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# Partial Rootzone Drying

## Who is being tricked?

*The question on whether placed irrigation can manipulate hormonal changes, so that irrigation water can be saved with only minor yield losses, has been discussed for quite a while. An experiment is being conducted by the University of Hohenheim in Thailand to clarify whether the plant can be tricked by employing Partial Rootzone Drying (PRD), or whether the effect is only controlled deficit irrigation (CDI) and placed irrigation is a useless effort.*

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### Keywords

PRD, drought stress, deficit-irrigation, ABA, mango, water use efficiency

Under PRD - irrigation the plant's rootzone is split in two parts which are alternately irrigated in an interval of ten to fifteen days, while the other side dries out. According to theory the plant-stress hormone abscisic acid (ABA) is produced in the root's dry part which makes the plant reduce its water loss through transpiration by closing its stomata. It is claimed that the thereby reduced photosynthesis has a minor negative effect on fruit development as water can be taken up through the moist part of the root. However, vegetative growth should be clearly hampered. Thereby yield decline is minor and as a consequence water use efficiency increases considerably. A useful side effect: During the time the plant suffers drought stress, biomass production which needs to be pruned is reduced [1].

Experiments to back this theory are plentiful, however, the plant's hormonal balance is not completely understood. There is also a number of studies supporting the assumption that the effect leading to an increased water-use efficiency is mainly based on the plant response to drought stress, which is the same under placed and non-placed deficit irrigation [2, 3].

### PRD in Mango - experimental setup

The University of Hohenheim conducts a comparative experiment in Thailand. (Location: Mae Jo: about 30 km north of Chiang Mai, 18.5° N, 98.5° E, 350 m a.s.l.) On the experimental plot there are 350 nine years old mango trees (*Mangifera indica L.*, variety Choak Anan) on 0,56 ha, planted in a 4•4 m pattern. The research question is whether a difference between PRD and controlled deficit irrigation (CDI) really exists. Due to its high tolerance to drought stress, mango is especially appropriate for this investigation [4].

As a natural reaction to the periodical undersupply of water during the dry season (November until May) this tree-crop closes its stomata and thereby reduces water consumption. This natural effect should be artificially enhanced by PRD-irrigation.

On the experimental plot stress symptoms and yield have been controlled in four different irrigation-treatments: control with sufficient irrigation (Con), controlled deficit irrigation (CDI), partial rootzone drying (PRD) and a non-irrigated control (0V).

In the treatments Con and CDI irrigation water was applied by use of NETAFIM Superjet50 micro sprinklers, which have a flow-rate of 50 l/h and throwing width of 1.5 m. The sprinklers are pressure compensated; therefore a high distribution uniformity is guaranteed. For every tree one sprinkler had been installed. The PRD treated trees have been equipped with six drippers NETAFIM JR8. These emitters are also pressure compensated. The flow-rate of a single dripper is 8 l/h. Consequently during the same application time the PRD plots received approximately half of the irrigation water as the rest of the irrigated plots.

The main line on the field is a 2 inch PE-pipe (50mm), the laterals are 16 mm PE-pi-

*Table 1: Economic parameters of the irrigated treatments in the experiment*

| Treatment | spec. cost ( /tree) | Pressure (bar) | irrigation mm | irrigation ($m^3$/tree) | Yield per tree (kg) | Water use efficiency |
|---|---|---|---|---|---|---|
| Con | 1,08 | 1,5 | 270 | 4,32 | 12,78 | 2,96 |
| CDI | 1,08 | 1,5 | 135 | 2,16 | 9,19 | 4,26 |
| PRD | 1,05 | 0,7 | 130 | 2,08 | 12,26 | 5,89 |

*Table 2: Yield and size classes*

| Treatment | Yield per tree (kg) | size class in g >500 | 401-500 | 301-400 | 251-300 | 201-250 | <200 |
|---|---|---|---|---|---|---|---|
| Con | 12,78 | 8,5% | 22,1% | 44,3% | 13,7% | 9,4% | 2,1% |
| PRD | 12,26 | 9,1% | 23,4% | 49,7% | 10,4% | 5,3% | 2,2% |
| CDI | 9,19 | 8,0% | 25,2% | 38,9% | 14,1% | 11,3% | 2,5% |
| 0V | 5,78 | 13,7% | 23,3% | 26,7% | 13,8% | 16,9% | 5,5% |

pes of up to 50m length, which can be separately closed by manual valves. Water is supplied from a storage basin, about 12 m higher and 3 km away from the field through a 4 inch PP-pipe (100 mm). For generation of the pressure required for operation of the sprinklers, a single stage centrifugal pump ARENO HS2FL with a 4 kW electro motor has been used. To calculate the specific costs of the irrigation treatments, the costs for laterals, (pipes and flanges) emitters and valves in the case of PRD-irrigation have been considered (*table 1*).

Optimal irrigation quantity has been determined based on the Penman-Monteith equation for Evapotranspiration. For calculation the computer code CROPWAT was used, which is provided by FAO [5]. The reference evapotranspiration (ET0) during the irrigation period varied between 3.9 and 5.6 mm/d, leading to an irrigation requirement of between 2.7 and 3.3 mm/d. At the deficit irrigated plots application time was reduced by the half. The sloped field with its high stone-content (70 %) has a very low water holding capacity. Therefore irrigation took place three times a week to keep intervals between irrigation events short.

### Drought stress

In order to investigate drought stress symptoms in the PRD treatment the stomatal resistance in the course of the day has been measured. A transportable Porometer AP4 (Delta T) has been used for that task. This device measures the increase in humidity within a measuring cup and correlates this value to the stomatal resistance. Measurements were carried out in regular intervals during the month of April when the highest temperatures were reached towards the end of the dry season before occurrence of the first rain falls. In half-an-hour intervals five leaves per tree have been examined in each orientation (N, S, E, W). The resulting curves have been analysed on drought stress.

During the dry season stomatal resistance was higher in all treatments (also in the irrigated ones) than during the rainy season. Especially in the afternoon hours stomata close more due to high irradiation and temperature. This reaction could not be observed in the PRD treatment. Consequently it could not be proved that by PRD an additional drought stress was induced. There is evidence for the assumption that irrigation water was more efficiently used than when it was applied by drippers (*Fig. 1*).

### Harvest

At harvest the fruit weight as well as the average number of fruits per tree have been measured. All mango fruits have been classified according to size classes as recommended by the Ministry of Agriculture of Thailand. The yield in the PRD treatment did not show significant differences to the completely irrigated control, while the CDI treatment had a much lower yield. Regarding size class distribution CDI and 0V treatment turned out to produce a high amount of fruit which are not useful but for processing (<300 g). The relatively high share of fruits in the uppermost size class of the 0-treatment can be explained by the fact that some trees suffering drought stress dropped some of their fruits. The absolute number of big fruits is however lower than under full irrigation and PRD (*table 2*).

The water-use efficiency was calculated as a relation between yield and volume of applied water [6]. As in both treatments PRD and CDI only half of the irrigation water has been applied, water-use efficiency in those treatments was high (*table 1*). The consequent yield loss in the deficit irrigated treatment would hardly be acceptable for a farmer, while yield as well as the share of marketable fruits in the PRD treatment differed little from the well irrigated control.

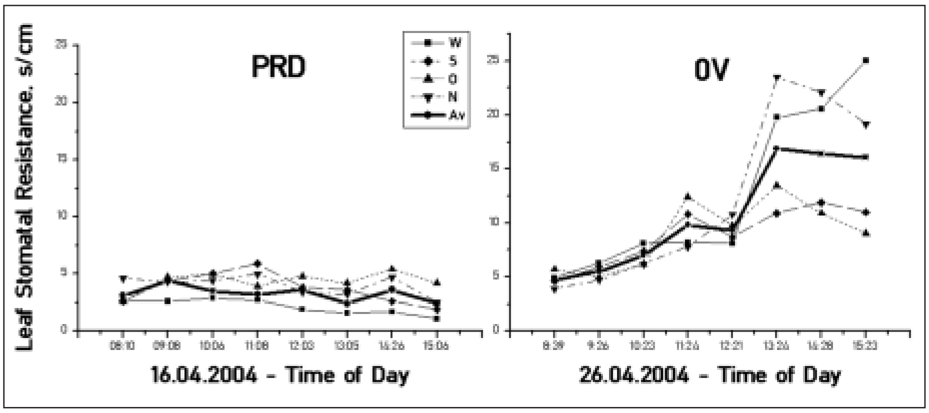


*Fig. 1: Stomatal resistance in the treatments 0V and PRD during the irrigation period and after start of the rainy season*

### Conclusion

In this experiment it was not possible to show that by use of PRD an additional drought stress can be induced. However, similar to previous experiments, a far higher water-use efficiency was measured, without significant yield loss, as obtained under deficit irrigation. The clear differences in yield can hardly be explained by an altered reaction to drought stress of the trees. It can be rather assumed that due to an interaction of a quicker infiltration into the dry soil and a direct application of irrigation water by drippers the irrigation efficiency was increased.

As a practical conclusion it can be stated that if water availability is a limiting factor of production, PRD can be an interesting alternative for a drought stress tolerant crop such as mango. The partly extreme increase in water-use efficiency can justify the application of PRD, even though presently there is the need for more research about the plant physiological basics for the functioning of the method.

As compared to a simple drip irrigation, higher costs are produced only due to regulating valves and the increased logistics. In comparison to an irrigation system with micro-sprinklers higher costs for pipes are mainly compensated by the lower costs of the emitters, making that only the higher expense for maintenance comes into the account. The lower pressure requirement for the drippers can play an important role for the decision.

Apart from plant response to drought stress the influence of application methods of irrigation water has to be examined, as low evaporation losses, enhanced by a higher infiltration rate of the dry soil, might be a main cause for the difference between the tested methods. An intensive research on the influence of irrigation techniques on the success of deficit irrigation will be in the foreground of our further experiments.

## Literature


Books are identified by •

[1] *Stoll, M., B. R. Loveys and P. R. Dry*: Improving water use effiency of irrigated horticultural crops. Journal of Experimental Botany 51 (2000), pp. 1627-1634

[2] *Dry, P. R., B. R. Loveys, M. Stoll, D. Steward and M. G. McCarthy*: Partial rootzone drying - an update. Australian Grapegrower and Winemaker 438a (2000), pp. 35-39

[3] *Caspari, H. W., T. Einhorn, S. Neal, P. Alspach, B. G. Leib, L. Lombardini and J. R. McFerson*: Irrigation volume rather than placement determines response of apple trees to deficit irrigation . On site program XXVIth International Horticultural Congress and Exhibition (IHC2002), August 11th-17th 2002, Toronto, Canada

[4] • *Rehm, S. und G. Espig*: The cultivated plants of the Tropics and Subtropics. Verlag Josef Margraf, Weikersheim, 1991

[5] • *Allen, R. G., L. S. Pereira, D. Raes and M. Smith*: Crop Evapotranspiration - Guidelines for Computing Crop Water Requirement. FAO Irrigation and Drainage Paper 56, Rom, 1998

[6] • *Doorenbos, J. and A. H. Kassam*: Yield response to water. FAO Irrigation and Drainage Paper 33, Rom, 1979