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Introduction of micro-sprinkler systems to mango production into the uplands Northern Thailand

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Abstract: In order to asses water saving potentials of advanced irrigation methods in irrigated mango production in Northern Thailand, micro sprinklers have been introduced and compared into the area. Three micro sprinkler treatments were established on two commercial orchards: a. Full irrigation based on climate data, b. Partial Rootzone Drying, c. Farmer's decision. These treatments were compared to the traditional irrigation methods. It was found that by the introduction of micro sprinklers, farmers were able to increase their water use efficiency, while the fruit size distribution was more favourable for export marketing.

Keywords: Water use efficiency, Water saving potential, Fruit yield, Fruit size

1. INTRODUCTION

Mango fruit is grown in more than 90 countries but less than 5% of the production is exported (Evans and Mendoza, 2009). Thailand is one of the largest mango exporters in the world and the main exporter for the Japanese market. The most important export variety is Nam Dok Mai. With its light to bright yellow color and harmonic oblong shape it meets consumer preferences. The quality is classified to be excellent with a pleasant aroma (Knight *et al.*, 2009).

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Flowering and fruit development takes place during dry season. Thus, irrigation is necessary to obtain high yield and to meet high quality standards for export.

In the northern part of the country farmers mostly water their trees by use of flexible hoses which are dragged over the field. While this technique involves low investment costs, operation costs in terms of labor and energy are high. The application efficiency of such systems is low. As farmers have no access to weather or soil data and do not measure the amount of water used, irrigation scheduling depends on the irrigators experience only.

As water for irrigation is an increasingly scarce resource in the Northern part of Thailand, deficit irrigation offers a water-saving alternative. There is considerable scope for improving water productivity, which means growing fruit with less water (Goodwin and Boland 2002). Deficit irrigation (DI) is a successful praxis to be used for the increase in crop water productivity (e.g. Fereres and Soriano 2007, Geerts and Raes 2009). While uncontrolled DI is generally linked with a decrease in yield quantity or quality (Kriedemann and Goodwin 2003), recent studies on different crops have shown that under partial rootzone drying (PRD) yield loss can be minimized or avoided (e.g. Costa et al. 2007).

In a series of on-station experiments mango-irrigation based on climatic water balance calculations has been tested and compared to deficit irrigation. It was shown that the yield is a function of irrigation water applied (Spreer *et al.*, 2009) while fruit ripening and internal quality parameters are not affected by the irrigation method (Spreer *et al.*, 2007). The increase in harvest yield obtained under irrigation is often due to more fruit as a consequence of less fruit drop, rather than bigger fruit (Pavel and Villiers, 2004; Spreer *et al.*, 2009). An economic analyses showed that due to better harvest the introduction of micro-irrigation has a payback time of less than five years and under conditions of restricted access to water PRD is the most economic irrigation method (Satienperakul *et al.*, 2009).

In order to compare traditional farmers' irrigation practices to modern micro-irrigation systems and up-to-date scheduling methods, a comparative study was carried out during two consecutive years on two commercial orchards in Northern Thailand. In this study PRD was used as the only DI method, as it was found that yields are better than under uncontrolled DI (Spreer *et al.*, 2009), while regulated deficit irrigation (RDI) on the other was considered to be too complicated for farmers to adapt, as it requires a very sensitive scheduling. Water use, yield and quality parameters were determined to analyze the suitability of different irrigation methods in the agricultural practice.

2. MATERIALS AND METHODS

The climatic water balance was calculated based on reference evapotranspiration (ET_0) estimation according to the FAO-Penman-Monteith approach (Allen *et al.*, 1998). Required data on air temperature, wind speed and relative humidity were measured with a weather station PCE-FWS 20 (PCE Group, Germany), at a distance to the two sites of one and three kilometers, respectively. Net radiation was estimated based on extraterrestrial radiation and daily temperature difference as proposed by RAES *et al.* (2009). Potential crop evapotranspiration (ET_c) of mango was calculated using a crop factor (K_c) of 0.8. Rainfall was recorded with the same weather station and subtracted from ET_c.

The experiments were carried out on two commercial orchards in Phrao, Chiang Mai Province, Thailand. Orchard A (19°24'N, 99°15'E, 440 m a.s.l.) is situated on a gentle slope with a sandy loam soil with a sand:silt:clay distribution of 73:12:15. Field capacity (FC) is at 34.6 % (vol.). The orchard is intensively managed, with trees being pruned to a uniform height of 2.5 meters and planted in a strict 4x4 meters pattern. Orchard B (19°26'N, 99°14'E, 490 m a.s.l.) is on a steeper slope with a high stone content. The soil fraction is sandy loam with a sand:silt:clay ratio of 62:14:24 and FC at 35.5% (vol.). This orchard is not managed intensively. The trees are planted in an irregular pattern, approximately 4x4 meters apart.

On each field three blocks with 20 trees each were equipped with micro-irrigation systems with one pressure compensating micro-sprinkler with a flow-rate of 50 l/h (Netafim Supernet 50NR) per tree. The system efficiency was estimated to be 90% for the calculation of crop water requirement (CWR).

The irrigation treatments were full irrigation (FI), partial rootzone drying (PRD), farmer's irrigation with micro-sprinklers (Fm) and farmer's traditional irrigation (Ft). FI, PRD and Fm were irrigated by micro-sprinklers; Ft was irrigated by the farmer with his traditional hose technique and according to his own scheduling criteria. Scheduling of FI was 100% of ETc, split in two applications per week, PRD with 50% of ET_c was irrigated weekly. Scheduling of Fm was done by the farmer himself.

Water use of the micro-irrigation treatments was determined by flow-meters. In Ft water consumption was determined based on the determination of the average flow rate and time of application as measured on the field.

Soil moisture was monitored by time domain reflectometry (TDR) at 10 cm and 30 cm, respectively, in each treatment.

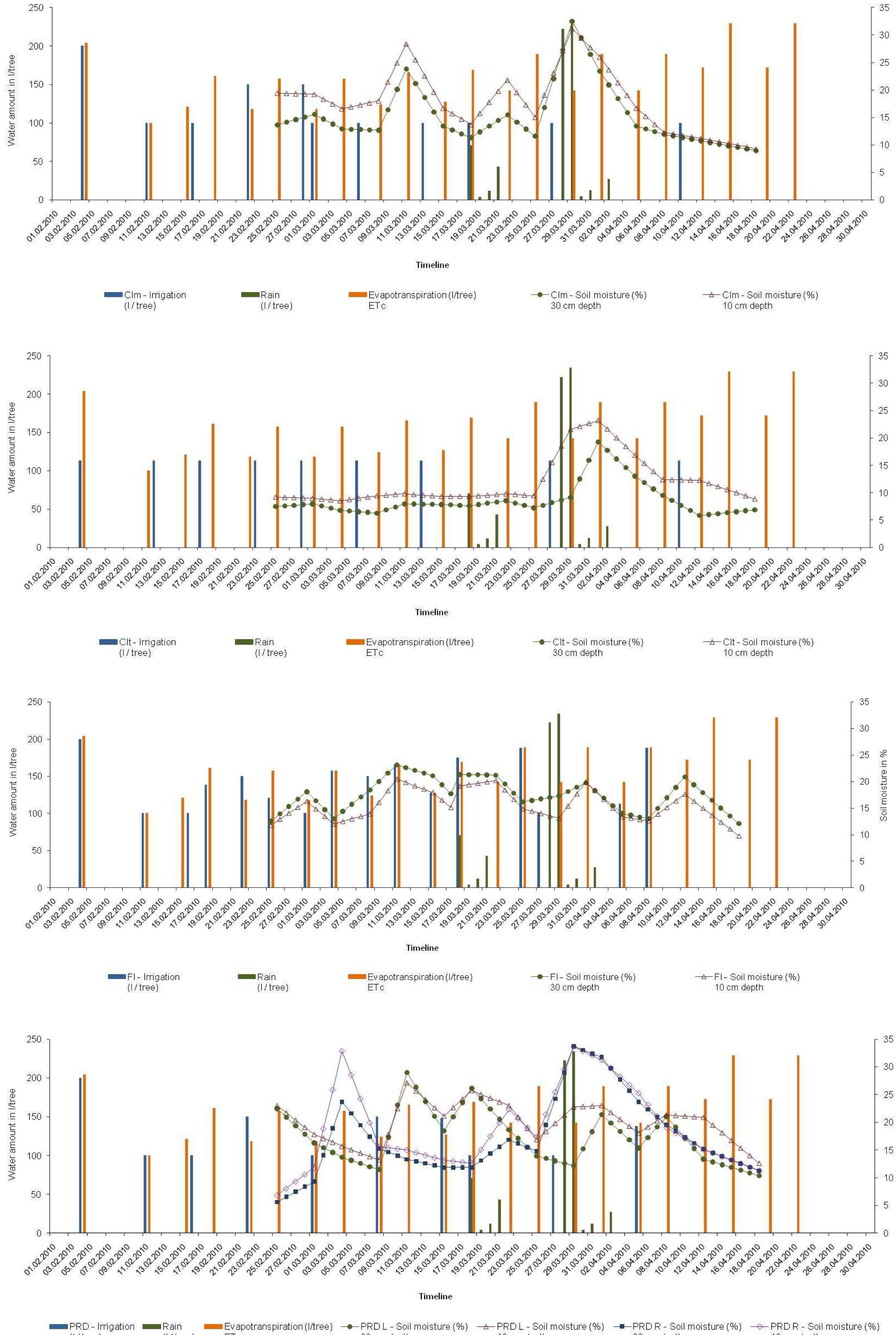

Figure 1: Soil water in balance under different irrigation treatments on mango field B: Farmer irrigating with micro sprinklers (Fm), farmer's traditional irrigation (Ft), calculated full irrigation (FI) and Partial Rootzone Drying (PRD)

While there was one measuring in each treatment for FI, Fm and Ft, PRD was equipped with two measuring points to monitor alternating wetting and drying of the different sides. Average water content during the cropping season was calculated to compare water supply in different treatments.

The yield formation was monitored in a one-week-interval. Length, maximum width and maximum thickness were measured with a vernier caliper. The product of the three dimensions rendered a parameter for fruit size, allowing the calculation of the growth rate, however, without estimating the fruit mass. As the correlation factor determined for another cultivar (Spreer *et al*., 2011) has not been determined for Nam Dok Mai Mango. Final fruit yield was determined in terms of total yield per tree and single fruit weight of all harvested fruit. Water use efficiency has been calculated as the amount of harvested fruit per unit of irrigation water applied (Doorenbos and Kassam, 1979)

After harvesting the fruit were cleaned and maturity was tested by the floating test. Colour and sugar : acid ratio were determined after harvest and during one week of post harvest ripening.

3. RESULTS

Irrigation started after full bloom on 4th of February and was continued until 16th of April (67 days after full bloom (DAFB)) when due to drought in the region irrigation water was no longer available. Harvest took place on 5th of May (86 DAFB). The ET_0 for the irrigation period was 278.5. Rain in the same period was recorded with 59.4 mm. The total irrigation requirement for the season was calculated to be 2.83 m^3/tree.

Figure 1 shows the soil moisture curve for different treatment during the irrigation period. Even though similar quantities of water were applied in FI as in Fm and Ft, the average water content was lower in Ft as in the treatments with micro-sprinklers. This is due to run-off of water on the sloping field with water application by hose which is higher than the infiltration rate. Moreover, in both farmer's treatments irrigation intervals were chosen longer than in FI leading

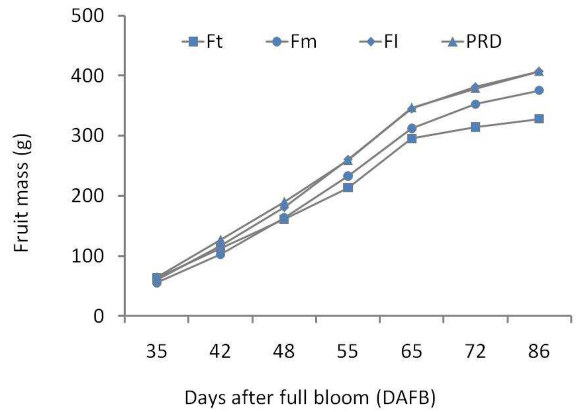

Figure 2: Mango fruit mass development in different irrigation treatments

to a periodical drying of the soil. The fruit growth showed clear differences between the scheduled treatments and the farmer's treatments (Figure 2). As FI and PRD were constantly well supplied with irrigation water the fruit growth was more, especially during the period of fast fruit development were most fruit biomass is formed. Therefore, fruit size in orchard A was significantly higher in PRD and FI as compared to Ft and Fm. The differences in orchard B were less pronounced as the yield in the farmer irrigated treatment was very low (Table 1).

Table 1: Yield, irrigation water use and water use efficiency for different irrigation treatment in Mango

Treatment	Average Yield (kg/tree)	Irrigation water applied (m^3/tree)	Water use efficiency (kg/m^3)
	Farmer A		
Ft	27.2 ± 18.1	3.12	8.72
Fm	27.3 ± 17.4	2.68	10.10
FI	25.7 ± 16.3	3.04	8.45
PRD	20.8 ± 6.6	1.89	11.01
	Farmer B		
Ft	4.3 ± 3.4	1.64	2.62
Fm	5.8 ± 2.4	1.92	3.02
FI	8.4 ± 6.9	2.81	2.99
PRD	9.4 ± 4.3	1.71	5.50

While farmer A reduced irrigation water consumption when applying micro sprinklers, maintaining his yield, farmer B increased both water use and yield. Thus, water use efficiency was generally increased by the use of micro-sprinklers as compared to the traditional irrigation. The highest WUE was obtained in Table 1 shows the yields in the different treatments in both orchards. On orchard A the farmer irrigated trees yielded highest. This was, however, an effect of a high number of fruits, leading to a high share in small, not marketable fruits. On orchard B the farmer irrigated treatment received less water than calculated, resulting in a low yield. The yield level is lower as compared to orchard A, due to the generally less intense management. This includes lower fertilizer and pesticide applications and shading due to discontinuous pruning. In orchard B FI and PRD yielded highest with no significant difference in fruit size. both orchards under PRD.

4. DISCUSSION AND CONCLUSION

The introduction of micro-sprinklers into irrigated mango production in Northern Thailand has the potential to increase both yields and WUE. It was shown that farmers can well handle and operate micro-irrigation systems, even if they receive no additional extension in terms of irrigation scheduling. Interestingly, it was shown, that farmers' experience matches quite well with the calculated irrigation water requirement. Further, it was observed that farmers may react differently if a more efficient irrigation system is installed. While farmer A reduced his irrigation water consumption, farmer B exploited the better irrigation system to increase his yield.

If scheduling is done based on a climatic water balance it is possible to further increase WUE and obtain fruit of a more uniform shape and size. As fruit size is a crucial factor in marketing of export fruit it is concluded that farmers who produce for export need to rely on improved irrigation scheduling to exploit the full benefit of installing a micro irrigation system.

Under the impression of extreme drought which occurred towards the end of the season the benefits of deficit irrigation were visible. However, on the intensively managed orchard A the application of PRD lead to reduction in yield. Under this kind of conditions the application of PRD can only lead to an improved situation in overall irrigation water availability, if all farmers who use the same source of water agree on applying deficit irrigation.

It is therefore, considered necessary to support the introduction of improved micro sprinkler systems on a communal level and, at the same time, establish an irrigation extension service who can advise farmers in water efficient irrigation including the option of deficit irrigation under the impression of extended drought periods.

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