A SIMPLE IRRIGATION SCHEDULING TOOL FOR SMALLHOLDER DRIP FARMERS.

UN OUTIL SIMPLE D`AIDE À L'ÉLABORATION DE PLANNINGS D'IRRIGATION, POUR PETITS EXPLOITANTS AGRICOLE, UTILISANT UN SYSTÈME GOUTTE À GOUTTE.

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ABSTRACT

Drip irrigation is widely recognized as potentially one of the most efficient irrigation methods. However, this efficiency is often not achieved because systems are not always well designed or maintained and many farmers lack the tools to assess the crop water requirements and to monitor the soil moisture conditions in the field. There is a vast amount of literature on irrigation scheduling but little literature takes scientific information the next step by preparing practical guidelines for smallholder farmers. There is a large and widening gap between the state of the art irrigation scheduling tools and current on-farm irrigation practices. Most farmers find current irrigation scheduling tools overwhelming and lack the means and skills to install and operate them. It is suggested that farmers need simple, cheap and more comprehensive support tools to achieve improved irrigation management at the farm level. Wageningen University and Research Centre (WUR) developed the Drip Planner Chart (DPC) to provide smallholder farmers with a simple tool to schedule drip irrigation to the crops' needs. DPC is a manual disk calculator to calculate daily irrigation requirement. Farmers' feedback was the basis for developing the DPC. Using DPC over a three-year period in Spain resulted in a 14% water saving and improved irrigation timing. Trials at smallholder farmer fields in Nepal and Zambia showed DPC advice is more adapted to the changing demands of the crop over the different growth stages and responds to the farmer's quest for practical drip scheduling advice. This paper presents the Drip Planner Chart and the scientific validation of the accuracy of the DPC. Experiments on farmers' fields show water saving in Nepal and improved yield in Zambia. In both countries an improved scheduling over the growing seasons was found using DPC.

Key words: drip irrigation, scheduling tool, small holders, DPC.

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RÉSUMÉ ET CONCLUSIONS

La méthode d'irrigation par goutte à goutte est largement reconnue comme pouvant être l'une des plus efficientes. Cependant, cette efficience maximale est rarement atteinte à cause de défauts de conception ou de maintenance des systèmes. De plus, beaucoup d'agriculteurs ne possèdent pas les outils nécessaires à l'évaluation des besoins en eau de leur culture ou au contrôle de la quantité d'eau présente dans le sol. Il existe une vaste documentation expliquant comment établir des plannings d'irrigation mais seulement une trop faible proportion nous renseigne, d'une manière scientifique, sur la manière d'élaborer des directives concrètes pour les petits exploitants. Il y a un important écart entre l'art d'élaborer un planning d'irrigation selon les outils disponibles, et la réalité du terrain. La plupart des agriculteurs sont submergés par le nombre d'outils existants, faute de moyens et de compétences pour les installer et les faire fonctionner. Il apparait ainsi que les agriculteurs ont besoin d'outils simples, bon marchés et plus compréhensibles afin d'améliorer la gestion de leur système d'irrigation. L'Université de Wageningen et son centre de recherche (WUR) ont développé le Drip Planner Chart (DPC) afin de fournir aux agriculteurs un outil simple, qui leur permette de définir un planning d'irrigation d'après les besoins de leurs cultures. DPC est un disque permettant de calculer manuellement la quantité d'eau d'irrigation quotidienne requise. La conception du DPC a été basée sur les commentaires des agriculteurs. L'utilisation du DPC durant trois ans, en Espagne, a permis une diminution de 14% de la quantité d'eau utilisée ainsi qu'une amélioration de la gestion du temps d'irrigation. Des essais, dans des parcelles de petit exploitants, au Népal et en Zambie, ont montré que les conseils donnés par le DCP s'adaptent bien au changement de la demande en eau de la plante au long de ses différents stades de croissance, et correspond aux attentes des agriculteurs. Cet article présente la charte Drip Planner Chart et la validation scientifique de l'exactitude de cette DPC. Les expériences sur les champs des agriculteurs montrent des économies d'eau au Népal et une amélioration des rendements en Zambie. Dans les deux pays, une planification améliorée des périodes de croissance des cultures a été trouvé à l'aide DPC.

INTRODUCTION

Drip irrigation can achieve application efficiencies as high as 95 % if the system is well maintained and combined with soil-moisture monitoring or other ways of assessing crop water requirement, (Keller, J. 1990) (Vickers and Cohen 2002). However, this efficiency is often not achieved because systems lack good design and/or maintenance and many farmers lack the tools to assess the crop water requirements. Irrigation scheduling has been an important topic in agricultural research for several decades. Optimal water management at field level needs a good knowledge of the frequency and the duration of the irrigation turn. Since crop water requirements varies over the growing season, the farmers will need to adjust the irrigation during the season. There is a vast amount of literature on irrigation scheduling and water management. Studies involve comparison of irrigation scheduling methods for particular crops and comparison of soil water measurement. Over the last years, several irrigation scheduling computer models were developed. Many of these models are based on water budgeting.

However, very few studies have dealt with the on farm implementations (Buchleiter 1996). There is a large and widening gap between the state of the art irrigation scheduling tools and current on-farm irrigation practices. Both big commercial farms and smallholder farmers make little use of the scheduling tools for various reasons. Most producers find state of art irrigation scheduling tools overwhelming and lack the skills necessary to install, operate and troubleshoot them.

Many smallholder farmers, especially in developing countries, lack the financial means to buy expensive equipment and many have no computer to run the models on. Stevens (2007) in a study to investigate the use of irrigation scheduling methods in South Africa observed that only 18 % of South African farmers used irrigation scheduling methods, while the rest makes use of subjective scheduling based on intuition, local knowledge and experience. The local knowledge and experience are valuable but might not do if farmers are introduced to new irrigation methods like drip irrigation. It is suggested that farmers need simpler, cheap and more comprehensive support tools to achieve improved irrigation management at the farm level (Clyma, 1996). Little literature is found taking scientific information the next step by preparing practical guidelines for farmers. In the Netherlands a simplified paper version of the computer based irrigation scheduling program was introduced to meet the needs of farmers without computers (Boomaerts and Hoving 1999). Raes et all developed charts for guiding irrigation during the growing season for tomato growers in Tunisia to meet the needs of practical guidelines without the investment in sophisticated equipment or software (Raes, Sahli et al. 2000).

Drip irrigation systems have greatly improved over the last twenty years with a lot of effort from the western irrigation suppliers who were responding to the demands of commercial agricultural enterprises. Initially it failed to meet the widespread need for cheaper, divisible irrigation systems for poor farmers on small plots. The development of a reliable low cost drip system that fits the needs of smallholder farmers in developing countries has got a lot of attention over the last decade (Polak, Nanes et al. 1997) (Postel, Polak et al. 2001) (Mehari Halle, Depeweg et al. 2003) (Manaktala 2005) (Maisiri, Senzanje et al. 2005).

The low cost drip irrigation sometimes saved about 35% of the water compared to surface irrigation system (Maisiri, Senzanje et al. 2005). With many of the poorest farmers living in water scarce areas it is important to make maximum use of the scarce water supply. Irrigation efficiency could greatly improve by having a tool that makes it easier to supply the right amount of water to the crops at the right place at the right time. Often water is manually pumped into drum kits so the saving in water also reflects a direct saving in labor input.

This paper presents the development of a simple manual scheduling tool; the Drip Planner Chart (DPC). A scientific validation of the accuracy of the DPC is performed by comparing the DPC to the scheduling program CROPWAT over three growing seasons lemon growing in Spain. Furthermore experiments on farmers’ fields in Nepal and Zambia to validate the effect of the DPC on water saving and production of cabbage in comparison to present irrigation scheduling.

The development of a simple drip-scheduling tool: the Drip Planner Chart (DPC):

Wageningen University and Research Centre developed the Drip Planner Chart (DPC) to provide smallholder drip farmers with a simple tool to schedule drip irrigation to the crop needs. The DPC is a simple manual chart to determine the irrigation requirement of various crops. A prototype was developed for fruit crops *(citrus, banana, grapes and pineapple)* and for vegetable crops *(tomato, cabbage, carrot, onion)*. The Drip Planner Chart consisted of two disks; one disk with crop and climatological data in order to calculate the irrigation requirement (Fig. 1). The second disk translates the irrigation requirement of disk 1 into a practical advice on the amount of drums to irrigate per plot per day.

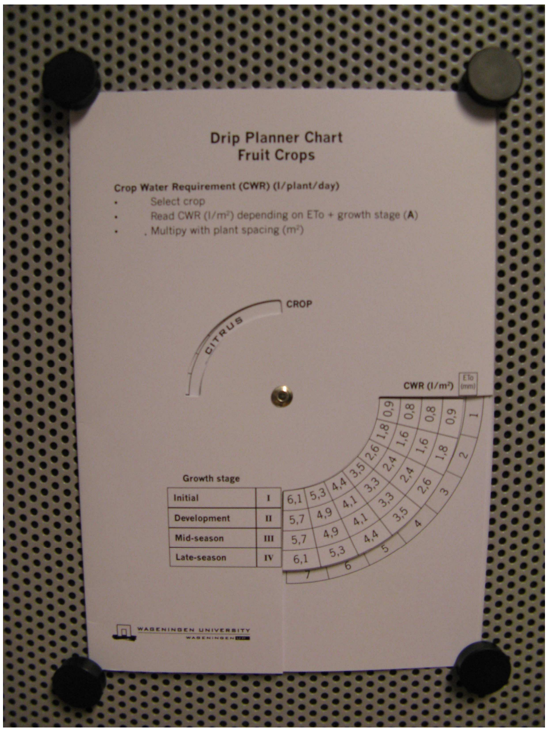

Figure 1: Example of the prototype of the Dip Planner Chart for fruitcrops.
Figure 1: Exemple de prototype de Drip Planner Chart pour les cultures frutières.

The crop water requirements of the DPC are based on the FAO method (Allen, Pereira et al. 1998). which is based on the reference evapotranspiration and the crop factors depending on the growth stage of the crop. Four distinct growing stages are distinguished during a growing season. Input ET_O values are acquired from nearby weather stations or agricultural extension service. For a chart developed for a particular region, it is possible to assign standard weather conditions by analyzing the probability levels of ET_O in that area during different seasons. This could even lead to the use of icons to indicate e.g. sunny during dry season, cloudy dry season, etc. For the irrigation requirement, the rainfall and the efficiency of the irrigation system come into account. The efficiency of drip irrigation systems is estimated at 80%. Possible other sources of water like rain or capillary rise are accounted for to determine the irrigation requirement.

Capillary rise is only substantial in soils with a groundwater table close to the root zone. In many arid/water scarce areas, this can be neglected.

THE RESEARCH

The research consisted of two parts. The first part is a theoretical validation of the prototype DPC by comparing the irrigation advice of the DPC with the irrigation requirement from CROPWAT (Smith 1992) and the actual irrigation performed by a citrus famer in the south of Spain over three cropping seasons from 2004 - 2007. To develop a simple tool many factors needed to simplified. In that process, some accuracy is lost. This first scientific validation to test if not too much accuracy is lost.

The second part of the research are two experiments on farmers' fields in Nepal and Zambia in outdoor cabbage growing. DPC was tested against current irrigation advice and farmers' practice to test the accuracy and applicability of the DPC for the selected target group in the field

Research part one: theoretical validation of Drip Planner Chart.

The crop water requirements (CWR) from CROPWAT. (Smith 1992) is compared with the results of the Drip Planner Chart. The research took place over a three year period from June 2004 till June 2007, in a lemon orchard *(variety Fino)* on a commercial citrus farm in the south of Spain *(Pizarra).*
On the citrus farm, the soil suction measurement was three times a day at three different depths in the root zone. A data logger automatically measured and stored the data. For this, the watermark sensor *(Type granular matrix sensor (GMS), Irrometer® Co., Riverside, California, USA)* is used. The sensor has a range of 0-200 centibars.
On the farm is a metrological station of the Junta de Andalucia, provides reference evapotranspiration (ETO) and rainfall data on a daily basis from the research field.

Results:
In Fig. 2, the average soil suction in the root zone is presented together with the rainfall. It is clearly visible that the rains in the period December – March create a drop in the soil suction to a level of Field Capacity. From April - August the soil suction increases to levels of 80-100 KPa. Water stress is expected at this level. This pattern of reaching FC in the winter and drying out to water stress levels in the summer is a repeated pattern over three consecutive years.

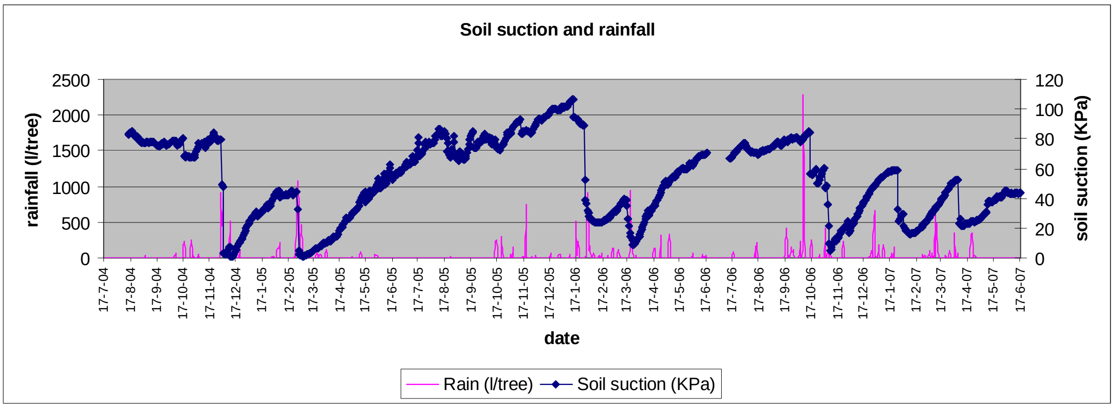

Figure 2: Average soil suction in the root zone (KPa) and rainfall (l/tree) in the period July 2004 – June 2007.
Figure 2: Succion moyenne du sol dans la zone racinaire (KPa) et précipitations (l/arbre) pour la période Juillet 2004 – Juin 2007.

Calculation of the Irrigation Water Requirement *(IWR)* on a decade basis with the CROPWAT method plotted against the actual drip irrigation application at the farm shows a clear under irrigation in the period March to July (Fig. 3.). In the period July-October, the actual irrigation appears to be more in line with IWR according to the CROPWAT method. This explains the rapid increase in soil suction in the period March – June and the relative stable soil suction in the period July – October (Fig. 2.). In the period March - October very little rainfall is present so the development of the soil suction is attributed to actual irrigation in relation with the IWR in this period. The daily Irrigation Water Requirement (IWR) according the DPC method follows the pattern of the CROPWAT method (Fig. 3).

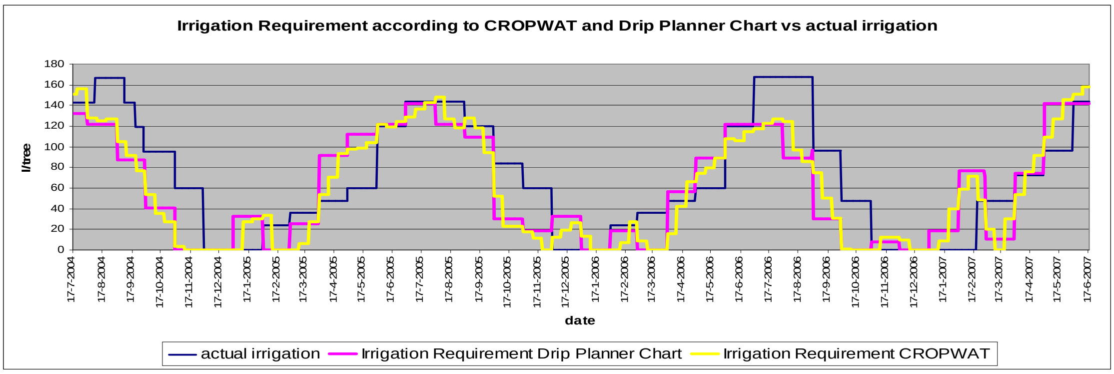

Figure 3: Irrigation Requirement according to CROPWAT and the Drip Planner Chart method (l/tree/day) in the period July 2004 – June 2007.
Figure 3: Besoins en eau d'irrigation d'après CROPWAT et la méthode du Drip Planner Chart (l/arbre/jour) pour la période de Juillet 2004 - Juin 2007.

The irrigation requirement takes into account the actual rainfall. In Fig 3, the irrigation requirement of the crop according the CROPWAT method and the Drip Planner Chart is together with the actual irrigation over the three years. This figure indicates that the timing of the actual irrigation is not in line with the irrigation requirement of the crop. Over the three consecutive years it appears that the actual irrigation starts too late in spring while irrigation during summer and autumn are slightly exceeding the IWR. The actual irrigation in the period July 2004 – June 2007 was 74641 liter per tree. Table 1 shows the Irrigation Water Requirement of the CROPWAT method and the Drip Planner Chart and the percentage of deviation of the DPC in comparison to CROPWAT. The deviation of IWR according to DPC varies from -5.5% to +7.6%. Over the three-year period the Irrigation Requirement of DPC is 2.7% exceeding the Irrigation Requirement according to CROPWAT but timing is very much in line with CROPWAT. This results in a good correlation (R^2 = 0.9203) of the Irrigation Requirement between the two methods (Fig. 4). Both CROPWAT and the Drip Planner Chart have a more accurate timing of the irrigation with higher amount of irrigation in period Mach – July and lower rates in the period August – November. This leads to a better timing and an overall lower water use. The actual irrigation is exceeding the irrigation requirement according CROPWAT and DPC. However, this over irrigation still leads to high soil suction and water stress to the crop due to bad timing of the irrigation. Water saving is 17% and 14% for CROPWAT and DPC respectively in comparison to the actual irrigation.

Period	Irrigation Requirement (l/tree)		
	CROPWAT	DPC	% deviation
July-Dec 2004	10204	9643	-5.5
2005	23828	25645	7.6
2006	16413	16302	-0.7
Jan-June 2007	11541	12080	4.7
Total	61987	63670	2.7

Table 1: Irrigation Water Requirement (l/tree) according to CROPWAT and DPC over the period 17 July 2004 – 17 June 2007 and (%) of deviation of DPC from CROPWAT.
Tableau 1: Besoins en eau d'irrigation (l/arbre) d’après CROPWAT et DPC pour la période du 17 juillet 2004 au 17 juin 2007 et pourcentage de déviation de la méthode DPC d’après CROPWAT.

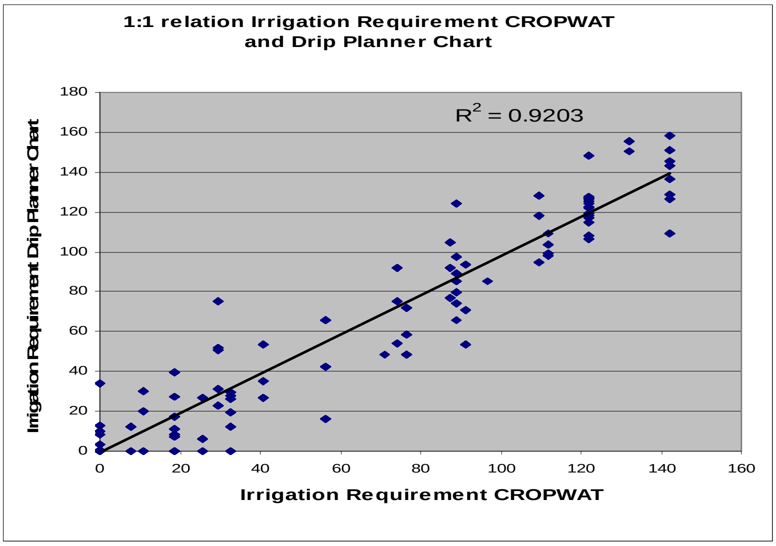

Figure 4: The 1:1 relation between the Irrigation Water Requirements according the CROPWAT method and the Drip Planner Chart method and its correlation.
Figure 4: Relation 1:1 entre les besoins en eau d'irrigation selon la méthode CROPWAT et la méthode du Drip Planner Chart et sa corrélation.

Research part 2: Field experiments with DPC on smallholder farmers' fields.

Further field trials were conducted to establish the applicability at smallholder fields. An orientation trial using DPC in 2008 in Ethiopia revealed that the advice from the DPC was realistic. Both the trial and feedback from farmers and agricultural extension workers flagged minor improvements to the DPC (Zisengwe L. and Yakami S., 2008) prior to the start of field experiments in Zambia and Nepal.

In 2009 field experiments were conducted in Zambia and Nepal comparing different irrigation schedules in outdoor cabbage production. The research sites were located in Chapagaon-6, Lalitpur district, Nepal and Kafue, Kabweza District in Lusaka Province, Zambia. International Development Enterprises *(IDE)* collaborated and facilitated the field trials at farmers' fields.

Treatments

Randomized Complete Block Design based with 4-replications (Zambia) and 5-replications (Nepal) in the outdoor cabbage experiments. In February the cabbage variety Riahanna (Zambia) and the winter cabbage variety YR (Nepal) was planted. Plot sizes in Zambia 30 m² and in Nepal 26 m² per plot. The cabbage growing season was from February till May 2009. Three irrigation treatments were identified:

- T1 = Farmers practices
- T2 = IDE advice
- T3 = DPC

Farmer practices treatment (T1) was based on interviews and consultations with farmers in the area. This treatment only applied in the outdoor cabbage experiment in Nepal. IDE advice (T2) was based on interviews and consultations with local IDE extension staff. DPC-daily treatment (T3) was based on the first disk of the DPC. Tables 2-3 indicate the amount of water required per treatment in Nepal (Table 2) and in Zambia (Table 3). Rainfall during the season was accounted for and deducted to reach the real irrigation requirement. Table 4 gives the total irrigation in (mm) per treatment over the complete growing season. The soil suction in the root zone was measured once a day by watermark sensors.

Yield measurements were at the end of the trial (Table 5). During the trial also plant height and leaf diameter and number of leafs was monitored.

Date	**Growth Stage**	**T1**	**T2**	**T3**
Feb 19-28	**Initial**	50	100	25
March 1-5	**Initial**	50	100	30
March 6-25	**Dev**	50	100	45
March 26-31	**Mid**	80	300	65
April 1-30	**Mid**	80	250	85
May 1-5	**Mid**	80	250	85
May 6-20	**Late**	80	250	85

Table 2: Cabbage Nepal. Irrigation per day over the growing season per experimental plot (l/plot/day).

Tableau 2: Choux, Népal : Volume d'eau utilisé pour l'irrigation, par jour, au cours de la saison de croissance, par parcelle expérimentale (l / parcelle/jour).

Date	**Growth Stage**	**T2**	**T3**
Feb 9-23	**Initial**	60	50
Feb 24-March 30	**Dev**	60	60
March 31 – April 29	**Mid**	60	70
April 30 May 9	**Late**	60	65

Table 3: Cabbage Zambia. Irrigation per day over the growing season per experimental plot (l/plot/day).

Tableau 3: Choux, Zambie : Volume d'eau utilisé pour l'irrigation, par jour, au cours de la saison de croissance, par parcelle expérimentale (l / parcelle/jour).

		T1	**T2**	**T3**
Trial 1	Cabbage Nepal	77	219	75
Trial 2	Cabbage Zambia	0	106	116

Table 4: Total irrigation (mm) over the growing season per treatment.

Tableau 4: Volume total d'irrigation (mm) au cours de la saison de croissance, par traitement.

		T1	T2	T3
Cabbage Nepal	Kg/m²	0.52	0.49	0.45
Cabbage Zambia	Kg/m²		0.51	0.75

Table 5: Total cabbage yield in kg/m².
Tableau 5: Rendement total en choux en kg/m²

Results field experiment Nepal:

In Nepal, the amount for T2 (IDE advice) was about three times the value for T3 (DPC). T1 (farmers practices) was expected to be equal to IDE advice but farmers applied less than advised by IDE due to water scarcity in the area. Interviews in less water scarce areas in Nepal revealed higher application by farmers in that situation. Under the circumstances of this trial T1 used more or less equal amounts to T3 (DPC) in total but with different variation over the growth stages during the season.

Yield showed no significant difference at 95% level of confidence between the different treatments *(one-way ANOVA).* No significant difference was observable with respect to plant height and leaf development during the trial. Use of DPC can give considerable water saving in comparison to the general advice without affecting the yield. This also suggests that considerable labor saving is achievable.

Result field experiment Zambia:

In Zambia the total amount of irrigation over the growing season did not divert much between the different treatments. However, the T2 (IDE advice) treatment was a flat rate over the growing season while the T3 (DPC) treatment showed a variable adaptation of the irrigation rate to the growing seasons. Farmers' practices were not included in the trial due to difficulty in establishing reliable "farm practices". However, interviews of farmers revealed large variations and application often exceeding the IDE advice indicating over applications in the region.

A higher yield appears in the T3 treatment in Zambia. Soil moisture monitoring showed moderate water stress levels in treatment T2 due to its flat rate over the season. Adaption of irrigation to the growth stages resulted in less water stress in the mid and final growth stage (Fig. 5)and possibly leading to higher yields. Cabbage yield is specially affected by water stress during the mid and late growing stages (Doorenbos, J. and A.H. Kassam, 1979). However, because of high variability within the treatments, the statistical analysis *(one way ANOVA*) showed no significant difference in yield at 95% level of confidence between the different treatments. No significant difference was observable with respect to plant height and leaf development during the trial.

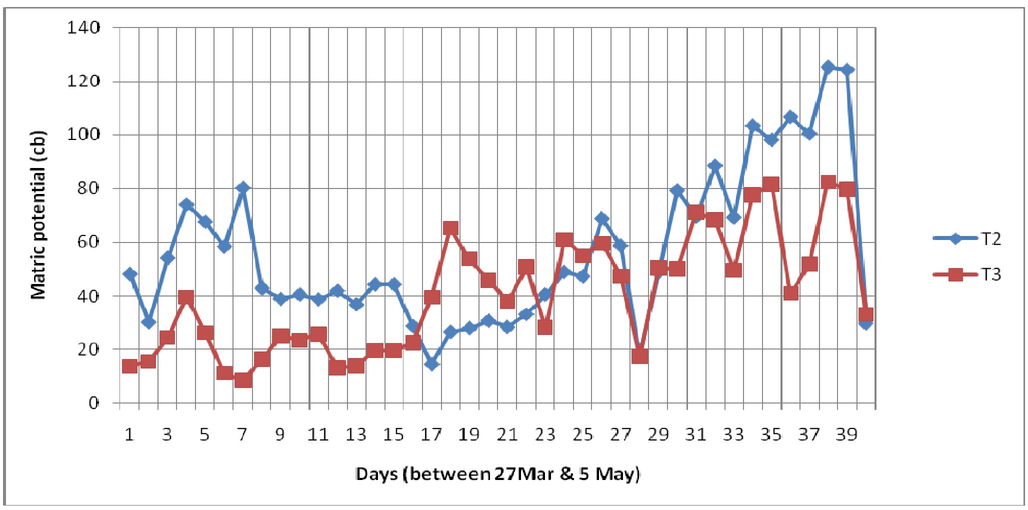

Figure 5: Average soil suction (KPa) in the root zone during the period of 27 March – 5 May 2009 in the cabbage field, Zambia.
Figure 5: Succion moyenne du sol dans la zone racinaire (KPa) pour la période du 27 mars au 5 mai 2009 dans un champ de choux, Zambie.

CONCLUSION

Drip irrigation has the potential to be an efficient irrigation technique. However, this is often not fully achieved because many farmers lack the tools to assess the crop water requirements and to monitor the soil conditions in the field. Many, especially smallholder farmers, lack the possibility to use the state of the art irrigation tools. Farmers make little use of these methods for various reasons. It is suggested that farmers need cheaper and simpler support tools to achieve improved irrigation management at farm level. This research suggest that the Drip Planner Chart (DPC is a reliable tool to improve irrigation at farm level for farmers who lack the access of sophisticated scheduling tools.

The DPC is a simple manual chart to determine the irrigation requirement and scheduling of various crops. In the development of this simple tool, many factors need simplification at the cost of losing some accuracy. Comparison of DPC with CROPWAT and actual irrigation of lemon trees in southern Spain demonstrates good results over a three-year period. From continuous soil moisture monitoring, it became clear that timing of actual irrigation fails to meet the crop water requirements in parts of the growing season. This resulted in an overall over irrigation with still spells of water stress. With monitoring tools like DPC and CROPWAT, an improvement in timing was achieved and saving of 14% (DPC) to 17% (CROPWAT) on total water use. CROPWAT and DPC show a good correlation in terms of irrigation requirement ($R^2 = 0.9203$).

Further trials at farmer fields in Nepal and Zambia showed that in some cases considerable water and labor saving are achievable. One sole “farmer practice” does not exist and farmer tends to be very sparse with water in water scarce situation but over applying in water abundant situations. IDE advice and “farmers practice” tends to stick to long periods of flat rates over the growing season. DPC advice is more adapted to the changing demands of the crop over the different growing stages and the climatic conditions. In Nepal, considerable water and labor savings were achieved without losing yield. In Zambia, not much water savings were observed but better timing of irrigation amount over the growing season resulted in less water stress and higher yield.

A simplified final version of the DPC is presented. The first disk of the DPC is suitable to determine the irrigation requirement per day depending on growth stage. The second disk of the DPC translates this irrigation requirement into a practical advice in terms of numbers of drums to irrigate per day. Wageningen University and IDE will further study the effectiveness and appropriateness of this tool at smallholder farmers’ level.

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