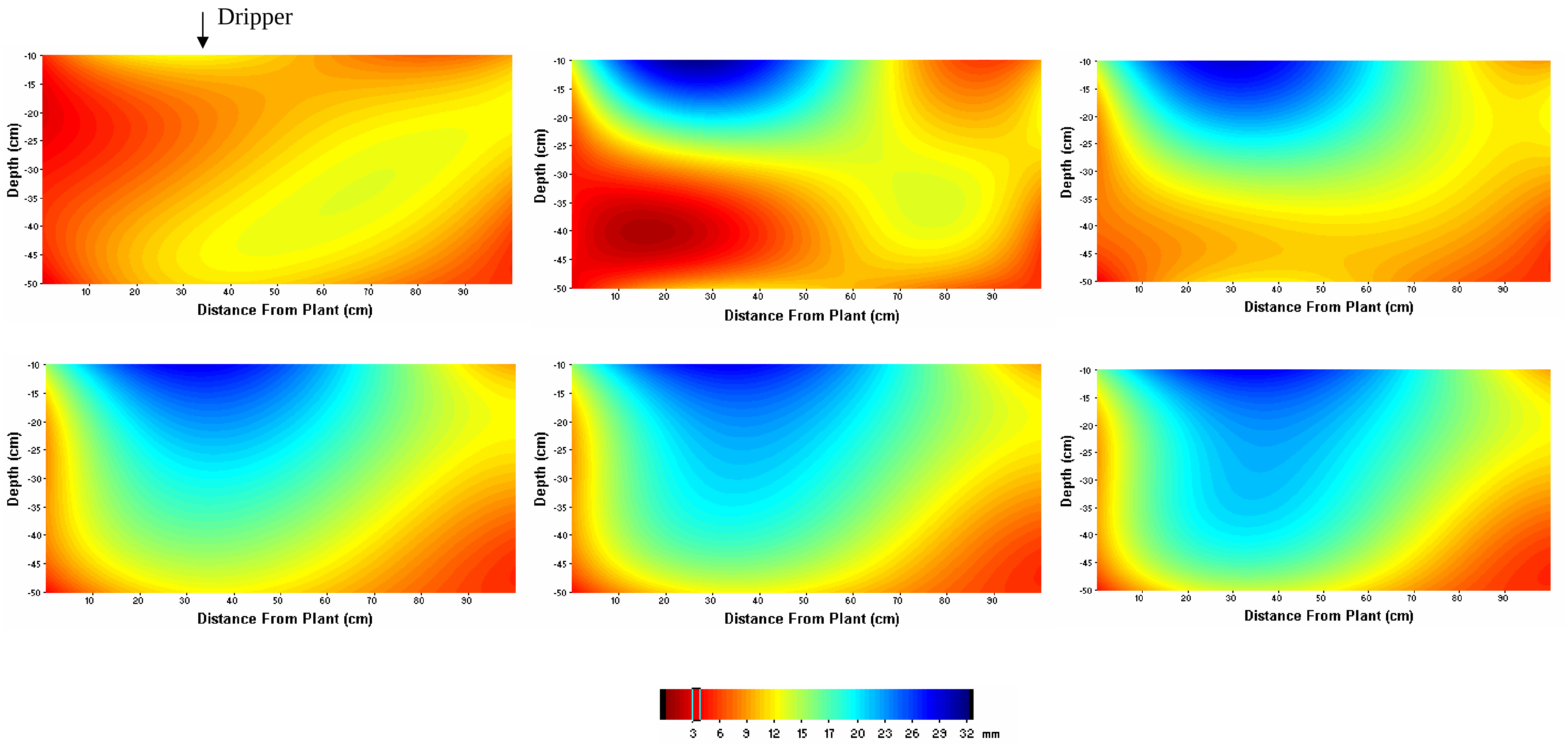

Fig.6a. *SWP obtained using WPA© from normal drip irrigation system (2 drippers/plant at 2 L/H each) on grapevines (cv. Shiraz). The pictures were extracted on an hourly basis, being the 1st before the irrigation and the last, the 5th hour of irrigation. Images were obtained from probes oriented N-S (along drip-line). See Fig.1. The X-axis corresponds to depth (cm), Y-axis to distance from vine (cm), soil moisture is in mm.*

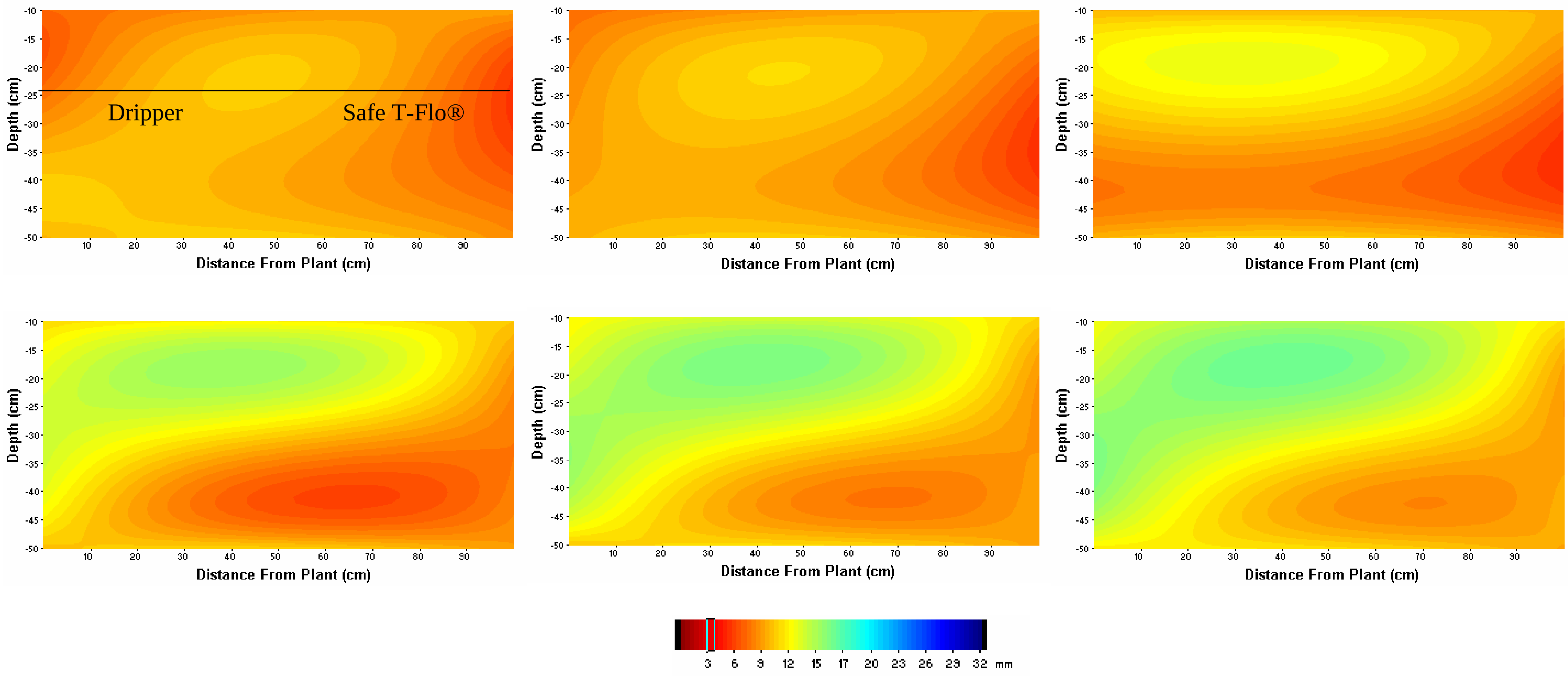

__Fig.6b.__ SWP obtained using WPA© from sub-surface drip irrigation system (4 drippers/plant at 1.0 L/H each) on grapevines (cv. Shiraz). The pictures were extracted on an hourly basis, being the 1st before the irrigation and the last in the 5th hour of irrigation. Drip-line was buried at 25cm depth. Images were obtained from probes orientated N-S (along drip-line). See Fig.1. Images show performance of a single drip (with half of water applied when compared with figure 6a). Soil moisture is in mm.