Sites description

In Richmond NSW (Season 2002 – 03), eight capacitance probes (EasyAG®, Sentek) were installed 50cm apart with the middle probe close to the dripper for a representative vine under normal drip irrigation (NDI) (Figure 2.1.A). Another nine probes were installed along the sub-surface PRD drip-lines to cover the wet side. Each probe had 4 sensors positioned at 10, 20, 30 and 50cm of depth (Figure 2.1.B). Measurements of soil moisture content were made every 10 minutes and logged using two RT6® dataloggers (Sentek Pty. Ltd.) connected to a GSM modem (Intercel Pty. Ltd.) for real time telemetry access. Averaged data from the NDI and PRD sites were used to construct progressive images of SWPs. This analysis permitted the 3D visualisation of SWPs evolution and drying out processes for single irrigation events. Since the probes used had a tube diameter of only 25 mm, this methodology produced minimal soil disturbance. Data analysis was performed using a novel software package, WPA©.

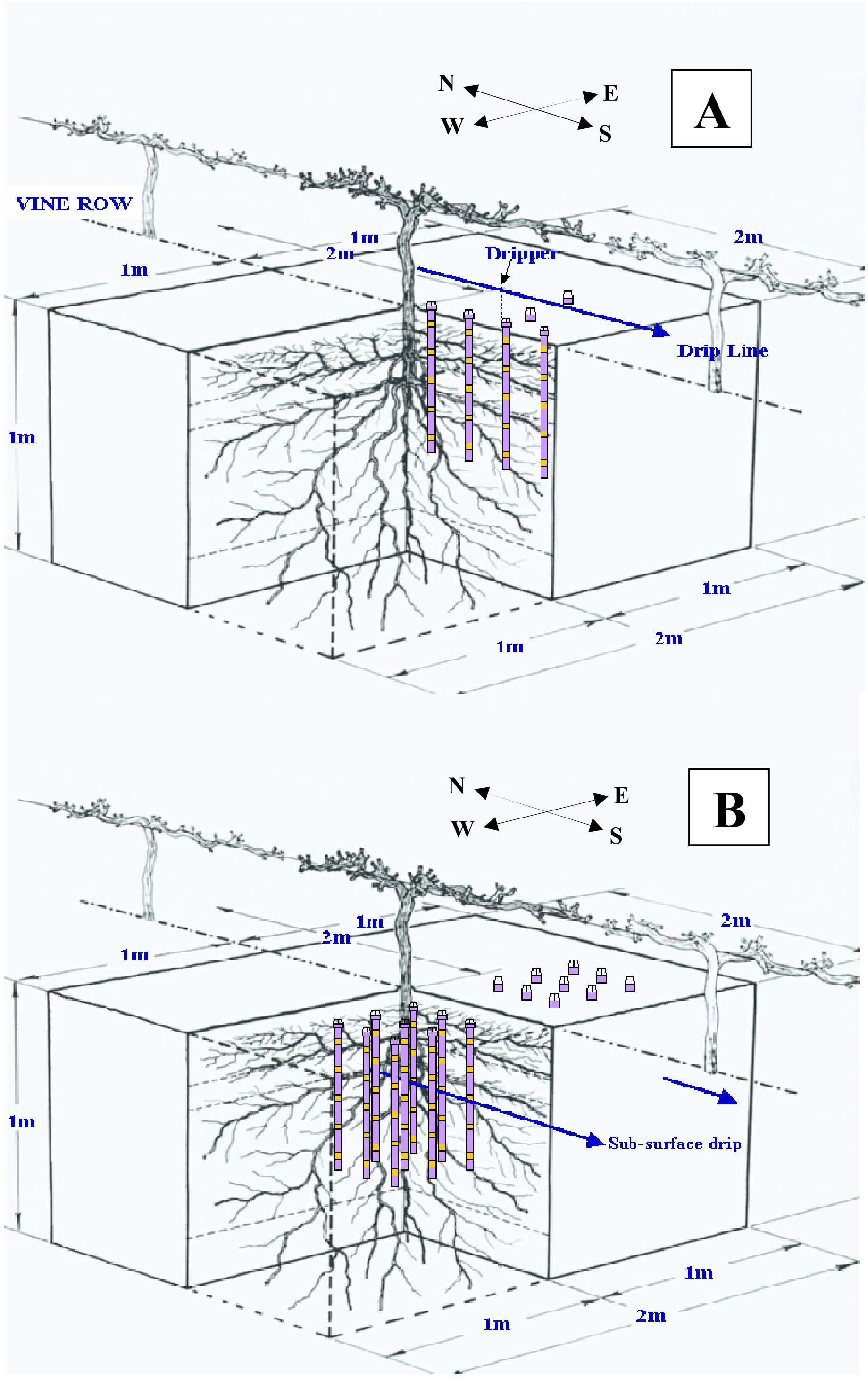


Figure 2.1: Soil moisture probes distribution on representative vines from NDI (A) and sub-surface PRD (B) treatments. Richmond NSW. Season 2002 – 03.

2.5.2 Analysis using WPA© for surface drip irrigation on grapevines

Animations and snapshots of irrigation events and drying out processes were achieved using WPA© and soil moisture probes arranged as shown in Figure 2.1.A for surface drip irrigation (Figure 5.8). Progressive images from before, the middle and end of an irrigation event shows the progression of the SWP. The image obtained prior to the irrigation event (Figure 5.8.A) shows a dry soil profile close to the plant up to a depth of 40 cm, which is close to wilting point (WP = 8.0 mm). However, an elliptical water pattern can be seen from 20 to 90 cm below the plant. Five hour irrigation in a sandy – loam soil was enough to reach a depth of 50 cm. The inter-plants images (Figures 5.8.A, B and C) show a broader SWP in width compared to inter – rows images (Figures 5.8. D, E and F).

Analysis using WPA© for sub - surface drip irrigation on grapevines

Images obtained in a sub-surface irrigation system installed on grapevines are from before, the middle and after an irrigation event at the same time of the irrigation presented in 2.4.2. The irrigation event length was also the same (5 hours). The images were achieved using the probe arrangement described in Figure 2.2. The 3D image presented in Figure 3.9.D, E and F were obtained from the middle arrangement of probes. The water flow direction is from left to right for Figures 5.9.A, B and C. As can be seen, there is a rapid movement of water to the surface from the position of the dripper (x = 10 cm; y = 30 cm). At the end of the irrigation (Figure 5.9.C) the water started to infiltrate deeper layers (below 50cm). There is a non uniform shape of the SWP in the inter – plant and a more “ellipsoidal shape” in the inter-row.

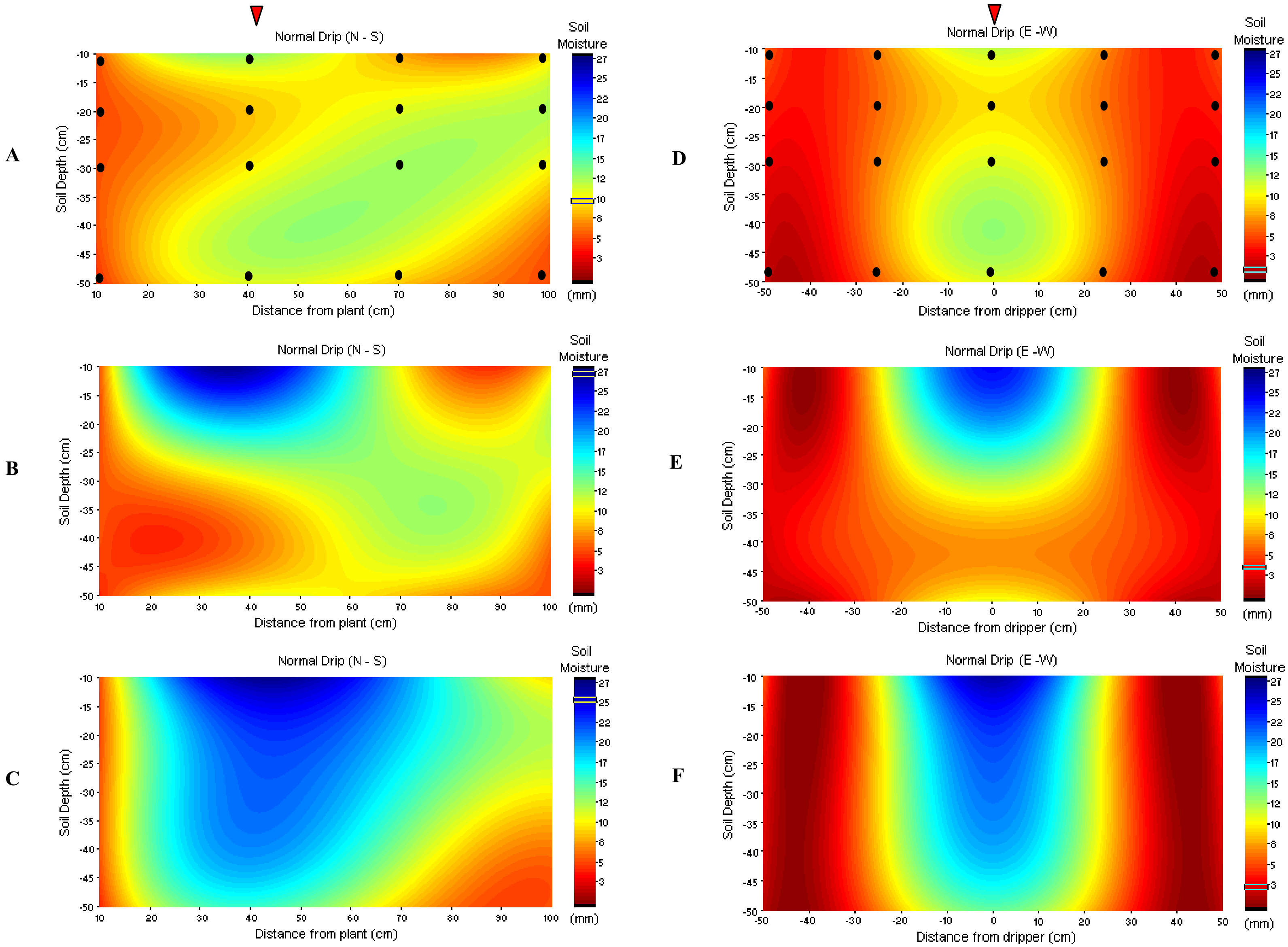


Figure 2.8: Snapshots taken at the beginning (A and D); middle (B and E) and end (C and F) of an irrigation event (5 hours) of surface drip using WPA©. Distance in A, B and C are from the vine trunk (inter-plant) and for D, E and F are from the emitter (inter-row). Black dots in Figs. A and D represents sensor locations, ▼ represents the dripper location. Richmond NSW (2002/03).

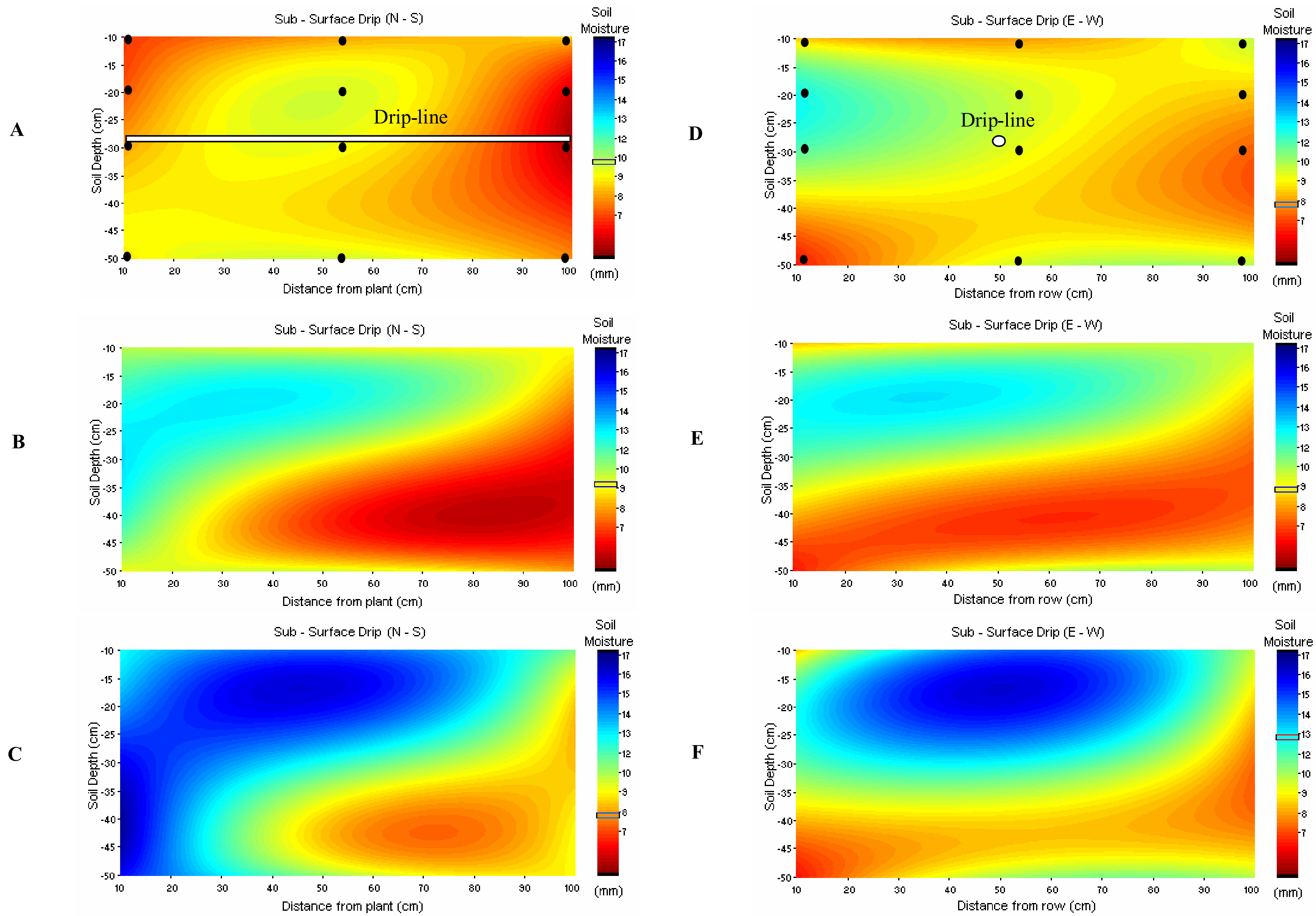


Figure 2.9: Snapshots taken at the beginning (A and D); middle (B and E) and end (C and F) of an irrigation event (5 hours) from a Sub-surface drip-line using WPA©. Figs. A, B and C are taken along the sub-surface drip-line and Figs. D, E and F is a cross section at 45cm from plant. The sub-surface drip-line was running at 30 cm depth and 40 cm from row. Richmond NSW (2002/03).

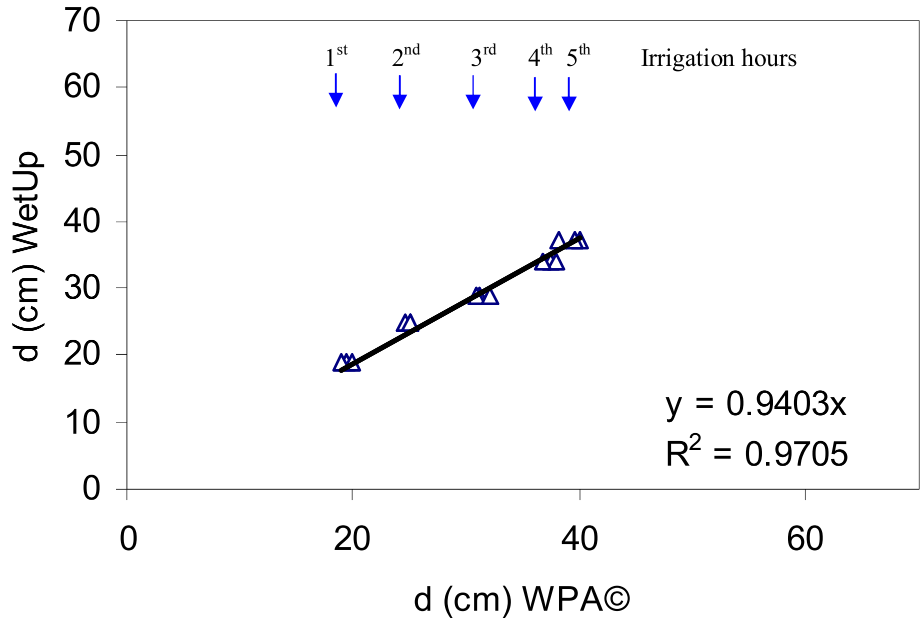
Comparison between SWPs visualised by WPA© and WetUp for surface drip irrigation.

The width (*w*) and depth (*d*) of SWPs of three surface drip irrigation events obtained from the WPA© was compared to the estimated w and d obtained using the WetUp software for three irrigation events from dry to wet soil conditions. Results demonstrates that there was high agreement between data obtained with the WPA© and those estimated through the WetUp models (Figure 2.10). The slope (b) between d WPA and d WetUp was b = 0.94 with an E_a = 1.71. The b between w WPA and w WetUp was b = 0.97 with an E_a = 2.47.

A comparison between shape and dimensions of SWP between WPA© (N – S) and WetUp results also shows a good fit (Figure 2.11). However, between images (E – W) from WPA© and WetUp did not show the same good fit for w (not shown). Also a manual measurement of SWP widths were made in the irrigation events used in this study giving a slope of b = 0.97 (data not shown).

Comparison between SWP visualised by WPA© and estimated using WetUp for sub-surface drip irrigation.

Non – uniform SWPs were obtained using WPA© and the distribution of probes N - S (Figures 2. 9.A, B and C), which were not comparable to the SWP estimated using the numerical models (Figure 2.12). Estimated SWP are uniform and with a spherical shape, which are more similar to SWP obtained from the E – W distribution of probes (Figure 2.9.D, E and F).



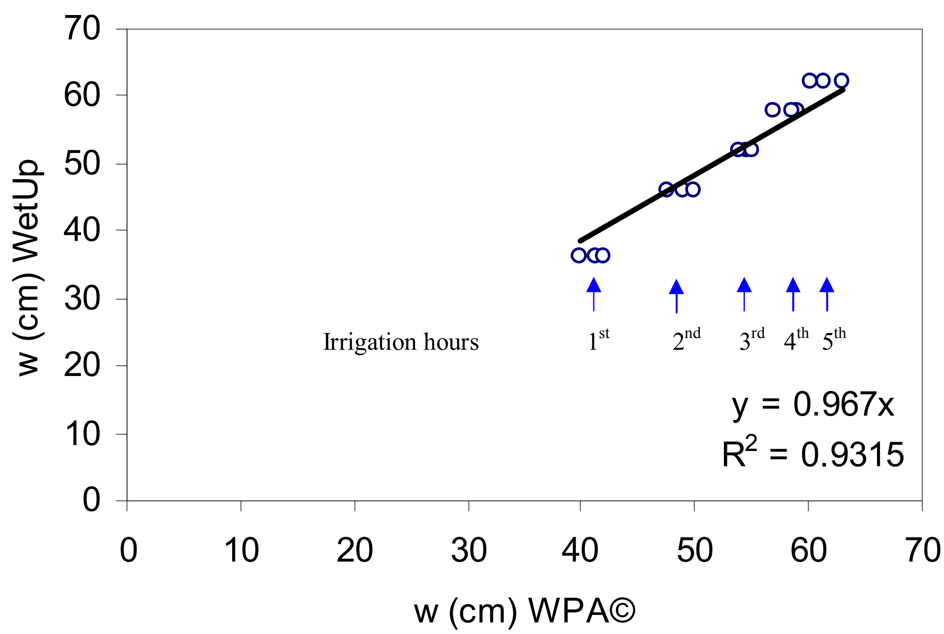


Figure 2.10: Comparison between w and d obtained from WPA© images and estimated using WetUp for three irrigation events of five hours. Richmond NSW. Season 2002 – 03.

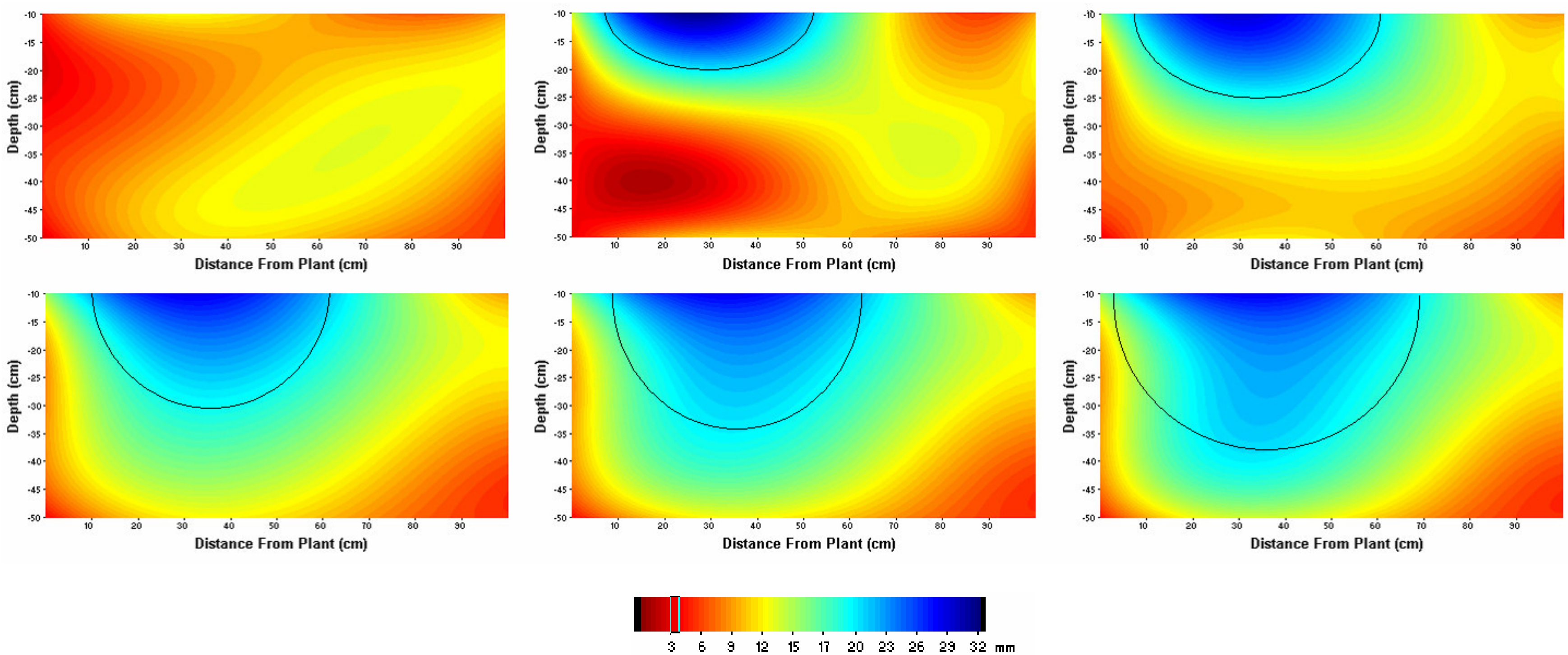


Figure 2.11: Comparison between SWP images from WPA© (colour) and from WetUp (black lines) for a single irrigation event of five hours. The images are shown in an hourly basis being the first image before the irrigation started. Richmond NSW (2002 – 03).

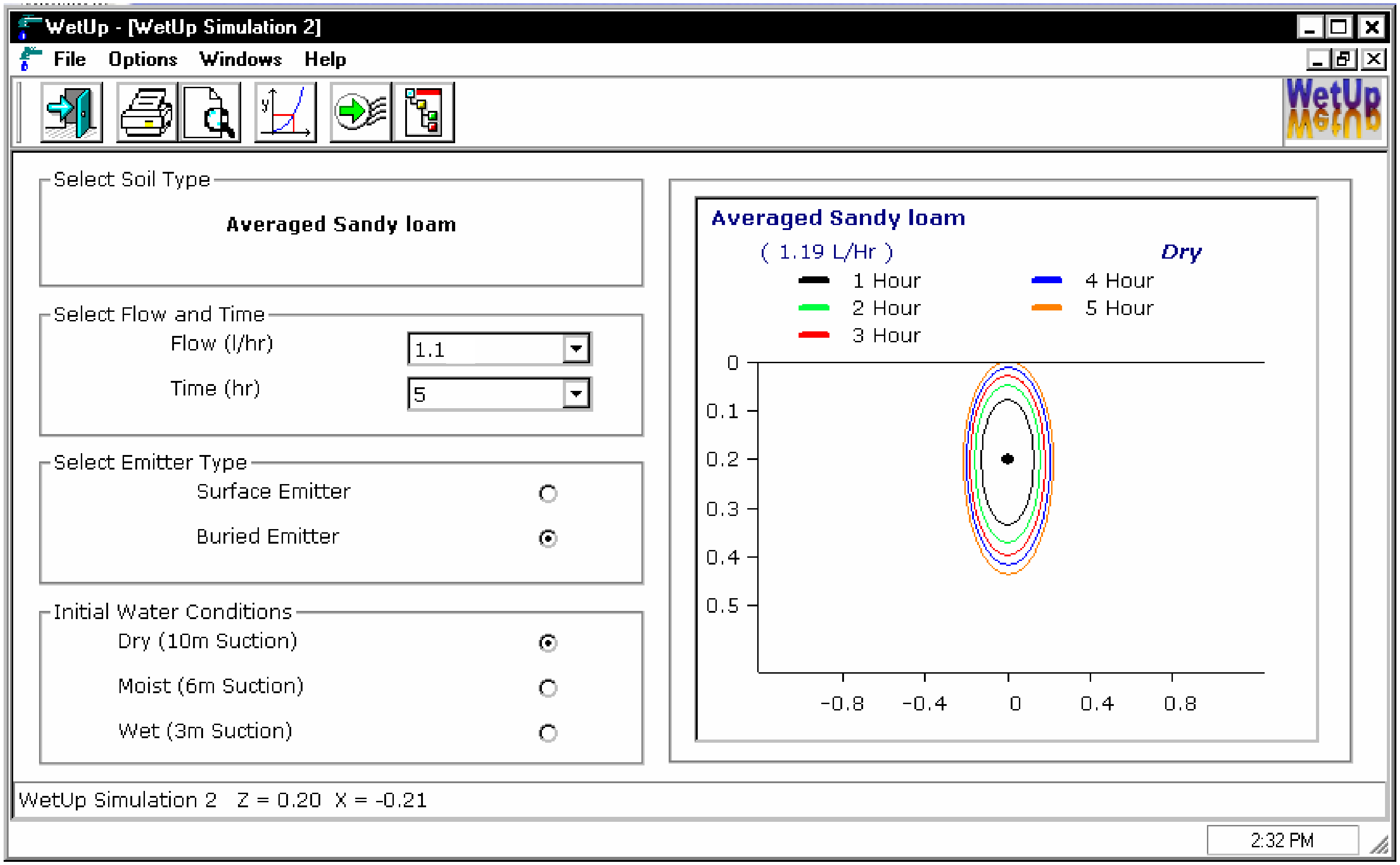


Figure 2.12: Estimated SWP in an hourly basis using WetUp software for sub-surface irrigation drip.

Discussions

The critical dimensions of SWPs from a point source (trickle irrigation) are width and depth, which depend on the hydraulic properties of the soil, the discharge of the emitter, the quantity of water applied and the initial soil moisture in the soil before the application. In addition, soil water content distribution within the wetted volume is not uniform; it decreases with the radial distance from the water source (Zur 1996). Real time 3D visualisations of SWPs offer the opportunity to study soil water dynamics close to the root-zone. These SWPs can be estimated using numerical models, however these fail to describe site-specific conditions (Cote et al., 2003; Zur 1996). Since the WPA© software analyses real soil moisture data, the only assumption required to estimate SWPs is that there is a steady – state flow in the soil profile.

2.6.1 WPA© a novel software to visualise real time 3D SWP.

The development of WPA© stemmed from the need to provide some clarification on the current debate among researchers and growers on the optimal positioning of soil moisture probes in the field. This positioning is dependant on the shape and dimensions of the SWP for trickle irrigation, therefore a SWP assessment tool was needed. Interpolation methodologies of soil moisture data are not a new way to represent the spatial distribution of water in the soil profile. However, the novelty in the application of WPA© is the capacity to obtain real time animations of SWP in 3D and the possibility of correlating volumes of water in the soil profile with plant water status. These capabilities are powerful tools, which could allow precision irrigation in grapevines. The software also offers the capability of visualising the differences in soil moisture within the wetted volumes.

The development of the WPA© software overcomes the problems encountered when estimating SWPs using numerical models, which are: (i) that numerical models are based on limiting assumptions pertaining to the source configuration; (ii) numerical modes consider homogeneous soil hydraulic properties and (iii) they can only be applied to water flow, hence their application in trickle management is limited (Cote et al., 2003). Numerical solutions of the flow equations have been developed for surface point sources, thereby widening the range of application (Bresler et al., 1971; Brandt et al., 1971). However, these solutions are limited in providing an accurate treatment of the surface boundary layer (Lafolie et al., 1989a, 1989b).

The software (WPA©) allows visualisation of SWPs through real time animations in irrigation events. One of the many advantages that this method offers is to observe changes in infiltration velocity when the wetting front reaches patches of soil with different soil moisture. This effect is seen in Figure 2.12, where there is initially a wet patch concentrated around 35 cm of depth and 70 cm of distance from the plant. When the SWP reaches this patch, the infiltration velocity increases making the advance of the wetted volume quicker in this area (to the right). The contrary effect can be seen in the left side of the SWP, where there was a dry patch (soil moisture around eight mm). In this patch the infiltration velocity is less, therefore there is a less lateral spreading of water to the left. This supports the notion that SWPs' final shapes are influenced by the initial soil moisture (Zur 1996). Also plant water uptake from this sector must be considered, since this process is almost instantaneous after irrigations.

The potential application of WPA© has broadened from the initial aim, which was to determine the optimal position for a single soil moisture probe in the wetting volume. Some further applications that seem to be supported by the current research are:

- To design irrigation systems
- For pulse irrigation applications
- To assess site – specific characterisations of SWPs
- To correlation SWPs with plant water status to determine optimal irrigation timing
- To detect rises in water tables
- To ascertain the effect of soil compaction layers on plant water status
- To assess the performance of new irrigation drip-lines under different soil conditions
- To compare the performance of different irrigation systems
- To validate numerical models that aim to predict SWPs.

Comparison between surface drip and sub-surface drip irrigation using WPA©.

Images obtained from SWPs using the WPA© for surface drip (Figure 2.8) and sub-surface drip (Figure 2.9) had some fit with wetting volumes predicted by the numerical models (Figures 2.10, 2.11 for surface drip and 2.12 for sub-surface drip). However, the model fails to completely describe SWPs in field conditions. The main difference for surface drip was the SWPs found in the E – W dimension (Figure 2.8.D, E and F). The narrower width of the SWP can be explained by compaction layers produced by machinery transit (tractor wheels), which pass at 40 cm from the middle row. Depth follows the same behaviour than the N – S dimension, therefore the shape of the SWP is an ellipsoid rather than a paraboloid. The last considers a circular shape of the SWP in the surface. This assumption creates an overestimation of total wetting volume by the numerical methods applied on this in-field condition compared to the SWP obtained by the WPA© software.

Modelling SWPs for sub-surface drip is more complicated, since the drip-line used was a novel drip-line called Safe-T-Flo®, which is constructed from a normal drip-line covered with a poli texture film to improve capillarity and lateral movement of water, it also has a plastic film running along the drip-line in the surface and underneath to avoid tunnelling and percolation respectively. Therefore, shape and dimensions of SWPs will be very different from predicted ones. The plastic film underneath the drip-line produces a clear ascending capillarity movement of water from the beginning of the irrigation (Figures 2.9.A.B and C). The effect of the poli texture film can also be clearly visualised, which allows the movement of water along the drip-line wetting a bigger volume of soil. Considering that the dripper is located at 30 cm of depth and close to 10 cm in distance from the plant, it is assumed that the same wetting volume is achieved to the left of the image, creating a “sausage” shaped SWP. Given that numerical models can not take into consideration these variables, they do not seem to be applicable when using this type of new technology.

A quick comparison of volumes of SWPs gives a total soil wetted volume of 700 L for surface drip irrigation after an irrigation of five hours. The total soil wetted volume for sub-surface drip was approximately 980 L, with a single dripper. This is a significant increment in soil wetted volume, since application of water in this case was at a rate of 1.1 L h^{-1} compared to 2 L h^{-1} of surface drip. This means that with almost half of the water applied the SWP for sub-surface irrigation was 1.4 times bigger compared to surface irrigation. There were four drippers per vine (separated every 0.5 m) which compensated the total water application (TWA) per grapevine. Therefore TWA for a single grapevine for a five hours irrigation was TAW = 20 L and TAW = 22 L for sub-surface irrigation.

Sub-surface drip offers another advantage compared to surface irrigation, as can be seen by using WPA© visualisations, which is that by using sub-surface irrigation it is possible to leave a dry layer in the surface of approximately five centimetres, which will increase the soil resistance to evaporation. This effect will favour transpiration through the plant over direct evaporation of water from the soil to the atmosphere. This dry layer can be achieved by monitoring irrigation timings using WPA©. In contrast, a surface drip irrigation system creates a continuous column of water from the soil surface to the bottom of the SWP, increasing the evaporation process after irrigations (Figures 2.8 and 2.11).

Conclusions

Results obtained in this comparison have demonstrated that the software WPA© can be a powerful tool with various applications for precision irrigation on grapevines. Potential applications have been further explored since WPA© can analyse data regardless of the type of sensors used. Thus, WPA© can be used with the newly developed sensor technology called TriScan ® (Sentek Pty. Ltd), which has a double measurement capability. This new sensor technology can measure soil moisture and salinity at the same time. Therefore, WPA© can produce animations of SWPs and solute movement in the soil profile close to the root-zone. This has the potential to be applied to conduct precision fertigations. Data for this application is already available to be analysed (season 2004 – 05).

In conclusion, the results from this study can provide the following answers for the main irrigation questions: when do we irrigate? and How much we do irrigate?:

- Comparisons between SWP dimensions (*w* and *d*) obtained using the WPA© software, manually (*w*) and through numerical models (WetUp software), showed that the methodology and software proposed in this study is capable of accurately representing in – field SWPs shape and dimensions.

- Results of SWPs obtained using WPA© are comparable only in some conditions with SWP obtained using numerical models. The main reason for this was that numerical models are not capable of incorporating changes in soil hydraulic characteristics and different initial soil moisture in the profile close to the root-zone. Therefore, WPA© offers a more versatile tool to represent different soil conditions such as rising water tables, compaction layers, changes in textural characteristics and changes in infiltration velocities in the soil profile.

- By using WPA© it is possible to compare different irrigation system performance since in-field soil physical characteristics can be included in the analysis and irrigation performance can be compared at the same time if the right number of probes and sensors are available. In this study, accurate comparisons between surface drip and sub-surface drip were possible and the advantages of sub-surface drips were identified.