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Effect of Partial Rootzone Drying on Growth, Yield and Biomass Partitioning of a Soilless Tomato Crop

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Abstract**—**The object of the present research was to assess the effects of partial rootzone drying (PRD) on tomato growth, productivity, biomass allocation and water use efficiency (WUE). Plants were grown under greenhouse, on a sand substrate. Three treatments were applied: a control that was fully and conventionally irrigated, PRD-70 and PRD-50 in which, respectively, 70% and 50% of water requirements were supplied using PRD. Alternation of irrigation between the two root halves took place each three days. The Control produces the highest total yield (252tons/ha). In terms of fruit number, PRD-50 showed 23% and 16% less fruits than PRD-70 and control, respectively. Fruit size was affected by treatment with PRD-50 treatment producing 66% and 53% more class 3 fruits than, control and PRD-70, respectively. For plant growth, the difference was not significant when comparing control to PRD-70 but was significant when comparing PRD-70 and control to PRD-50. No effect was on total biomass but root biomass was higher for stressed plants compared to control. WUE was 66% and 27% higher for PRD-50 and PRD-70 respectively compared to control.

Keywords**—**Biomass, growth, partial rootzone drying, water use efficiency yield.

I. Introduction

IRRIGATION accounts for more than 85% of water consumption worldwide [1]. That's why water saving techniques such as partial rootzone drying (PRD) was introduced. The PRD requires that only half of the root system is irrigated while the other is left to dry. Wet and dry sides of the root system are alternated at a predetermined frequency. It was demonstrated that there is no significant difference between the control and the plant irrigated by PRD at doses of 90%, 70% and 50% of water needs in terms of yield and fruit number [2]. The effect of PRD on vegetative growth was also extensively treated. Thus, many studies have shown that the PRD decreases vegetative growth by means of leaf area reduction [3]. The same finding was reported for grapevine [4] showing that PRD decreases the growth of primary and secondary branches and leaf area. Regarding the biomass, the PRD doesn't affect only its production but also its distribution within the plant [5], [6]. In fact, PRD plant root biomass significantly increases compared to shoots and compared to control roots.

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II. Materials and Methods

The experiment was carried out in the Agronomic and Veterinary Institute Hassan II- the Horticultural Complex of Agadir in a multi-tunnel greenhouse and on an area of 1300 m2. The used tomato cultivar is 'Pristyla' that was grafted on 'beaufort'. The crop was planted in 25th November 2010 and was conducted in vertical trellising and on a single stem. Each experimental unit was composed of 20 plants and consists of a soilless container (10m length, 25cm depth and 40cm width). The used sandy-silty substrate was deposed over two drainage layers: 5cm coarse gravel layer and 5cm fine gravel layer. The separation between root sides for PRD treatments was allowed by planting plants on the middle line of two juxtaposed substrate filled containers.

A. Irrigation

The irrigation was performed using double line drip irrigation system with 40cm spaced emitters dripping 2l/h. Switching of PRD treatments was allowed through small valves that are placed in the beginning of each drip line. Irrigation and fertilization were controlled through electro-valves and computer. Daily reference evapo-transpiration ETo was calculated using (1) [7]. Global radiation was measured by a pyranometer (kipp and Zonen model splite):

$$ETo\ (mm/j) = 0.0016 \times Rg\ (cal/m2/j) \qquad (1)$$

B. Experimental Design

A complete randomized design was used. Three treatments were applied: besides control treatment that received 100% of its daily water requirement, PRD-70 combined PRD and 70% of crop water requirements, PRD-50 consisted of combination between PRD and 50% of water crop requirements. Data were analyzed using MINITAB software version 15.1.1.0. Treatment means were separated by Tukey's test at $P \leq 0.05$.

C. Measured Parameters

1. Plant Growth

Plant growth was determined through weekly plant height measurement.

2. Biomass Production

Since old yellowed leaf pruning lasted along the experimental period, leaf biomass production was performed continuously by putting 100g sample of eliminated leaves in an oven at 65°C. When a constant mass was reached, samples were re-weighted. At the end of the crop cycle, all plant organs (stem, root, leaf) were subjected to the same process. For different plant organs, biomass production was calculated as the percentage of dry weight on fresh weight.

3. Yield and Fruit Size

25 harvests were achieved beginning on 28th December 2010. During each harvest, fruits were weighted and counted. As far as fruit diameter measures, two plants per treatment per replication were chosen and their fruits were subject to this process using a manual fruit sizer. Percentage of each class size was determined dividing total fruit number of each size by total fruit production.

III. Results and Discussion

A. Yield

The Control performed the highest total yield (252 T/ha). Statistically, two homogeneous groups were distinguished: the first one is composed of control and PRD-70 and the second one contains PRD-50. Although there is no significant difference between control and PRD-70 in terms of yield, there was a decrease of 10%. Compared to PRD-70 and control, PRD-50 yield decrease rate was, 16% and 30%, respectively. Yield decrease under PRD-50 treatment was also concluded by several researches [8] and could be explained by activity restriction under water supply shortage through stomatal closure [9].

Fruit number parameter had the same trend than previously discussed fruit weight (Fig. 2). PRD-50 showed the lowest fruit number compared to PRD-70 and the control. The decrease rates were 23% and 16%, respectively. Thus, fruit weight parameter was as affected by water shortage as fruit number [8] in the contrary of what was concluded by [10] who reported that, for PRD-50 treatments, and for water shortage sensitive crops such as tomato, fruit number is more affected than the other yield parameters. Fruit number reduction could be the result of floral abortion induced by water deficit [11]. Expressed as the ratio between total fruit weight and number, the averaged fruit weight of PRD-50 decreased by 7% and 5% compared to control and PRD-70, respectively (Fig. 3). Statistically, no significant difference was found. Such result can be explained, for PRD-70 by water availability and can be attributed, for PRD-50, to the root water uptake enhancement under PRD–50 as showed by [12].

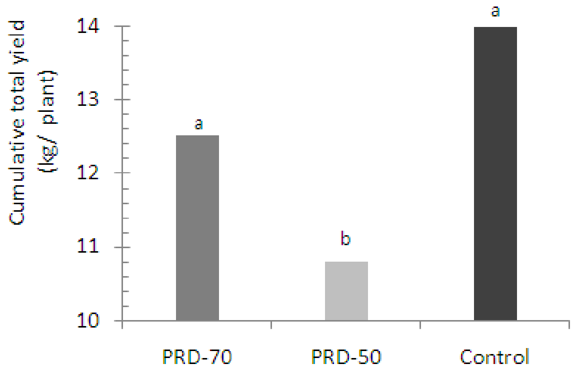

Fig. 1 Cumulative total yield (kg/plant)

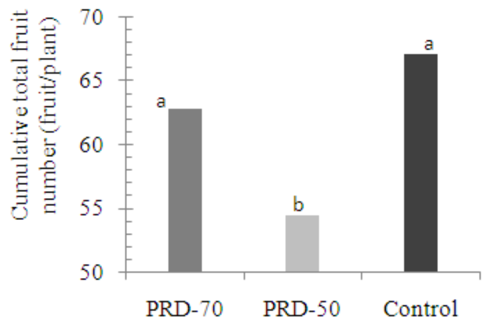

Fig. 2 Total fruit number (fruit/plant)

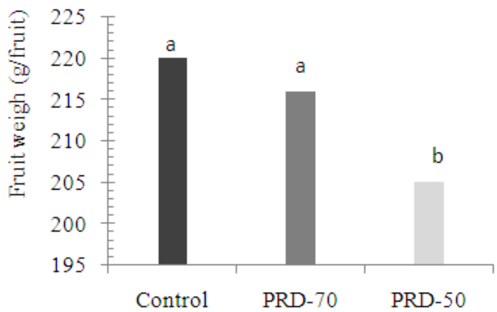

Fig. 3 Averaged fruit weight (g/fruit)

B. Plant Height

The used cultivar is of undetermined growth type. That's why the growth curve is continuously increasing during the crop cycle (Fig. 4). As far as height plant comparison, Treatment receiving less water (PRD-50) showed the lowest plant height as concluded by [13] who confirmed that growth is the most water stress sensitive process. The plant height of PRD-70 treatment weren't affected since no statistically significant difference was noticed when compared to control.

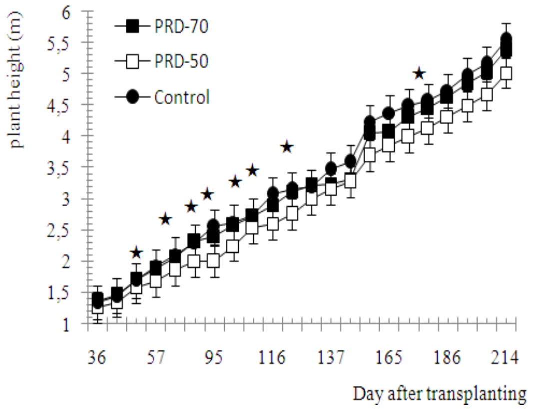

Fig. 4 Measured plant height: PRD-70 (■), PRD-50 (□) and control (●)

C. Biomass Production and Partitioning

The averaged produced leaf biomass for PRD-50, PRD-70 and the control were 22%, 20% and 16%, respectively. Thus, the control was the lowest leaf biomass productive treatment although the absence of statistically significant difference.

Comparing biomass allocation within each treatment, root biomass were about twice that of stem and leaf biomass showing that roots were the main biomass accumulating organs (Fig. 5). In fact PRD-70, PRD-50 and control produced 32%, 35% and 20% of dry matter in their roots while stem and leave biomass was only 14%-15%, 14%-17% and 12%-16%, respectively. A statistically significant difference between treatments in terms of root biomass accumulation was noticed (P = 0,011): PRD-70 and PRD-50 root biomass was, in fact, improved by 60% and 75% compared to control since exposure of roots to soil drying and re-watering increases root growth, which may enhance root biomass production [14], [15]. Besides, [16] and [17] confirmed that, even when water stress decrease plant biomass, its allocation to roots remains greater than to other organs. Reference [5] proved that PRD applied with 50% of water requirements enhanced root development through increasing root biomass by 55% while [2] and [18] concluded that, for PRD irrigated tomato, leaf and stem biomass production decreases as water stress increases.

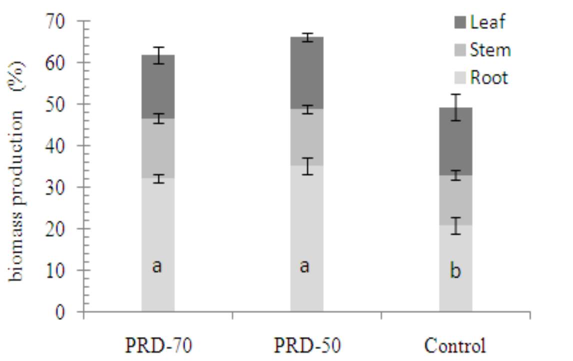

Fig. 5 Biomass production and distribution on different plant organs

D. Fruit Size

For all treatments, fruit size of class 2 (77mm–82mm) is the most dominant followed by class 3 (67mm-77mm) while class 1 and 4 fruit sized percentage remain low. For class 1, the control has the largest fruit size percentage that exceeds PRD-70 and PRD-50 by 0.5% and 26.5%, respectively (Fig. 6). Within the first fruit size class and according to statistical analysis, fruit size parameter presented a very high statistically significant difference between treatments (P <0.001). Mean comparison by Tukey's test allowed distinguishing two groups: PRD-70 and control in one hand and PRD-50 in the other hand. Hence, water quantities influenced fruit size. Well-irrigated treatments produced larger fruits than PRD-50, which can be explained by water and nutrient shortage as confirmed by [10]. Concerning the class 3, fruit percentage presented by PRD-50 was higher than control and PRD-70 by 66% and 53%, respectively. Statistically, there was a significant difference between treatments (P = 0.021<0.05). Fruit size "4" doesn't show any statistical significant difference. Knowing that all mentioned fruit sizes are suitable for export, treatment comparison could be more efficient if completed with economic study which allows determining the financial profitability.

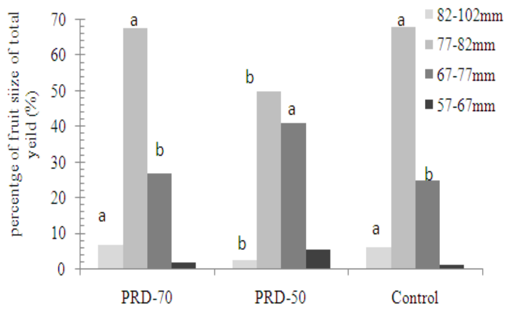

Fig. 6 Fruit size classification

E. Water Use Efficiency

The water use efficiency was calculated in terms of yield and total supplied water volume. While PRD-70 was 127% more efficient than control, the least irrigated treatment (PRD-50) was the most efficient since it was 166% and 150% more efficient than control and PRD-70, respectively.

TABLE I
WATER USE EFFICIENCY AND ITS IMPROVEMENT RATES COMPARED TO THE CONTROL

	PRD-70	PRD-50	Control
Total water supply (l/plant)	288	205	410
Total yield (kg/plant)	10	9	11
WUE (g/l)	33 ^{b}	43 ^{a}	26 ^{c}

IV. CONCLUSION

Supplying 70% of tomato water requirements using partial rootzone drying strategy don't affect any agronomic parameters since there was no significant difference between PRD-70 and the control neither for yield and biomass production nor for vegetative growth. These parameters were, however significantly reduced by water shortage of 50% ETc. Conversely, PRD-50 yielded the highest root biomass allocation which allowed for a better water use efficiency that reached 166% compared to the control.

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