# Chile root water uptake under partial root drying: a greenhouse drip irrigated study

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**Abstract**

*Partial root drying (PRD) experiments were conducted in greenhouse to evaluate comparative effects of compensated and noncompensated (no water stress) root water uptake patterns for chile (NuMex* Joe Parker*;* Capsicum annuum). *Three drip irrigation treatments used were: (1) control (fully irrigated), (2) PRD using vertically split-root system, and (3) PRD using two-compartment or lateral split-root system. In the vertically split system, water stress was applied to top 33% of the root zone whereas in the lateral split-root system alternate wetting and drying was imposed on each compartment. The two year experiment showed that chile plants under both PRD treatments with higher root length density and deeper rooting depth could compensate for water stress by taking up more water from the water available portion of the root-soil system to sustain transpiration or photosynthetic rates. Both PRD techniques have the potential for saving water in chile production especially for water limited arid environments.*

Keywords. Partial root drying, root water uptake, photosynthetic rate, transpiration rate

## Introduction

Water is one of the principal limiting factors for plant growth and development in arid climates. In arid regions, the plant growth is sustained by irrigation using surface and ground water resources because of low and non-uniform distribution of rainfall. Since good quality freshwater is becoming increasing scarce, there is a growing need for development of efficient irrigation methods. PRD is one of the efficient irrigation methods in which water can be applied directly to the root zone. PRD techniques were successfully applied in Olive (*Olive europaea;* Badia et al., 2009), Tomato (*Solanum lycopersicum;* Zegbe et al., 2004), and Canola (*Brassica napus;* Mousavi et al., 2010). However, only few accounts are available for PRD in chile that has deeper root system (Deb et al., 2012). Therefore, the objective of this study was to evaluate root and plant growth and water usage of chile plants under PRD. Our hypothesis was that plant growth would be the same for PRD treatments and control.

## Materials and Methods

### *Experimental set up*

Fig. 1. Experimental set up

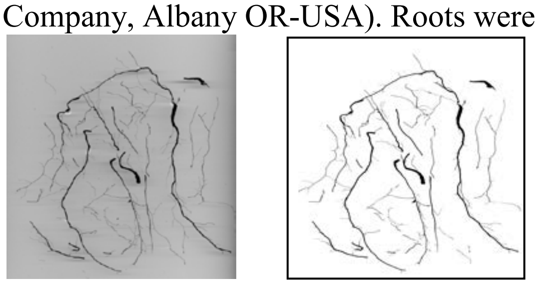
Experiments were carried out in the greenhouse (Fig. 1). New Mexican pod type chile (NuMex Joe E. Parker; *Capsicum annuum*) was sown on February 13, 2013. At eight leaf stage, seedlings were transplanted into containers (70 cm deep × 26 cm dia.) filled with sand, loam and organic matter in 1:1:1 by volume. Each pot was drip irrigated for 30 minutes on alternative days with flow rate of 2 $Lh^{-1}$. The drip irrigation treatments were Control in which water was applied by two emitters at surface using standard procedure, PRDv in which root zone was vertically divided and water applied by two emitters at 20 cm depth below surface, and PRDc in which root zone was divided laterally into two compartments and irrigated alternately using one emitter at a time. Completely randomized block design (CRBD) was used with three replications per treatment. To avoid edge effect and RLD determination two additional rows of plants were placed around treatment plants. Slow release fertilizer (Scotts Osmocote Classic) and liquid fertilizer (liquinox fish emulsion) were used as per the recoomendation.

***Measurement of soil water content, soil temperature and meteorology***

Two TDR sensors (Campbell Scientific, Inc., Logan, UT) at 0-30 and 30-60 cm for volumetric water content (θ) and two TMC6-HD sensors (Onset Computer Corp., Bourne, MA) at 5 and 25cm for soil temperature were installed in two containers per treatment. Air temperature, humidity sensor, and a net radiometer (Campbell Scientific, Inc., Logan, UT) were installed at 2 m above the bench. The Murray's equations (1967) were used for VPD calculations both inside and outside the greenhouse.

***Plant Parameters***

Photosynthetic rate, stomatal conductance, transpiration rate and leaf temperature were measured using LI-6400 XT portable photosynthesis system (LI-COR Biosciences, Lincoln, NE). These measurements were carried out on three fully expanded and exposed leaves per treatment between 800 h and 1100 h at two-week intervals. Plant height was measured manually and stem water potential (SWP) on bagged leaves was measured using Pressure Bomb (PMS Instrument Company, Albany OR-USA). Roots were washed manually and root images were scanned using Epson Perfection 3200 Photo flatbed scanner (Fig. 2a) and analyzed with ImageJ program after creating threshold image (Fig. 2b).



(a) (b)

Fig 2 (a) Scanned image of chile roots using EPSON PERFECTION 3200 PHOTO flat bed scanner and (b) Threshold image of chile roots created by ImageJ program

**Results and Discussion**

***Soil water content and soil temperature***

In control θ varied from 0.169 to 0.226 at 0-30 cm depth and from 0.192 to 0.279 at 30-60 cm depth. The lower water content in the upper 0-30 cm depth could be explained by higher moisture loss from surface because of evaporation (Fig. 3). θ values in PRDv treatment varied from 0.169 to 0.218 at 0-30 cm and

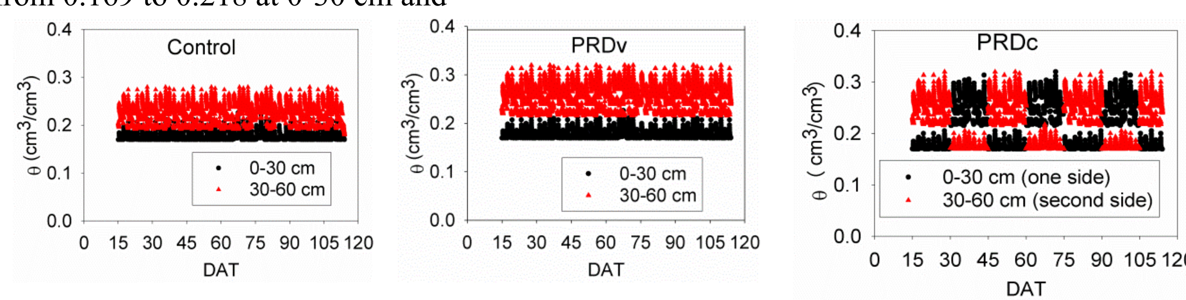



Fig 3. Variation of volumetric water content (θ) at 0-30 and 30-60 cm depths among three treatments i.e., control, PRDv and PRDc during growing period from 15 days after transplant (DAT) to 120 DAT, where date of transplant is April 29, 2013

0.215 to 0.320 at 30-60 cm depths (Fig. 3). In PRDv subsurface irrigation was applied and upper 33% soil was water stressed. The variation of θ in upper 0-30 cm depth was due to capillary rise or the root water extraction. In PRDc treatment, the trend of water content in both compartments followed the timing of irrigation (Fig. 3). The variations in soil temperature were similar in all treatments (Fig. 4).

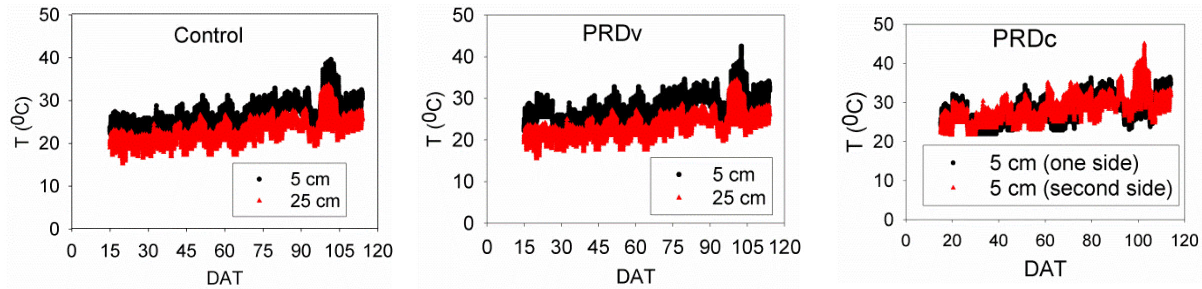



Fig 4. Daily variation of soil temperature (T) at 5 cm and 25 cm depths among three treatments i.e. Control, PRDv and PRDc during growing period from 15 days after transplant (DAT) to 120 DAT, where date of transplant is April 29, 2013

***Plant parameters***

In PRD treatments, RLD and root lengths were consistently higher than control during all three measurements (Fig. 5). The total root length in PRDv was about 152 to 195% of control while that in the PRDc was about 132 to 160% of the control. In control, roots were mainly concentrated in upper 0-20 cm. depth, while in PRD treatments rooting depths were up to 30 cm. Higher root lengths in PRDv treatment could be because of the low availability of water in the upper 0-20 cm depth and roots grew deeper into the soil profile to extract water from deeper depths. The root growth and root distributions in PRDc treatments were similar in both compartments, but deeper than that in control.

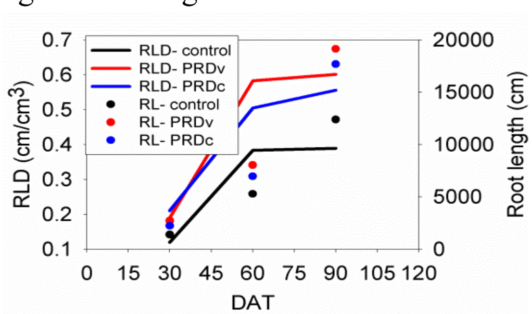



Fig 5. Root length density (RLD) and root length among control, PRDv and PRDc during 30 DAT and 90 DAT (May 14 – July 14, 2013)

Photosynthetic rates, stomatal conductance and transpiration rates remained similar among treatments (Deb et al., 2012) [Fig 6a & b and 7a]. Similar photosynthetic and transpiration rates were also reported for bell pepper by Pallas (1973). In order to sustain peak water demand, plants in both PRD treatments seemed to compensate for water stress in upper 20 cm depth in PRDv and compartment in PRDc by taking up more water from less stressed root zone (zone of higher θ). On accord with the photosynthetic rate and stomatal conductance, the plant height and SWP

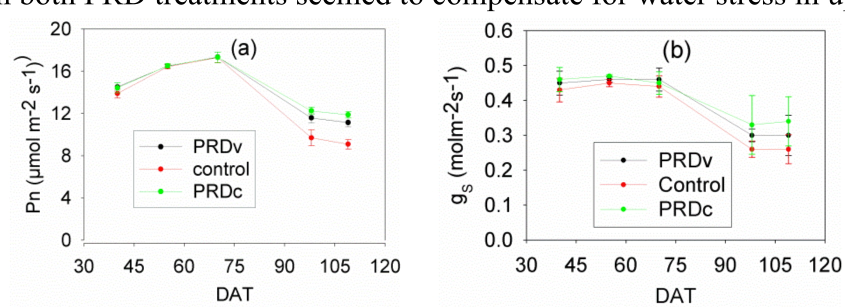



Fig. 6. Photosynthetic rate (Pn) and stomatal conductance ($g_S$) among all three treatments during growing season from 30 DAT to 120 DAT (May 14 – Aug. 05, 2013)

values among the treatments show only minor temporal variations (Table 1).

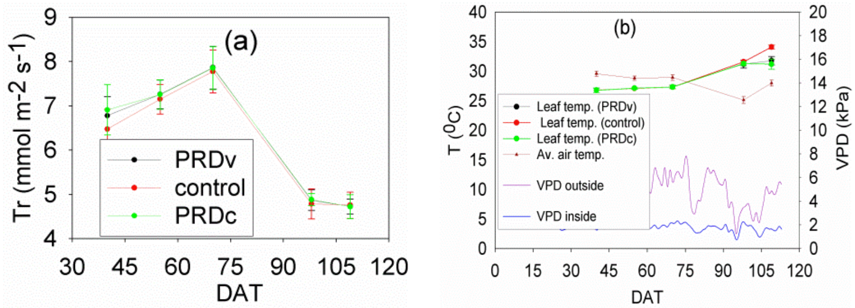



Fig. 7(a) Transpiration rates (Tr) among treatments during growing season from; (b) Average air and leaf temperature for control and PRD treatments, VPD inside and outside the greenhouse during 30 DAT to 120 DAT (May 14 – Aug. 05, 2013)

Table 1. Plant height and stem water potential (SWP) in. Control, PRDv and PRDc

| Parameters | Treatment | Days after Transplanting (DAT) on April 14,2013 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 15 | 30 | 45 | 60 | 75 | 90 | 105 |
| | | Apr. 14 | Apr. 29 | May 14 | May 29 | June 13 | June 28 | July 13 | July 28 |
| Height (cm) | Control | 9.4 | 12.4 | 18 | 26.4 | 31.6 | 32.2 | 39.6 | 42.9 |
| | PRDv | 10 | 14.2 | 20 | 29.2 | 34.4 | 36.6 | 39.3 | 40.6 |
| | PRDc | 10.1 | 12.4 | 16.4 | 24 | 31.8 | 33.2 | 38.0 | 43.5 |
| Stem water potential (bar) | | | | | | | | | |
| (Before irrigation) | Control | - | - | - | -4.88 | - | -4.93 | - | -4.90 |
| | PRDv | - | - | - | -4.81 | - | -4.88 | - | -4.82 |
| | PRDc | - | - | - | -4.90 | - | -4.89 | - | -4.80 |
| (After irrigation) | Control | - | - | - | -1.30 | - | -1.31 | - | -1.27 |
| | PRDv | - | - | - | -1.27 | - | -1.29 | - | -1.25 |
| | PRDc | - | - | - | -1.31 | - | -1.28 | - | -1.20 |

## Conclusions

Partial root zone drying could be used as a water conservation method for chile production in water limited areas. PRD methods can maintain potential photosynthetic and transpiration rate because of deeper roots and more root development in water available zones. In PRDc treatment, the root volume was about 50-50% in both compartments and roots were deeper and RLD were higher in both PRD treatments than control. We conducted this experiment under greenhouse conditions without interference of rainfall, but PRD methods are expected to maintain advantages in field conditions also.

## Acknowledgements

We thank New Mexico State University Agricultural Experiment Station for support. The support from GREG program of VPR is also acknowledged. We are highly thankful to National Agriculture and Forestry Research Institute (NAFRI) for imageJ program and EML of NMSU.

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