RESEARCH ARTICLE OPEN ACCESS

Partial Rootzone Drying: Changing Alternation Frequency at Different Phenological Stages and Impact on Tomato Crop

N. Affi*, A. El Fadl*, M. El Otmani*, M.C. Ben Ismail*, L.M. Idrissi**, R. Salghi***

* Département d'horticulture, Institut Agronomique et Vétérinaire Hassan II, IAV-CHA, BP 121 Ait Melloul, Morocco, Agadir

** Département de biologie, laboratoire de biotechnologies végétales, faculté des sciences, université Ibn Zohr, BP8106 Agadir, Morocco

*** Département de Génie de l'Environnement et Biotechnologie, ENSA, Université Ibn Zohr, BP1136 Agadir, Morocco

ABSTRACT
The goal of the current work was to assess the effect of different alternation frequency applied at different phenological stages on physiological parameters of a Partial rootzone drying (PRD) irrigated tomato crop. Three treatments were applied. Besides the control irrigated at 100% of its water requirements, T3 and T4 are both treatments that received 50% of water requirements and that were irrigated by PRD strategy. Crop cycle was divided into three stages: S1 lasted from transplanting to 6^{th} truss flowering, S2: the period separating the 6^{th} truss flowering and the 2^{nd} truss harvest, S3: lasted for the remaining crop cycle period beginning at 2^{nd} truss harvest. While T4 was alternated every 10 days similarly, T3 was alternated every 14 days, 12 days and 10 days during S1, S2 and S3, respectively. T3 maximum daily shrinkage (MDS) was 70% higher than T4 showing that the later is more efficient than the former. As far as stomatal conductance (Cs) and leaf water potential (Ψl), results show that both PRD treatments were affected by stress without noticing any statistical differences in terms of those parameters. The control presented the highest Cs and Ψl levels during the whole crop cycle and the lowest water use efficiency (WUE).

***Keywords* –** alternation, Cs, leaf water potential, MDS, PRD

I. INTRODUCTION

It is all known that water supply is limited in the world and irrigation of agricultural lands accounts for over 85% of water usage worldwide [1]. New water-saving techniques such as the partial root-zone irrigation (PRI) or partial root-zone drying (PRD) have been proposed as an agronomic practice for more efficient use of the limited water resources. The PRD is a potential water saving irrigation strategy that utilizes plant-to-shoot chemical signaling mechanisms to influence shoot physiology. It works in drip irrigation or furrow irrigated crops where each side of the row is watered independently. When the crop is irrigated, soil on only one side of the row receives water while the other is allowed to dry [2]. at each irrigation time, only a part of the rhizosphere is wetted while the other side is kept dry [3].

Earlier results demonstrated that PRD reduced transpiration, and maintained higher level of photosynthesis [4]. Regarding the effect of PRD on plant water relations, it was shown that the PRD reduces tomato stomatal conductance by 20% and maintain, therefore, the leaf water potential.

II. MATERIALS AND METHODS

2.1 Experiment Location

The experiment was carried out in the Agronomic and Veterinary Hassan II Institute - the Horticultural Complex of Agadir in a multi-tunnel greenhouse and on an area of 1322 m2. The used tomato cultivar is 'Pristyla' that was grafted on 'beaufort'. The crop was planted in 10^{th} October 2012 and was conducted in vertical trellising and on a single stem. Crop cycle lasted for 9 months.

2.2 Soilless system

Soilless system consists of containers (10 m length, 25 cm depth and 40 cm width). Each container is an experimental unit composed of 20 plants. The used substrate is sandy-silty (78% sand, 19% silt and 3% clay). This later was deposed over two drainage layers: 5 cm coarse gravel layer and 5 cm fine gravel layer. As far as the separation between root sides for PRD treatments, each container consists of two juxtaposed substrate filled containers and plants were planted on the juxtaposition line to allow root separation.

2.3 Irrigation

The irrigation was performed using double drip lines irrigation system with 40 cm spaced emitters that generate a flow of 2l/h/emitter. Concerning PRD treatments, alternation was allowed through small valves that are placed in the beginning of each drip line. Irrigation and fertilization management were made within a fertigation station through electro-valves. Daily reference evapo-transpiration ETo was calculated using the formula of [5]. Global radiation was measured by a pyranometer (kipp and Zonen model splite).

ETo (mm/j) = 0,0016 x Gr (cal/m2/j) (1)

To avoid water loss, net maximum irrigation dose was determined referring to granulometric properties of the substrate using the following formula

NMD = f x (Hcc – Hpf) x Z x PSH (2)

Where, f is the allowed water stock decrease (10%), Hcc and Hpf are, respectively, field capacity and welting point substrate moistures, Z is the root depth and PSH is the percentage of the wetted zone. According to substrate physical properties, calculated NMD was equal to 0.768 mm. Using irrigation system rainfall (4mm/h), each irrigation supply must last 12 mn. As far as irrigation frequencies, they were variable since they depend on the Etc/NMD ratio.

2.4 Experimental Design

A complete randomized design was used. Three treatments were applied. Each treatment consisted of 20 plants and was replicated eight times. Data were analyzed using MINITAB software version 15.1.1.0. Treatment means were separated by Tukey’s test at $P \leq 0.05$.

2.5 Adopted Treatments

Besides control treatment that received 100% of its daily water requirement, two PRD treatments were applied:

- T3: that treatment combined PRD and 50% of crop water requirement supply and was alternated every 14 days during transplanting – 6th truss flowering stage, every 12 days during 6th truss flowering – 2nd truss harvest stage and every 10 days during 2nd truss harvest – cycle end stage.
- T4: It consists of 50% tomato water requirements supply and irrigation events alternation every 10 days similarly during the whole crop cycle.
-

2.6 Measured Parameters

2.6.1 Greenhouse climate:

Two parameters were automatically and continuously measured: temperature and greenhouse air relative humidity (ADCON Model TR1). Measures were used to determine vapor pressure deficit using the following formula:

VPD = es - ea (3)

Where, es is the saturation vapor pressure at a given air temperature and ea is the actual vapor pressure.

Stem Diameter Micro-Variations: In order to monitor, continuously and at real time, stem diameter microvariations, linear variable transducer (LVDT) sensors (Sifatron Model D.F. 2.5) were used as indicators of plant water status in tomato. Indices derived from continuous stem diameter micro-variations data have been developed to interpret these data. Maximum daily shrinkage (MDS) is the studied parameter and was calculated as the difference between maximum daily stem diameter (MXSD) and the minimum daily stem diameter (MNSD).

2.6.2 Stomatal Conductance:

Its weekly measurements were performed using a porometer (Leaf Porometer, SC1, Dacagon, USA) and occurred between 12:00 and 14:00.

III. RESULTS AND DISCUSSION

3.1 Greenhouse internal climate

According to VPD variation during the crop cycle, three phases are observed. The first period can be considered of law evaporative demand since the VPD didn’t exceed 1,5kPa. The second period registered a slight VPD increase that remains, however, suitable for tomato crop development and growth . At the end of the crop cycle, VPD values reached their maxima (4,5 kPa) and the internal greenhouse climate became too difficult.

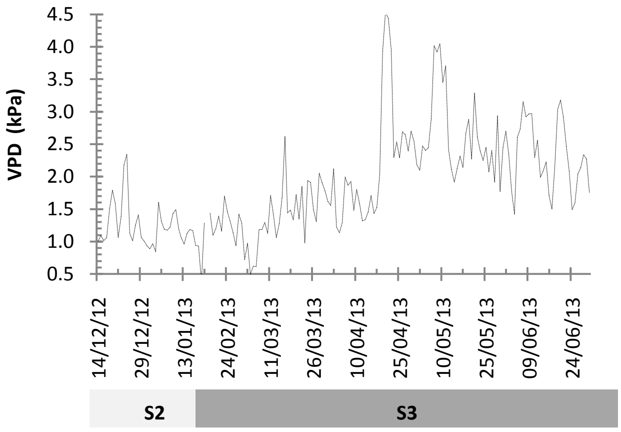
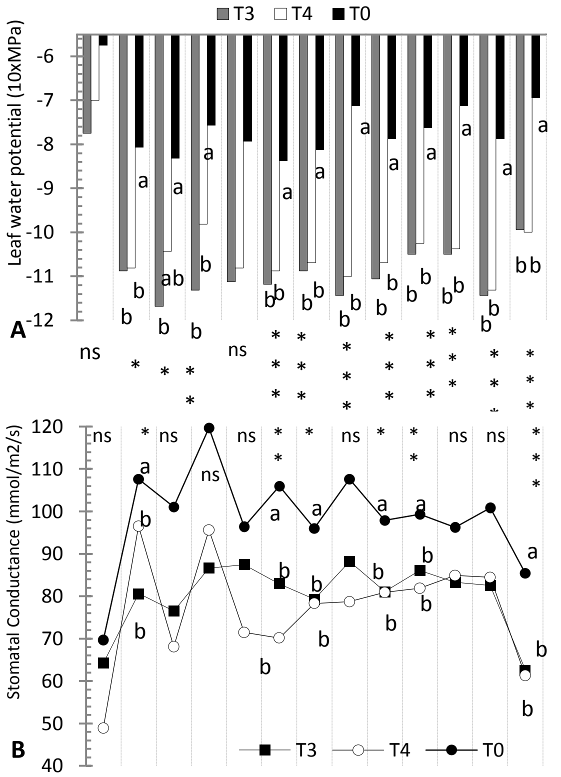


Figure 1: Greenhouse internal vapor pressure deficit variation through the crop cycle.

3.2 Midday stomatal conductance and leaf water potential responses

The average midday VPD varied between 1 kPa and 5 kPa recording several fluctuations. Different treatment responses in terms of stomatal conductance and Ψl during different measurement points are illustrated by fig. 2B and fig.2A. The highest stomatal conductance and Ψl levels were recorded by the control T0 with statistically significant differences at 46 % and 84 % of the measurement points, respectively, showing that the Ψl is more water stress sensitive compared to the stomatal conductance. Some research works suggest that the PRD strategy helps maintain the water status of tomato plant [3]. However, others researches that are in accordance with our findings reported the difference between the PRD treatment Ψl and control Ψl which records the highest values [6], [7], [8], [9]. These differences are results of phenological stage effect on tomato crop[8], the soil water status within the irrigated rootzone side [8], [9] and specie and variety specificity [6].

During the whole measurement period, there was no statistically significant difference neither for stomatal conductance nor Ψl when comparing T3 to T4. Nevertheless, regression curves (fig.3) show another difference. In fact, when comparing regression line slopes, we noticed that T3 regression line slope is twice that of T4 indicating the ability of T4 to maintain Ψl despite of stomatal conductance decrease whereas T3 Ψl was greatly reduced when same stomatal conductance decline occurs. According to [10], for tomato crop , a permanent value of Ψf less than -0.6 MPa indicates that plants are affected by water stress although midday Ψl could vary between -0.8 MPa and -1.2MPa without any effects on plant performance. Thus, PRD treatments were along the measurement period under progressive stress without reaching the threshold of danger.



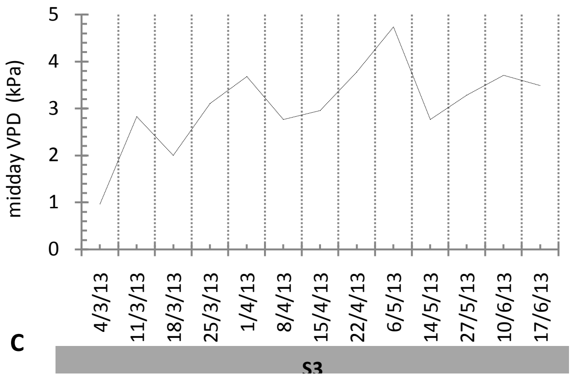


Figure 2: Stomatal conductance (B), leaf water potential (A) and midday VPD variation (C)

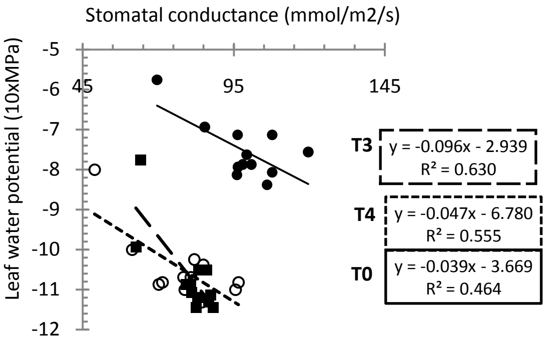


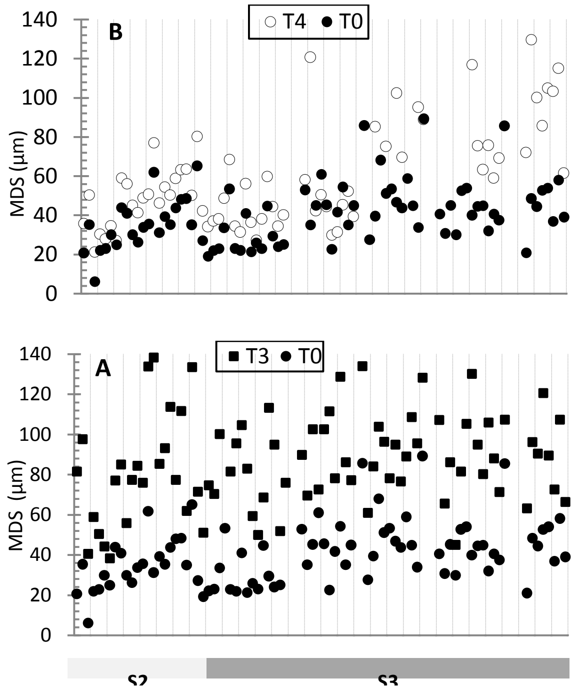
Figure 3: leaf water potential and stomatal conductance correlation

3.3 Maximum daily shrinkage

At the beginning of the measurement period, which corresponds to S2 and in terms of MDS, T3 and T4 responses were completely different. While T3 MDS reached an average of 81µm, that of T4 didn't exceed 47µm, 40% lower than T3. Besides, the rates of the average increase over the control were 141 % and 40 % for T3 and T4, respectively. Hence, MDS results indicate that T3 is 100% more stressed than T4. Since S2 is a low evaporative demand period (VPD≤2kPa) and the phenological stage of the crop is identical (F6 -R2), the explanation of the previous results exclude any climate or phenological stage role. Thus, the effect of alternation frequency adopted during S1 is confirmed. It seems, in fact, that developing roots were not enough able to search for water when they were left to dry the soil.

The beginning of the period S2 corresponds to the alternation frequency decreasing by two days for each treatment except T4. The least MDS values were recorded for T4 reminding, in one hand, the benefit of alternation frequency maintenance at different crop cycle periods and, in the other hand, previous adopted frequencies during S1. The same explanation was found by [11] who found that the application of regulated deficit irrigation with varying doses depending on the phenological stages leads to a lower performance in citrus plants while providing the same dose (50%) identically along the cycle improves both agronomic and physiological performances.

As far as the stage S3, during the period ranging from 01/14/2013 to 24/05/2013, which is considered the beginning of S3, the averages recorded MDS were 90µm and 53µm for T3 and T4, respectively. Compared to the control, the fore mentioned treatments increase rate were 126 % and 33%. Hence, T3 treatment remains the most stressed despite frequency alternation decrease. This response confirms the role of alternation frequency previously applied. T3 MDS results leads to conclude that long alternation frequency should be avoided at the beginning of tomato crop subject to PRD strategy. Referring to the greenhouse internal climate data, during the same period (Fig.4C), the values of the VPD are similar to those of S1 showing that the studied crop was not affected by the internal climate [12]. In fact, during vegetative stage, root system wouldn't be enough developed and would be unable to meet plant water needs during prolonged dehydration period. Identically, [13] concluded that applied to 100% water requirement irrigated tomato, the appropriate PRD introduction period is recommended between fruit set and harvest.



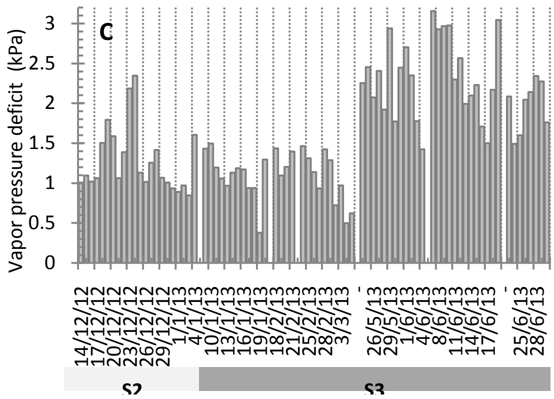


Figure 4: MDS (A and B) and VPD (C) variation

3.4 Water use efficiency

As showed by the fig.5 below, the control performed the lowest WUE comparing to PRD treatments. In fact, T3 and T4 were, respectively, 132% and 168% more efficient than T0. This result confirms previous findings since higher WUE means less water loss allowed by stomatal conductance decrease and leads to MDS reduction as found for T4.

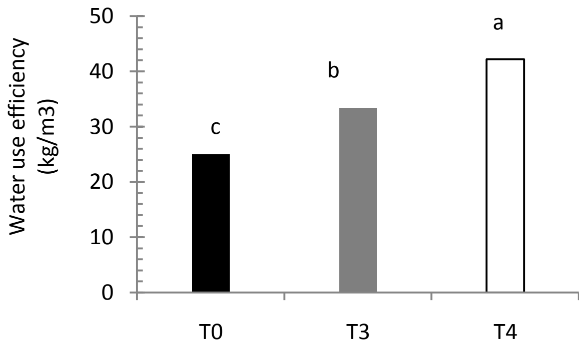


Figure 5: obtained Water use efficiency

IV. CONCLUSION

Applying fixed alternation intervals during the crop cycle seems to be better than varying them at different phenological stages. Besides, at the beginning of the crop cycle, long lasting alternation interval should be avoided.

V. ACKNOWLEDGEMENTS

This work was carried out within the SIRRIMED « Sustainable use of irrigation water in the Mediterranean Region» project which was funded by the European Union within the 7th Framework Program for Research and Development.

REFERENCES

[1] J. Van Schilfgaarde, Irrigation–a blessing or a curse, *Agricultural Water Management, 25*, 1994, 203–219.

[2] D.M. Mingo, J.C. Theobald and M.A. Bacon, Biomass allocation in tomato

(Lycopersicon esculentum) plants grown under partial root- zone drying: enhancement of root growth, *Funct. Plant Biol, 31,* 2004, 971–978.

[3] J.A Zegbe, M.H. Behboudian and B.E. Clothier, Partial rootzone drying is a feasible option for irrigating processing tomatoes, *Agric Water Manag*, 2004, 195-206.

[4] C. Kirda, M. Cetin, Y. Dasgan, S. Topcu, H. Kaman, B. Ekici, M.R. Derici, and A.I. Ozguven, Yield response of greenhouse grown tomato to partial root drying and conventional deficit irrigation, *Agricultural water management*, *69*, 2004, 191–201.

[5] O. De Villèle. Besoins en eau des cultures sous serre. Essai de conduite des arrosages en fonction de l'ensoleillement, *Acta Horti. 35*, 1974, 123–129

[6] S. Savic, F. Lui, S. Radmila, S.E. Jacobsen, R. Jensen and J. Zorica, Comparative effects of partial rootzone drying and deficit irrigation on growth and phyiology of tomato plants, *Arch. Biol. Sci., Belgrade*, 61 (4), 2009, 801-810.

[7] J.A Zegbe, M.H. Behboudian and B.E. Clothier, Responses of "Petopride" processing tomato to partial rootzone drying at different phenological stages. *Irrig. Sci*, *24*, 2006, 203-210.

[8] F. Liu, A. Shahnazari, M.N. Andersen, S.E. Jacobsen and C.R. Jensen, Effects of deficit irrigation (DI) and partial root drying (PRD) on gas exchange, biomass partitioning, and water use efficiency in potato, *Sci. Horticult*, *109*, 2006a, 113-117.

[9] F. Liu, A. Shahnazari, M.N. Andersen, S.E. Jacobsen and C.R. Jensen, Physiological responses of potato (Solanum tuberosum L.) to partial rootzone drying: ABA signaling, leaf gas exchange, and water use efficiency, *J. Exp. Bot*, *57*, 2006b, 3727-3735.

[10] J. Rudich and U. Lushinisky, Water economy in tomato crop, a scientific basis for improvement, 1986. (Eds) Atherton J.G and Rudich J. London, New York. 235-267

[11] A. Abouatallah, R. Salghi, B. Hammouti, A. El Fadl, M. El-Otmani, M.C. Benismail, N. Eljaouhari, El. El Kabous and A. Ziani, Soil moisture monitoring and plant stress measurement of young citrus orchard, *Der Pharma Chemica*, *3 (6)*, 2011, 341-359

[12] R.I. Grange and D.W. Hand, A review of the effects of atmospheric humidity on the growth of horticultural crops, *J.Sci*, *62(2)*, 1987, 125-134.

[13] A.J Zegbe, M.H Behboudian and E.C Brent, Responses of ' Petopride ' processing tomato to partial rootzone drying at different phenological stages , *Irrig Sci*, *24*, 2006, 203-210