CHAPTER 4

COMPARISON BETWEEN TRADITIONAL AND SCIENTIFIC IRRIGATION SCHEDULING PRACTICES FOR FURROW IRRIGATED POTATOES IN ETHIOPIA

4.1 Introduction

In Ethiopia, small-scale traditional irrigation schemes constitute about 40% of the total irrigated land area. Despite this fact, the sector has largely been overlooked by authorities and was not supported by improved water management technologies. Due to land and water resource shortages and the need for food self-sufficiency in the region, it has become essential to improve the productivity of this sector. A recent survey conducted at Godino, one of the representative schemes, revealed that farmers applied irrigation water according to its availability, regardless of profile deficit, crop type and growth stage. This highlights the fact that scarce water resources are not being used optimally and emphasises the potential for improved water productivity by implementing efficient irrigation management practices.

Potatoes (*Solanum tuberosum* L.) are one of the most important crops grown on the Godino scheme. Potatoes are shallow-rooted and more sensitive to soil water stress than other deep-rooted crops (Canada Saskatchewan Irrigation Diversification Centre (CSIDC), 2005; Tekalign & Hammes, 2005a ; Tekalign & Hammes, 2005b). Most of the potato root system is confined to the top 0.2 - 0.3 m of the soil profile, although, depending on the soil type and available soil water, some roots may penetrate to a depth of 1 m. In addition to its shallow root system, the complex physiological response to water stress makes potatoes sensitive to even moderate plant water deficits (Bradley *et al.*, 2005). The major physiological responses of potatoes to water stress, next to stomatal closure, are reductions in leaf expansion, stem and tuber growth (Van Loon, 1981; Bradley *et al.*, 2005). Potatoes are particularly sensitive to water stress during tuber initiation, early tuber development and tuber bulking (Jefferies, 1993; Juzl & Stefl, 2002; Lahlou *et al.*, 2003; Tourneux *et al.*, 2003; Bradley *et al.,* 2005).

The goal of irrigation management is to maintain the water level in the root zone within a range where crop yield and quality are not hampered due to either insufficient or excess water. For potatoes, soil water content in the root zone should not be allowed to drop below 65% of the available soil water storage between irrigations (King & Stark, 2002).

Monitoring soil water in the crop root zone will allow better management of water applications in order to meet the requirements of the crop. However, direct measurement of soil water in the field is tedious and usually requires specialised equipment. Irrigation scheduling models can estimate how much water is needed and when best to apply it on different soil types and crops. Many water balance approaches have been used to estimate crop water availability and irrigation requirements. Most of the time, calculations are based on potential evapotranspiration values estimated by locally tested formulae or, at best, on the Penman generalised expression (Smith, 1992a; Allen *et al.*, 1998). The Soil Water Balance (SWB) model is a mechanistic, real-time, generic crop, and soil water balance irrigation scheduling model (Annandale *et al.*, 2000; Jovanovic *et al.*, 2002). It gives a detailed description of the soil-plant-atmosphere continuum, making use of weather, soil and crop management data. The model has been tested extensively and found to give reliable estimates of water use for a wide range of crops (Annandale *et al*., 2000; Jovanovic *et al*., 2002; Geremew *et al*., 2007). As an alternative to real-time scheduling, SWB can also be used to generate Irrigation Calendars, using site-specific soil and management inputs and long-term weather data. The generated irrigation calendar guides the user on when to irrigate and how much water to apply (Annandale *et al.,* 2005). This approach can be very useful to small-scale farmers, who may not have access to computers or the skills to use them.

The wetting front detector (WFD) is also another simple and affordable irrigation-scheduling tool that monitors the physical movement of water down the soil profile (Hanan *et al.*,1994; Stirzaker, 2003; Stirzaker *et al.,* 2004). It was suggested that the combined use of SWB and WFDs could provide a more useful recommendation to the user (Annandale *et al.,* 2005). Detectors are usually placed in pairs at different soil depths. Recommended placement depths for flood are 20 cm for the shallow WFD and 50 cm for the deeper WFD. Deeper placement may be considered for infrequent irrigations or very long furrows (Stirzaker, 2007). If the detectors are rarely activated, the crop is likely to be under-irrigated. If both shallow and deep detectors regularly respond to irrigation, the crop is likely to be over-irrigated (Stirzaker, 2003; Stirzaker *et al*., 2004). This information can then be used to adjust the calendar recommendation upwards or downwards, as necessary.

An experiment with potatoes as test crop was established at the Debre-Zeit Research Centre in Ethiopia. The objective was to compare two commonly- followed traditional irrigation regimes with two scientifically- based irrigation management methods, namely SWB Irrigation Calendars (with WFD feedback) and soil water monitoring, using a neutron probe. The hypothesis was that the use of scientific irrigation scheduling methods could improve water use efficiency.

4.2 Materials and methods

Site description

The study was conducted at the Debre-Zeit Agricultural Research Centre experimental farm from January to April 2005. The site is located at 8^o 44' N, 39^o 02' E at an altitude of 1 900 m. It receives an average annual rainfall of about 900 mm, with the highest average monthly maximum temperature of 28 ^oC in May and the lowest average minimum temperature of 9^oC in December. According to the data from the National Soil Laboratory Service (unpublished), the soil is classified as clay loam in texture, with a bulk density of 1.29 Mg m^{-3}, field capacity of 0.33 kg kg^{-1} and permanent wilting point of 0.18 kg kg^{-1}, which gives a plant available water (PAW) of around 200 mm m^{-1}.

Field procedures

The soil was thoroughly prepared using a mouldboard plough, then levelled and ridged, to give a row spacing of 0.75 m. Sprouted potato tubers (local variety Awash) were planted on 12 January 2005 at a spacing of 0.3 m within the row. Each plot consisted of six 5 m long rows. A ridge of about 25 cm high was constructed around each plot to facilitate the even distribution of furrow- applied water within the plot and to avoid water from flowing out of the plot. Fertilisers were applied according to recommended guidelines (W.G. Gebremedhin, 2003, HARC, Ethiopia). The crop received 110 kg ha^{-1} N in a split application, half at planting and the rest 30 days later, in the form of urea. The crop also received 92 kg ha^{-1} P as di-ammonium phosphate at planting. The experiment was arranged in a randomised complete block design (RCBD) with four replications. Since the soil was dry at planting, four weekly irrigations of 60 mm each were applied to all plots before treatments were imposed, to ensure uniform plant establishment. There was no obvious pest infestation, except for tuber moth at levels far below the threshold for chemical control. Three fungicide sprays were applied at fortnightly intervals for the control of early and late blight. Weeding and inter-row cultivations were performed by hand hoeing when deemed necessary.

Irrigation treatments

1. *SWB treatment*: the 29- year average daily maximum and minimum temperatures, as well as soil physical properties, planting date and irrigation management options were used as inputs to the SWB model (Jovanovic *et al.*, 2002) to produce a site- specific seasonal Irrigation Calendar. For the first part of the growing season (until about 40 days after planting (DAP)) an irrigation interval of once every five days was used, whereafter the interval was increased to once every seven days. Two WFDs were installed in each plot, one at 0.3 m soil depth (Shallow WFD) and the second at 0.5 m (Deep WFD). These depths were slightly deeper than the most recent recommendations (Stirzaker, 2007). The WFDs were used as feedback to decide whether the irrigation amount recommended by the SWB calendar needed upward or downward adjustment. Ideally, all shallow WFDs should respond after each irrigation event, while deep WFDs should only respond occasionally. A simple algorithm was used to decide when to adjust the recommended irrigation amount, depending on the number of shallow and deep WFDs responding after

the previous irrigation event (Annandale *et al*., 2005). When the WFDs indicated under- irrigation, the recommended water amount for the next irrigation was increased by 20%. Likewise, when the detectors indicated over-irrigation, the next irrigation amount was reduced by 20%.

2. The *Farmers' Traditional Practice* (FTP) was based on the average irrigation depth and interval practised by the Godino scheme farmers close to the experimental station. For this treatment 50 mm of water was applied once every 10 days.
3. The *Research Centre Practice* (RCP) treatment was implemented, using the average irrigation depth and interval as practised by the Debre-Zeit Agricultural Research Centre, namely 60 mm of irrigation applied every six days.
4. In the fourth treatment, soil water content was monitored weekly using a *Neutron Probe* (NP), and the profile was refilled to field capacity. However, for the first part of the growing season (until about 50 DAP) the NP instrument was not functional. During this period a water amount of about 40 mm was applied every seven days, including rainfall.

Data recorded

Soil water content (WC) was measured with a neutron probe (Model 503DR CPN Hydroprobe, Campbell Pacific Nuclear, California, USA). The neutron probe was calibrated for the site and weekly readings were taken before irrigation. One access tube was installed in the middle of each plot and readings were taken to 1.2 m depths at 30 cm intervals. Furrow-flood irrigation was used to irrigate the plots, according to the treatments. Irrigation water was measured using a three-inch (76.2 mm) throatwidth Parshall flume and the duration of irrigation was calculated according to equation 4.1 (Kandiah, 1981). The Parshall flume was installed at the entrance to the plot to minimise water loss during conveyance and distribution.

$$T = AD/60Q \qquad (4.1)$$

where

T = time in minutes, A = plot area (m^2), D = application depth (mm) and

Q = discharge rate ($l\ s^{-1}$)

.

Fractional interception (FI) of photosynthetically active radiation (PAR) was measured weekly with a Decagon sunfleck ceptometer (Decagon, Pullman, WA, USA), making one reference reading above and 10 readings beneath each canopy. Growth analyses were carried out weekly by harvesting plant material from a 1 m^2 representative surface area from each plot. Fresh mass was measured directly after sampling and separated into leaves, stems and tubers. Leaf areas were measured on the fresh leaf samples, using a CI-202 leaf area meter (CID Inc., Vancouver, WA, USA). Dry masses were determined after drying samples in an oven at 60°C for four to five days. Phenological development was monitored during the growing season. Weather data was obtained from a weather station located about 200 m from the experimental field. Water use efficiency (WUE) was calculated for all treatments using the net seasonal irrigation plus rainfall amount during the growing period and the tuber yield obtained (equation 4.2):

$$IWUE = \frac{FTY}{(I + P + \Delta SWC)} \qquad (4.2)$$

where

WUE = water use efficiency ($kg\ ha^{-1}\ mm^{-1}$), FTY = the fresh tuber yield ($kg\ ha^{-1}$), I = the total seasonal irrigation amount (mm),

P = the total amount of precipitation during the growing season (mm) and

ΔSWC = the change in soil water content between the last and first day of crop growth (mm).

Statistical analysis

Analysis of variance was performed, using the SAS system for Windows 2002 (SAS Institute Inc. Cary, NC, USA). Means were compared using the least significant difference (LSD) test at p=0.05.

4.3 Results and discussion

Leaf area index (m^2 m^{-2})

The maximum leaf area index (LAI) obtained per treatment and the overall seasonal LAI trends are given in Table 4.1 and Figure 4.1. In general, potato yield and other agronomic parameters obtained from this experiment were relatively low compared to values achieved for temperate regions. Smith (1968) and Kooman *et al.* (1996a) indicated that potato yields are usually lower in eastern and tropical Africa, compared to those obtained in temperate zones. Smith (1968) suggested that it could be attributed to the detrimental effects of short-day length and high air and soil temperatures. Photoperiod plays an important role in potatoes, as tuberisation is triggered when the day-length falls below a certain critical threshold. Under short day-length conditions, tubers are initiated much earlier than under long-day conditions, making tuberisation more abrupt and, consequently, leading to much faster maturity and lower tuber yields (Smith, 1968; Juzl & Stefl, 2002).

Leaf area index (LAI) data revealed that the NP treatment for most of the growing season produced the highest LAI, followed closely by the SWB treatment (Fig. 4.1). Significant differences in LAI occurred between emergence and peak vegetative growth (about 68 DAP). The two traditional treatments, FTP and RCP, produced similar but lower LAI values, compared to the NP and SWB treatments (Fig. 4.1). However, the NP and SWB treatments resulted in similar LAI values, which were significantly higher than those of the two traditional practices. After reaching peak LAI values at about 68 DAP, the LAIs for all treatments declined drastically to reach similar minimum values at about 90 DAP. In general, the NP and SWB treatments were similar and consistently superior to the traditional treatments until about 76 DAP.

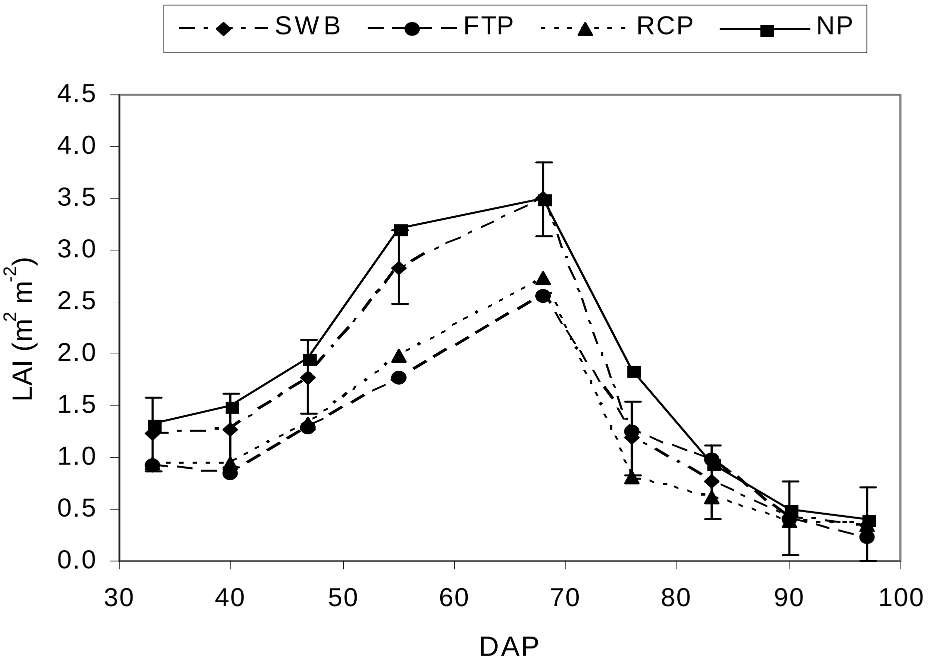

Figure 4.1 Leaf area index (LAI) for four irrigation treatments: Soil Water Balance (SWB), farmers' traditional practice (FTP), research centre practice (RCP) and neutron probe (NP) treatments.

The maximum LAI values obtained from the four irrigation regimes also confirmed that the two traditional practices were inferior ($p>0.05$) to the scientific scheduling practices (Table 4.1).

Table 4.1 Potato fresh tuber yield (FTY), average leaf dry mass (LDM), average canopy dry mass (CDM), average tuber dry mass (TDM), maximum leaf area index (LAI), average fractional interception (FI) of PAR and standard error of mean (SEM) for the irrigation treatments compared.

Treat-ment	FTY kg m^{-2}	LDM kg m^{-2}	CDM kg m^{-2}	TDM kg m^{-2}	LAI m^2 m^{-2}	FI
NP	2.37a	0.11a	0.14a	0.44a	3.50a	0.58a
SWB	2.34a	0.09b	0.12b	0.39a	3.49a	0.52b
RCP	2.14ab	0.08bc	0.10bc	0.38a	2.73b	0.43c
FTP	1.79b	0.07c	0.09c	0.28b	2.55b	0.40c
SEM	0.076	0.004	0.005	0.017	0.013	0.022
CV %	9.99	9.42	9.73	9.90	18.02	8.01

Means followed by the same letter are not significantly different at $p=0.05$

NP = Neutron Probe

SWB = Soil Water Balance

RCP = Research Centre Practice

FTP = Farmers' Traditional Practice

Leaf area index is one of the important parameters indicating potential crop growth performance and yield. Many researchers (Lahlou *et al.*, 2003; Anita & Giovanni, 2005; Bradley *et al.*, 2005) agree that the maximum LAI achieved by a crop gives an indication of the total fraction of solar radiation interception, which determines photosynthetic production and tuber yield. For potatoes, a larger photosynthetically active leaf surface is important to maintain high tuber bulking rates for extended periods (Bradley *et al.*, 2005), which is required for high tuber yields.

Leaf dry mass (LDM), canopy dry mass (CDM) and total dry mass (TDM)

Leaf dry mass (LDM) yield is usually a good indicator of potential plant growth and yield. As indicated by David *et al.* (1983), Jefferies & MacKerron (1987) and Tourneux *et al.* (2003), tuber growth and development are dependent on the presence of sufficient foliage to produce the necessary assimilates and roots for adequate supply of water and nutrients to the canopy. In this experiment, seasonal LDM increment followed the same trend as that of LAI and reached maximum values at about 68 DAP, regardless of the irrigation treatment (Fig. 4.2). The highest LDM was produced by the NP treatment, followed by SWB. LDMs started declining for all treatments after 68 DAP and converged to similar values from 76 DAP (Fig. 4.2). This period coincided with the stage when maximum assimilate partitioning to the tubers occurred, and when tubers gained substantial mass in a relatively short period of time.

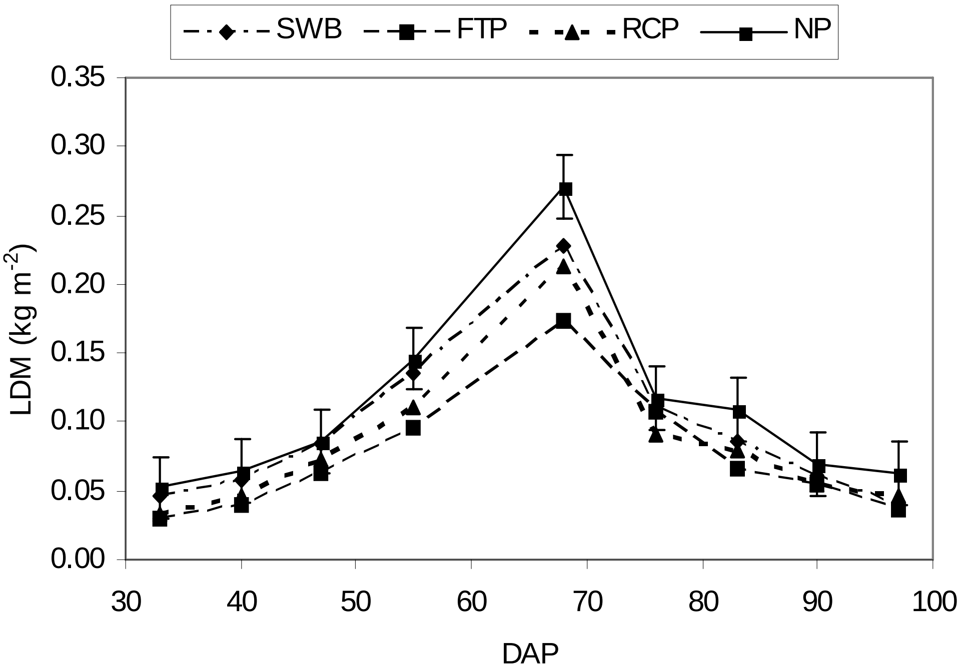

Figure 4.2 Leaf dry matter (LDM) for four irrigation treatments: Soil Water Balance (SWB), farmers' traditional practice (FTP), research centre practice (RCP) and neutron probe (NP) treatments.

Canopy biomass production is proportional to the fraction of solar radiation intercepted, which influence photosynthetic production and final tuber yield. Juzl & Stefl (2002) found that potato cultivars with significantly higher canopy biomass also resulted in significantly higher tuber yields. Research has also proven that water shortage at any growth stage results in reduced canopy dry matter and tuber yield (Epstein & Grant, 1973; MacKerron & Jefferies, 1988; Deblonde & Ledent, 2000; Juzl & Stefl, 2002). The average LDM and CDM obtained in this experiment confirmed these findings, where the NP treatment significantly out-yielded ($p<0.05$) the other treatments, followed by SWB (Table 4.1). Treatment FTP produced the lowest TDM yield ($p<0.05$), while the other three treatments did not differ significantly from each other ($p>0.05$).

Fresh tuber yield (FTY)

The fresh tuber yield (FTY) followed more or less the same trend as for the above-ground dry mass yield (CDM) and LAI during the growth period (Table 4.1). Hence, treatments NP and SWB resulted in the highest fresh tuber yields, compared to the FTP treatment ($p<0.05$). Similar findings were also obtained by Deblonde & Ledent (2000), who reported that most agronomic parameters, photosynthetic production and yield were affected by levels of water supply. Tourneux *et al.* (2003) also stated that water stress slightly reduced LAI and canopy cover in all the genotypes they tested, and that final dry matter production was greatly affected.

In general, the NP and SWB treatments produced the highest final fresh tuber yields, LDM, CDM and TDM, compared to the two traditional practices (RCP & FTP) (Table 4.1). The fresh tuber yield obtained by FTP was inferior by 32% to that of NP and by 31% to that of SWB. Differences were statistically significant at $p<0.05$ (Table 4.1). Irrigating less than the crop water requirements was primarily responsible for the reduction in LDM, which negatively affected CDM and consequently tuber yield (Table 4.1).

Figure 4.3 shows the reference evapotranspiration of the cropping season in comparison to water applied for each treatment.

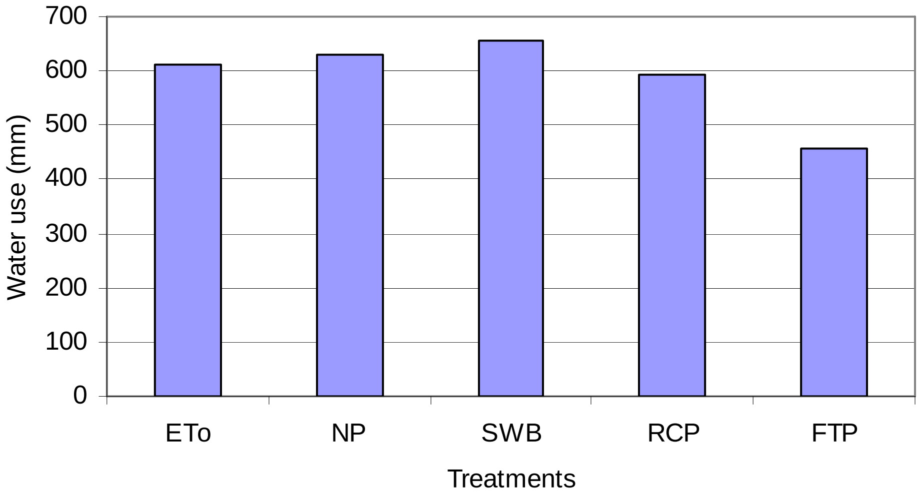

Figure 4.3 ETo (reference) for the cropping period at Debre-Zeit as compared to water applied for each treatments.

Fractional interception (FI)

The fractional interception (FI) of PAR is an important indicator of biomass production and tuber yield (Williams *et al.,* 1996; Lahlou *et al*., 2003). FI results (Table 4.1) show that the NP and SWB treatments had significantly higher canopy cover or FI values ($P<0.05$), compared to the two traditional treatments, implying that they intercepted the highest average fractions of solar radiation. Lahlou *et al*. (2003) reported that the first manifestation of water shortage is a reduction in potato leaf size, resulting in a reduced amount of radiation intercepted, which finally leads to a decrease in tuber dry mass accumulation. The same authors further explained that reduced leaf growth and accelerated leaf senescence are common responses to water deficits and are adaptations of plants to water deficit. Deblonde & Ledent (2000) also reported that intercepted radiation is mostly influenced by the level of water application and to a lesser extent by other factors such as ambient conditions. Measured FI values over the growing season revealed a sharp increase in FI until 47

DAP, whereafter it levelled off and reached peak values at about 68 DAP (Fig. 4.3). A gradual decline in FI was observed between 68 and 90 DAP, whereafter FI declined sharply. Treatments NP and SWB maintained the highest FI values throughout the growing season, while FTP demonstrated the lowest values.

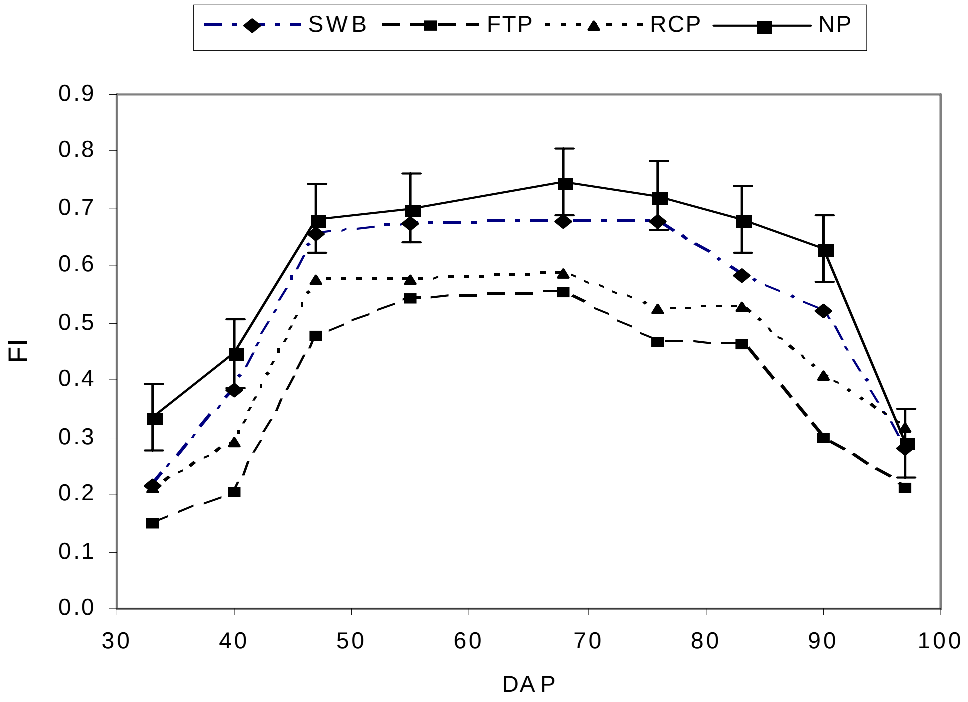

Figure 4.4 Fractional interception (FI) of the photosynthetically active radiation (PAR) for four irrigation treatments: Soil Water Balance (SWB), farmers' traditional practice (FTP), research centre practice (RCP) and the neutron probe (NP) treatments.

Irrigation water use and water use efficiency (WUE)

The difference in total water use is one of the main reasons for yield variation in crops in general and potatoes in particular. For this experiment, irrigation water use for the different scheduling treatments ranged from 456 mm for FTP to 654 mm for SWB (Table 4.2). The treatment (SWB) with the highest total irrigation amount resulted in the second highest tuber yield. Irrigation amounts recommended by the SWB calendar were often adjusted upwards by 20%, due to the fact that WFDs responded rarely

(Fig. 4.4). This adjustment most probably resulted in over-irrigation of the SWB treatment at times, which could have resulted in leaching of nutrients and a slight lowering in tuber yields. The poor WFD response could possibly be attributed to detectors being placed too deep for the specific soil, which is known to reduce WFD sensitivity. The FTP treatment had the lowest water application, but it resulted in the smallest canopy size and lowest tuber yield ($p<0.05$).

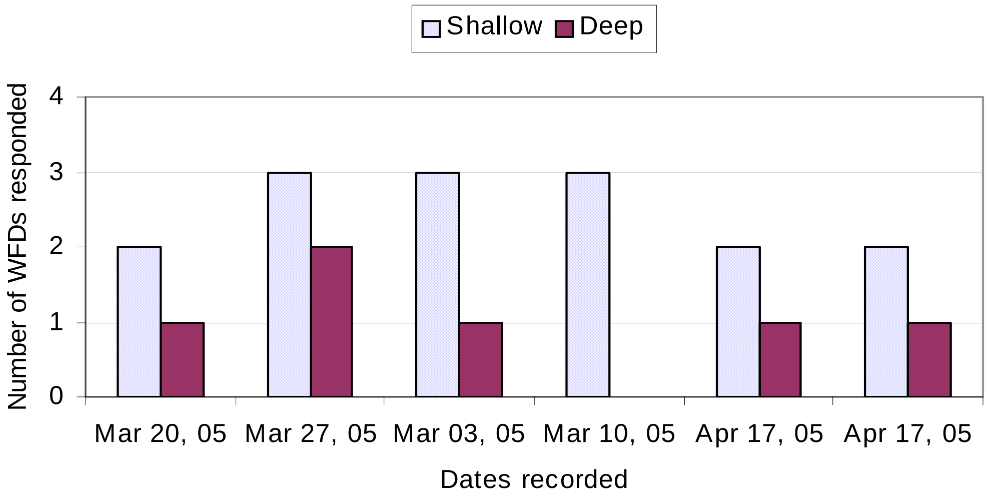

Figure 4.5 Response of wetting front detectors (WFDs) responding 24 hrs after irrigation to correct the SWB model Irrigation Calendar

Irrigation water use efficiency (WUE) gives the relationship between the quantity of water applied (I + P $\pm$ ΔSWC) and yield or dry matter produced (Della Costa *et al.*, 1997). Table 4.2 shows the calculated WUEs expressed per fresh tuber yields obtained for each treatment. The results revealed that the highest WUE was obtained for the FTP treatment, followed by the NP treatment (Table 4.2). WUEs did not vary much between treatments and ranged from 35.8 kg ha^{-1} mm^{-1} for the SWB treatment to 39.2 kg ha^{-1} mm^{-1} for the FTP treatment. The lower WUE achieved by the SWB treatment can probably be explained by occasional over-irrigation, as explained above.

Table 4.2 Total seasonal water applied, tuber yield and irrigation water use efficiency (WUE) for four irrigation treatments: re-filling to field capacity as per the neutron probe reading (NP), Soil Water Balance (SWB), research centre practice (RCP) and farmers' traditional practice (FTP) treatments.

Irrigation treatment	Tuber yield (kg ha^{-1})	Total water applied (mm)	WUE (kg ha^{-1} mm^{-1})
NP	23700a	631	37.6
SWB	23400a	654	35.8
RCP	21400ab	594	36.0
FTP	17900b	456	39.2

Means followed by the same letter are not significantly different at $p = 0.05$

WUE = Water use efficiency

WUE values obtained for all treatments are substantially lower as compared to the results obtained by other researchers (Onder *et al.*, 2005; Lim & Hyun, 2006; Lowery *et al.*, 2006). Onder *et al.* (2005) evaluated the WUE of potatoes under two irrigation regimes and obtained values that ranged from 66 to 114 kg ha^{-1} mm^{-1}. Similarly, Lowery *et al.* (2006) evaluated potato water use efficiency under drip and sprinkler irrigation systems, and obtained values ranging from 119 to 160 for drip irrigation and 50 to 100 kg ha^{-1} mm^{-1} for sprinkler irrigation. The low WUEs recorded for this experiment could probably be attributed to the overall low irrigation efficiency of furrow/flood irrigation, which is usually around 60%. Water conveyance and application losses for flood irrigation are substantially higher, compared with other irrigation systems, such as sprinkler or drip irrigation (Lowery *et al.,* 2006). Furthermore, yields were much lower than those typically obtained from areas with temperate climates, combined with optimal management practices (Cooper, 1988; Kooman *et al.,* 1996b). These authors argue that the low yielding potential of potatoes in the tropics and subtropics result from high temperatures and short day length conditions, to which most potato cultivars are not well adapted. The combined effects of low yields and high irrigation amounts finally culminated in the low WUEs recorded. However, high WUE on its own is not necessarily an indication of the best scheduling method. The findings of many research reports (Shimshi *et al.*, 1983; Ferreira & Carr, 2002; Yuan *et al.*, 2003) usually conclude that the less water applied, the higher the irrigation water use efficiency. Although the FTP treatment had a slightly higher WUE than other treatments in our study, its tuber yield was 24% lower than that of the NP treatment, for example. Therefore, any of the other three irrigation strategies would make better use of resources (solar radiation, fertilisers and land) compared to the FTP treatment.

Figure 4.5 illustrates the soil water deficits measured just before each irrigation event during the growing season. From this illustration, it is clear that the FTP treatment, which had the lowest seasonal water consumption (Table 4.2) and lowest final tuber yield (Table 4.1), also had the highest soil water deficits throughout the growing season.

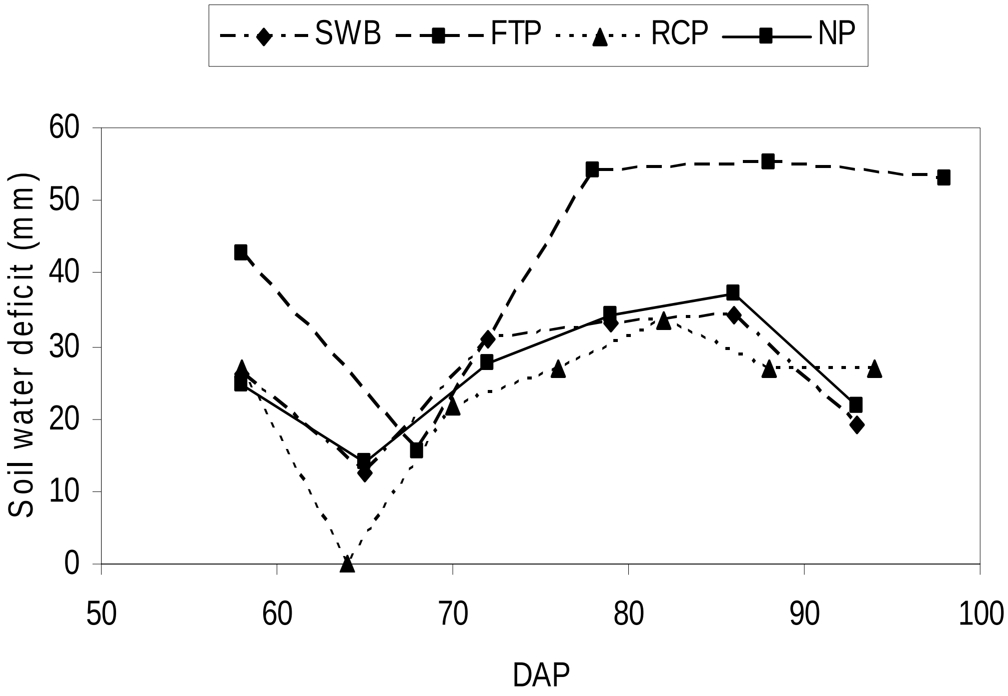

Figure 4.6 Soil water deficit measured before irrigation for four irrigation treatments: Soil Water Balance (SWB), farmers' traditional practice (FTP), research centre practice (RCP) and re-filling to field capacity as per the neutron probe reading (NP) treatments

The low soil water deficit recorded for the RCP at 64 DAP was due to a heavy rainfall event that occurred just after irrigating this particular treatment. Although soil water deficits for this treatment remained the lowest for the remainder of the growing season, it still had lower tuber yields than the SWB and NP treatments. The lower tuber yield recorded for RCP could probably be attributed to serious water stress earlier in the growing season, from which the crop could not fully recover. Although there is no soil water content data during the first part of the growing season to support this argument, the presence of early stress is confirmed by the lower LAI, LDM and CDM values recorded for the RCP earlier in the growing season.

4.4 Conclusions

The potato water regime experiment conducted at Debre-Zeit, Ethiopia, indicated that the traditional water application regime practised by farmers was not adequate for high potato production. The results revealed that fresh tuber yield and other yield attributes (LDM, CDM & FI) were significantly affected by the different irrigation scheduling methods. LDM and CDM were markedly reduced with the FTP and RCP treatments, with statistically significant ($p<0.05$) differences. Reduction in canopy size was mainly responsible for reduced interception of solar radiation or (FI), which resulted in reduced dry matter accumulation and, finally, lower tuber yields. Water use and WUE results revealed that the FTP scheduling method had slightly higher applied water productivity, followed by the NP method. However, WUE values of all treatments were similar, ranging from about 36 to 39 kg ha^{-1} mm^{-1}.

Since treatment differences in the WUE were small, it should not be the only parameter used to differentiate between scheduling methods, but tuber yield should also be considered. Although the FTP treatment had a slightly higher WUE than other treatments, its tuber yield was substantially lower than that of the NP and SWB treatments. Therefore, any of the other three irrigation strategies could be considered better than the FTP treatment. The FTP scheduling method resulted in significantly lower dry matter and tuber yields, indicating that water supply was not sufficient to maintain water requirements of the furrow- irrigated potato crop.

Hence, it is suggested that the current watering practice at the Godino Irrigation Scheme or (FTP) be replaced by a more efficient water management technique, based on thorough scheduling. From the results obtained, NP and SWB performed best, taking yield components and fresh tuber yields into account. However, the adoption of NP scheduling at the Godino scheme would require skilled NP users. Furthermore, this method is time-consuming and the equipment not affordable to individual farmers. Therefore, it is recommended that the SWB calendar scheduling method, which performed similarly to the NP method, be introduced to farmers at the Godino scheme. Extension staff at the adjacent Debre-Zeit Agricultural Research Centre could generate and supply farmers with site-specific SWB calendars for different soils, crops and planting dates commonly used by farmers on the scheme. This method is simple, but could have a substantial impact on the productivity of subsistence farmer irrigation schemes in Ethiopia.