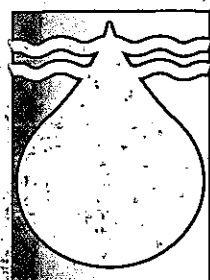


**IRRIGATION REQUIREMENTS OF  
SELECTED CROPS UNDER  
SMALL-SCALE PRODUCTION:  
LINKING ON-FARM AND  
ON-STATION RESEARCH**

**S Walker**

**WRC Report No 689/1/00**



Water  
Research  
Commission

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**IRRIGATION REQUIREMENTS OF SELECTED CROPS UNDER  
SMALL-SCALE PRODUCTION: LINKING ON-FARM AND ON-  
STATION RESEARCH**

by

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**Report to the Water Research Commission on the project  
"Irrigation Requirements for Small Plot Vegetable Farmers"**

by

**Institute for Soil, Climate and Water,  
Agricultural Research Council, Pretoria**

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## **Executive Summary**

### **IRRIGATION REQUIREMENTS OF SELECTED CROPS UNDER SMALL-SCALE PRODUCTION: LINKING ON-FARM AND ON-STATION RESEARCH**

There are many irrigation schemes in the former homeland areas where the farmers have been allocated rather small plots. The Farming Systems Research and Extension (FSRE) approach was used in this project to address the need for improved technology transfer to these farmers. Participatory techniques were used during the needs assessment at two irrigation schemes in the Northern Province, which formed part of this project. Using these techniques farmers, researchers and extensionists were able to identify the potential of the natural resources available to them. They were also able to identify some of the stumbling blocks to smooth running of the irrigation farming operations. The results from these participatory needs assessments were used to motivate and apply for funding for other development projects. It is recommended that these techniques should also be used in the diagnostic phase of other water related projects.

The team consisted of farmers, extension staff and researchers who then planned and implemented several on-farm trials that addressed the shortage of natural resources. During the needs assessment the low crop yields were identified as an ongoing problem for farmers. It was also identified that cattle manure was available at many households as the animals are enclosed in a kraal at night. The on-farm project then proceeded to test the use of cattle manure, and inorganic fertilizer on the production of maize. Another limitation to continued sustainable food production was unreliability of the irrigation water source. This sparked the addition of a mulch treatment into the maize trial run at 4 – 6 farmers' fields. The trials were essentially farmer managed for the duration of this project and this accounts for the lack of an adequate data-set to make statistically significant conclusions about the scientific application of manure on maize yield. This point highlights precisely one of the parts of the paradigm shift that needs to take place in this approach to agricultural research science. The fact is that the agricultural researchers continue to want to focus on

quantitative values of hard science. The reason is apparently, that if as is the case here, there are no clear quantitative results that can be tested by standard statistical methods, the trials will be considered unsuccessful. However, one needs to return to the objectives for the “on-farm” trials. The aim of on-farm trials is not the same as the aim for on-station trials, even if the two experiments may have similar treatments. The purpose of the on-station trials is to test basic principles, the basic science of processes involved and principle reasons behind why certain results are obtained. In contrast, the purpose of on-farm trials is to allow local farmers to test the application of technology or techniques under the farmers’ own conditions. It allows for an in-depth interaction with the farmers themselves thus integrating their knowledge base with that of the scientists. The purpose includes a strong technology transfer objective together with the integration of the wealth of local knowledge with the scientific expertise.

Many lessons were learned from these on-farm trials. One of them centers around the difficulty encountered in the selection of farmers to participate in the on-farm trials. Several different methods of selection were used in different seasons. One of the principles that must be upheld is of participation of the relevant community in this case the farmer themselves. At all times a team must include farmers as well as extension and research personnel. It is difficult, however, to attribute failure of the experiment to this factor. A detailed impact assessment would need to be carried out on the irrigation scheme to ascertain the influence of the on-farm trials on farmers’ decisions and agricultural production. There was certainly a good measure of capacity building amongst extension staff and researchers as they applied new and different methods and were able to implement the theory they had learned.

On-farm trials by their very nature involve participation from a wide range of people, from farmers to extensionist and agricultural suppliers to researchers across the private and public sectors. The on-farm trials need to be managed in a “win-win” situation for all the participants. This means preparation and commitment is needed from all members of the team to enable the logistics of the project to move forward smoothly from the objective stage to the action stage.

The on-station experiment was designed to generate yield-water production functions for vegetable production under some alternative agronomic practices. The use of cattle manure and mulch applied at planting time was investigated. A range of irrigation treatments was applied from various combinations of applications of 20-mm per week, to the application of only 10-mm per fortnight. The effects of straw mulch covering the soil were also included in the experiments. It was found that despite the fact that the irrigation applied ranged from half to double only small changes in yield were measured. The yield of the various treatments did not differ significantly from each other. The crops receiving sparse irrigation also extracted the water available in the soil at the beginning of the season giving similar seasonal water use values. Under the conditions at Roodeplaat with a deep irrigation soil, a lower water application rate (10 mm) can be used for vegetables if one begins with a full soil profile. This type of deficit irrigation gave a saving of 16 – 26 % total water use over the season to produce a crop of similar yield.

As similar vegetable crops are grown in both summer and winter seasons, the length of the growth periods need to vary and be specified for each season to give realistic crop factor values. For instance, for Swiss Chard in winter at Roodeplaat, a crop factor value of 0.5 to 0.7 is adequate for the whole winter season. The Soil Water Balance (SWB) model was tested using the FAO calculation of crop evapotranspiration. The model shows potential for the mono-crops, but further calibration would be needed to simulate the inter-cropping system.

This project has successfully implemented a typical FSRE project where the farmer is considered as the center of the viable agricultural production system. The various aspects of participatory methods for needs assessment, and both the on-station and on-farm trials have contributed to its success. The process was one of learning by doing as the theoretical principles were applied in practice by the team which involved members from the farm community, the extension staff and researchers.

During the running of the project, regular farmer training seasons were conducted on a monthly basis at the Wonderboom Training Centre at the Olifants-Arabie Irrigation

Scheme and at the Hoxane Irrigation Scheme. Large, well attended formal farmers days were held towards the end of each season's on-farm experiments at Hoxane and New Forest Irrigation Schemes during 1996, 1997 and 1998. Conference presentations were made during 1995, 1996, 1997 and 1999 as follows:

- WALKER, S, 1995a. The Role of the Agricultural Research Council in technology transfer. Paper Presented at the South African Agricultural Extension Society Conference, May 1995.
- WALKER, S, 1995b. Participatory rural appraisal at two irrigation schemes. Paper Presented at the Southern African Association for Farming Systems Research-Extension Conference, Harare, Zimbabwe, October, 1995.
- WALKER, S, 1995c. Technology available to optimize the use of natural resources for farm households. Presented at the 22nd Meeting of SARCCUS Plant Production Standing Committee in Malawi, October 1995.
- KGOLE, A., WALKER, S., THACKRAH, A., MASHIANE & MAHLAKOANE, A., 1996. Co-operation Between Extension Staff and Researchers for the Benefit of the Farmers on the Olifants Irrigation Scheme. Paper Presented at the South African Agricultural Extension Society Conference, April 1996.
- WALKER, S., SHABANGU, D.E, NGOMANE, V.M., DE WET, E.O. & SMAL, J. 1996. Lessons learned from on-farm trials at Hoxane irrigation scheme. Paper presented at the South African Agricultural Extension Society Conference, April 1996
- WALKER, S, 1999. Participatory on-farm trials at irrigation schemes in South Africa. Risk Management for Maize Farmers in Drought-prone Areas of Southern Africa. Proceedings of Workshop, Kadoma Ranch, Zimbabwe, October 1997.
- WALKER, S, 1999. The application of participatory methods in irrigated on-farm trials. Presented at 4<sup>th</sup> Crop Science Conference for Africa, Casablanca, Morocco, October 1999.

The data is archived in Quattro Pro 6.0 or Excel files at the Institute for Soil, Climate and Water, Private Bag X79, Pretoria, 0001.

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Mr. C. Stimie	ARC – Institute for Agricultural Engineering

The project was made possible as a result of the co-operation of many people and organizations. Some of the people worked on different sections of the project at different times. The participatory rural appraisal and the on-farm trials at Olifants, Hoxane and New Forrest Irrigation Schemes were done in full co-operation with the Northern Province Department of Agriculture (NPDA). Many of the staff gave their full support to the ARC team and were considered an integral part of the on-farm trials team. The team is most grateful to the farmers who co-operated during the on-farm trials and loaned a piece of land for experimental purposes.

The following list is of those who were part of the team at various times:

Organisation	Name	Time dates
ARC-ISCW	E.O. De Wet	1994-May 1996
	H. Du Toit	1994-October 1996
	P. Kamau	November 1996-1998
	J. Mahlabe	October 1995-January 1997
	F. Mahlangu	November 1995-May 1997
	T. Mokone	January 1996-December 1997
	L.O. Nethononda	April 1995-May 1996
	L. Peense	1994-1998
	G.N. Sithole	January 1996-1998
	A. Thackrah	1994,1997,1998
	S. Walker	1994-1998

NPDA	A. Kgole	1994-1997
	B.A. Marule	1994-1996
	A. Mashilakoane	1994-1996
	V.T. Mdluli	1994-1998
	R. Ndlovu	1994-1998
	V.M. Ngomane	1994-1997
	D.E. Shabangu	1994-1997
	J. Shabangu	1994-1998
	E. Swele	1994-1998
Farmers	E.P. Manzini	1996-1998
	T. Mashele	1996-1998
	W. Mathebula	1996-1998
	O. Mdludi	1996-1998
	M.A. Nukeri	1996-1998
	H.H. Nxumalo	1996-1998
	W. Poku	1996-1998

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## ABBREVIATIONS

ARC	Agricultural Research Council
BCSinter	Crop parameter file for SWB for intercropped beetroot, cabbage and swiss chard
CPN	Neutron moisture meter used to determine soil water depletion level for irrigation
dap	Days after planting
DBSA	Development Bank of Southern Africa
ET <sub>o</sub>	Potential evapotranspiration
FAO	United Nations Food and Agricultural Organization
FSRE	Farming Systems Research and Extension
GTZ	Deutsche Gesellschaft Für Technische Zusammenarbeit
ISCW	Institute for Soil, Climate and Water
NPDA	Northern Province Department of Agriculture
PRA	Participatory Rural Appraisal
PTO	Permission to occupy
SAS	Statistical Analyses System
SWB	Soil Water Balance
TSWC	Total soil water content

## Chapter 1

### INTRODUCTION

Development of sustainable small-scale agriculture in South Africa is considered an important means to uplift the rural community (Corbet, Coulter, Lipton, Nhlapo & Vaughan, 1994). As large portions of South Africa are semi-arid it is important to utilize irrigation water optimally. However, there is a lack of information regarding irrigation requirements for vegetable crops grown at a subsistence level. Unlike the situation in fully commercial vegetable farming, crops are frequently grown under sub-optimal conditions and together with other crops in a single field. Often crops are grown in very wide rows to compensate for the lack of water. Other factors that play a role are the use of alternative cultivation practices such as multi-cropping or the application of cattle manure to fields or use of mulch between plant rows to limit soil surface evaporation.

During this transition time in South Africa, everyone is being faced with serious questions as to the validity of research and farming systems in place at present. It has also provided an opportunity for researchers to evaluate their methods and to involve all role-players in the process of improving agricultural production in South Africa despite the adverse semi-arid conditions. Concern for sustainable development which addresses the needs of the people has turned attention to irrigation schemes that lie within the former homeland regions (Van Zyl, 1995). Initially, a survey of the natural resources should be conducted, followed by initiating contact with farmers and extension staff in specific areas. Using participatory techniques an evaluation of "felt needs" of the people can be conducted and potential areas identified where possible changes could be made to increase productivity and sustainability. The local value system and the dreams of farmers are kept in sight as researchers present various possibilities or options. Together these options can be evaluated and presented to the community and then some on-farm trials can be planned to enable technology transfer.

## **1.1 Aims of Project**

The original aims of the project were as follows:

1. To determine the water requirements of small plot vegetable farmers under water limiting conditions.
2. To calculate crop factors for predicting water use by small plot vegetable farmers.
3. To generate water production function models for selected vegetable crops.
4. To evaluate the water use on small vegetable plots in household and community gardens.
5. To establish demonstration trials in both urban and rural areas.

During the planning of this project there was much time and energy spent in discussions with a cross-section of people involved in irrigation schemes in the former homelands. The various irrigation schemes have had a checkered history of development and management with overall low crop productivity. Part of the reason appears to be due to lack of technical expertise and technology transfer in the area of water provision and agricultural practices.

This project was initiated to address the dearth of water-use data applicable to the small-scale farmers' situation. The project has two thrusts – namely the on-station field trials and the participatory on-farm work. For the on-station experiment, the idea was to try to emulate some of the methods used when planting and irrigating vegetables in community and home gardens.

## **1.2 Chronological sequence of events**

It was observed that in community gardens each person mostly has a small plot and they plant a variety of vegetables to be able to supply their household needs with a little to spare to sell locally. There are a variety of methods used to apply water and so during the first season (planted prior to the beginning of this WRC project) the different application methods were compared – namely micro-drippers and using buckets by hand. The other general practice was that the profile is normally dry at the beginning of the season and so an attempt was made to simulate this during the first

summer season. However, the methods used to dry out the soil profile are not very efficient and the following seasons had heavy rainfall. Therefore the idea of comparing an initially full soil profile with an initially dry profile were abandoned.

During 1995, it was decided to use the bucket method of furrow irrigation to simulate the short furrows used in the rural areas. A precise amount of water could be applied which was good for the experimental purposes. During 1996 and 1997, following the PRA, further variations on cultivation practices were introduced when mulch and cattle manure treatments were used in the experiment. These results are reported in Chapter 5 and discussed in further detail in Chapter 6.

In the on-farm trials there was also a progression as the project proceeded. The requirement was that trials conducted in the rural areas should involve participatory methods and include the various role-players. During 1995, a needs assessment was conducted on a section of the Olifants-Arabie Irrigation Scheme in the former Lebowa and at the Hoxane Irrigation Scheme on the Sabie River using participatory rural appraisal methods. As the project proceeded and the on-farm trials were initiated, it was discovered that it would not be possible to conduct on-farm trials on the Olifants-Arabie Irrigation Scheme due to logistic problems. The scheme was run on an estate management basis and so there were no facilities to implement individual treatment plots on the farmer's fields. However, a parallel project continued at the Wonderboom Training Center of the Northern Province Department of Agriculture (NPDA) where demonstration trials were conducted for several years. These demonstration trials were conducted in cooperation with other ARC institutes and focussed on cultivar suitability and methods of combating pests and diseases for a range of crops. They did not focus on water use of crops and were not funded by the WRC and therefore do not form part of this report.

At Hoxane, the technology transfer part of the project was initiated with monthly training workshops focussing on the crops commonly grown in the area. The idea of on-farm trials was initiated in discussion groups with the farmers. As this continued as a participatory project, the topics for on-farm trials were selected according to the

farmers' requests and preferences. This meant that there was a wide variety of trials, including cultivar and pesticides trials. However, water application, scheduling or irrigation methods were never on the list of farmers' priorities. Following discussions with the WRC Steering Committee it was decided to move the on-farm trials to the New Forest Irrigation Scheme, also in the Northern Province Lowveld region, a little to the north of Hoxane.

The larger group of extension officers who had been involved in the project at Hoxane, were actually based at Tulamahashe which serves the New Forest Irrigation Scheme. It was reported that they often suffered from water shortages, as the irrigation water comes from dams that are dependent on runoff water. Due to the advanced stage of the project and time constraints, it was not possible to conduct a needs assessment in this area as well. Therefore, the team leaned heavily on extension staff and farmers' committee members for guidance and direction. These farmers then agreed to consider treatments for the on-farm trials that were more pertinent to the water use topics of this project. However, the farmers were most concerned about green maize and chose to apply water saving treatments to maize planted during late winter and/or early spring.

The above short chronological sequence of events is given so that the project report may be better understood. This type of project is by its very nature guided by the local clients' needs, preferences and priorities. This meant that the focus of the on-farm part of the project was dependent on the participation of farmers and extension staff at the chosen sites. However, as described above, the project team also attempted to meet the requirements of the original objectives while satisfying the communities as well. This however, was a fine line to walk and it was only possible to move the project to a new location as other operational projects in various places had been established and were being funded by the ARC. These factors need to be brought into consideration when planning and funding projects involving communities in the future. These factors have also effected the outcome of this project. It can be clearly seen that the on-farm and on-station trials were not conducted hand in hand and are not matched or comparable. This of course is not an

ideal situation from a research point of view, but the needs and preferences of the farm communities where the project was conducted were allowed to lead and guide the researchers and extensionists in implementation of the project. This is how a typical farming systems research and extension (FSRE) project would be operated. So the clearly stated goals and objectives of the project proposal cannot include all the treatments and variables as the farmers must be allowed to have input into the make-up and direction of the trials.

Despite these variations from the normal flow, the project has achieved most of the objectives initially presented. The water requirements of small-plot multi-cropped vegetables have been determined under two locally practiced cultivation methods (Chapter 5). The crop factors and water production functions have been generated from on-station vegetable trials conducted at Roodeplaat (Chapter 6). An attempt was made at measuring the water use in rural areas, however not for vegetables and not in household or community gardens (Chapter 3). Demonstration trials were established in rural areas and on-farm trials with maize were conducted at New Forest Irrigation Scheme to test different cultivation practices (Chapter 3). The proposed demonstrations in urban areas were not included in this project due to logistic problems. However, the initial efforts at Mamelodi have led to European Union funding for a project on the use of composted household waste in peri-urban vegetable production.

## Chapter 2

### THE PARTICIPATION PROCESS AT TWO IRRIGATION SCHEMES

#### 2.1 Introduction

Farming Systems Research and Extension (FSRE) is a systems approach with a farm family perspective. It is applied to agricultural research and extension, support services and policy for project formulation and execution to develop rural communities on a sustainable basis (Mettrick, 1993; FAO, 1993). The farming system encompasses all the production and consumption decisions of the farm-household, including choice of crop, livestock, off-farm enterprises and farming practices as a complete inter-linked system with the farm household as the central point (Norman, Siebert, Modiakgotla & Worman, 1994). The objective of the systems approach is to integrate all activities of the farm so as to meet the farm family needs and optimize farm production within the limitations of the environment, while improving the welfare of the farm family. Farming systems research is a process aimed at increasing the productivity and sustainability of farming systems by analysis of the constraints and opportunities of existing farming systems, implementation of suitable adaptive research programmes, and subsequent development of appropriate technology and complementary policies (Mettrick, 1993). Researchers are involved together with farmers in identifying areas in the current farming system that could possibly be improved or changed. The process is an integrated interaction with full participation from members of the farm community, various government departments and non-governmental organizations dealing with agriculture, including professionals across a wide range of disciplines (Gibberd, 1993).

When using the FSRE approach to a project it is important to evaluate the needs of the client at grass-roots level to formulate objectives for the project. The method used is called Participatory Rural Appraisal (PRA) and as the name indicates it is of utmost importance that the farmers to be surveyed are participating in the process together with the scientists (Chambers, 1992a, 1992b). During the PRA, discussions were held

with interest groups in the area and many farm or home visits were made. At these meetings, selected topics were discussed in an informal manner so as to accumulate information about the farming activities in the area. The information being collected was continuously diagrammatically drawn so that all members of the group could follow the proceedings (Schönhuth & Kievelitz, 1994). The objective of this chapter is to discuss the participatory techniques that were used and to comment on the interpretation of the information forthcoming from the needs assessment.

### ***2.1.1 Hoxane irrigation scheme***

The Hoxane Irrigation Scheme is on the Sabie River in the lowveld subtropical region between Hazyview and the Kruger National Park. The irrigation scheme has been upgraded and further developed by the Development Bank of South Africa (DBSA). Mr Hannes Sauermann (DBSA) introduced members of the Agricultural Research Council (ARC) to the role-players at Hoxane during August 1993, with a view to supplying agricultural technical expertise to the farmers. Due to a lack of funds, the researchers were unable to become further involved until after some internal ARC funding was released late in 1994. However, there had also been a delay in commissioning the new pumps and so the farmers had not been able to expand their operations as soon as previously expected. The involvement of ARC researchers in the project was initiated by a meeting with the extension staff working in the area. During January 1995, Dr. Sue Walker and Mr. Arthur Sippel of ARC and Mr. Joseph Shabangu, Mr. Solomon Baloyi, Mr. Elmon Shabangu and Mr. Victor Ngomane, all of the Department of Agriculture and Conservation, Northern Province, made preliminary plans to initiate the needs assessment amongst farmers at the Hoxane Irrigation Scheme. The first farmers meeting with the team took place on 16 February 1995 at the Ngonini co-op.

There were about 70 farmers on the irrigation scheme of 565 ha, mostly men with about 3 to 5 women farmers. At that time, they all occupied the land under a PTO (Permission to Occupy) from the local chief. The time of occupation of the land ranges from 5 to 20 years. A number of the farmers had their own diesel pumps in the

Sabie River before the DBSA initiated the upgrading of the scheme. The new electric pumps were commissioned during 1995 and numerous problems with pumps or irrigation pipelines were still present.

Although the team tried to facilitate some action for repairs and maintenance of the new pumps, no practical action was taken by the team. However, by the time of the visit the following month, the management committee and extension officers had managed to alert the consultant to the main problems which were then rectified. The information gained from the mapping exercise was that most of the farmers are fairly close to the river, the road and the railway line as they all run almost parallel. The Ngonini Co-op is situated roughly in the middle of the area and the scheme is divided into 5 to 6 sections. The main cash crop grown is tomatoes and the main fruit tree crop is mangoes. Maize is planted by all the farmers without exception, producing green mealies for home consumption or to be sold to local consumers.

### ***2.1.2 Olifants-Arabië irrigation scheme***

The project centered at Wonderboom was initiated by Mr. Abram Kgole, an extension officer of the Marketing Board of the Former Lebowa Department of Agriculture, while completing his practical training for the National Diploma at the Institute for Soil, Climate and Water (ISCW) during 1994 (Kgole, Walker, Thackrah, Mashiane & Mashlakoane, 1996). It was decided that if some experimental trials were planted, it would help to revitalize the training center. To begin with some basic vegetable irrigation experiments were proposed by the researchers and extension officers. The first experimental plots were planted during November 1994 and included various fertilization treatments and irrigation levels on vegetables including spinach, tomatoes and beetroot. The irrigation treatments could not be compared as they were not applied due to heavy rains and flooding. The fumigation against nematodes and the use of cattle manure gave good results and can definitely be recommended for this area.

Several community meetings were held to disseminate information from the trials. A very successful farmers day was held at the vegetable demonstration trials in February 1995 and attended by the then MEC of Agriculture for the Northern Province, Dr. Tienie Burgers. However, the fact that no needs assessment of the communities had been conducted, became a matter of urgency.

## **2.2 Methods**

A participatory type of needs assessment was conducted amongst farmers on two irrigation schemes during a six-month period in 1995. The PRA at the Hoxane Irrigation Scheme was conducted during two single week-long periods in February and March 1995, although individual farm visits continued each month for the following six months. The PRA at three villages close to the Wonderboom Training Center on the Olifants-Arabië Irrigation Scheme in the former Lebowa was conducted during the last two weeks of May 1995 (Walker, 1995b). At each of the irrigation schemes there was a slightly different agenda due to the history of the development of the scheme and the present assistance given by the local para-statal organizations. As the project developed, a multi-disciplinary team was drawn together from the various ARC institutes and other role-players.

In each of the situations, first contact was with the Extension Officers of the Department of Agriculture, who requested the help of the researchers with technology transfer. At Olifants, the extension staff were initially considered the client as they needed assistance with their work. The end-user, however, is of course ultimately the farmer him/herself. At Hoxane, the specific request was due to the fact that the new pumps were commissioned and that meant that a new capacity was developed at the irrigation scheme.

Following the initial meeting with extension staff, a rough plan was made in each case for the scientists to visit the project on a regular basis for one week each month. At Olifants it was also decided to plant a vegetable irrigation experiment at the training center to introduce the people to the ARC. Only after several months, and some in-

service training, was it decided to go ahead with the needs assessment and a PRA training for all the extension services in the district as a whole. At Hoxane, the first step was to call a 'Farmers Information Meeting' to introduce the ARC and to begin the needs assessment and training program. These activities were always arranged by the extension staff in the area.

At Olifants, a PRA exercise was conducted during the last two weeks of May 1995. The team consisted of about 30 people each day made up of various combinations of 20-30 extension staff from Nebo district and 5-10 ARC staff members from four different institutes. Some basic training was given as the first session each morning, including the concepts of FSRE, household economics, exploratory diagnosis, explanations and exercises to learn some of the PRA methods (Nethononda and Walker, 1996). Three villages along the irrigation scheme were selected for their proximity to the Wonderboom Training Center, namely Vlakplaats, Hakdoringdraai and Wonderboom. Each of the villages is situated near to the river and the irrigation canal, with the arable lands lying between the two. The team was divided into three groups, one for each village. Each group used a selection of various combinations of community meetings, interest group meetings (including schools, soccer, sewing, community gardens, choir, etc), informal individual interviews (at selected houses on a transect through the village) and meetings with the Kgoshi (local chief) and other key informants. The various activities used included a labour analysis or schedule or time-line, long-term trends in agriculture, rough wealth determinations from size of house and contents etc., matrix ranking for importance of crops and problems with pests and diseases, seasonal calendars and distribution of labour along gender lines, and mapping of resources available to the community. The last session at Olifants was to briefly analyze the data collected and to begin to formulate a project proposal with the key role-players, extension staff and researchers. Each group then wrote a report on the specific characteristics of the village. The next step was to formulate proposals that could be presented to the community as a whole and then to prospective funders.

The principles of FSRE were briefly summarized at Hoxane and then some training was given on the participatory methods used to do a needs assessment. Usually, some of the exercises were performed with extension staff and scientists first during the training sessions. This appeared to help them to grasp the way the different activities were set-up and the objectives and involvement of the people. The idea is that the facilitator must take a back seat and that there must be plenty of time for each person to make a contribution. These principles were emphasized and then played out during the training sessions. The exercises were usually performed in small groups, either during a community meeting or at separate interest group meetings or at meetings held with the key informants or role-players.

At the Olifants scheme this historical information was gathered by using time-line methods to generate long-term trends in crop production and also changes in percentages of land planted to different crops or cropping methods. A Venn diagram was also used to describe the present relationships between the most important role-players.

Information about the level of indigenous knowledge was obtained by constructing seasonal calendars for several crops. The crop preferences and severity of pest and disease problems were detailed using matrix ranking methods. The time spent and type of work needed for operation of the farming system was documented by means of a daily time schedule and division of tasks along gender lines. The natural resources available in the area and the general infra-structure or lack thereof was documented on a hand drawn map.

There was a very good attendance at the farmers information meeting and the objectives of the ARCs involvement at Hoxane was explained to the farmers. Following the opening and introduction, they were divided into three groups to do some of the preliminary appraisals namely (a) draw a map of the area marking the infrastructure pertinent to agriculture; (b) to form a matrix of the crops grown and their relative importance, and (c) to formulate some time-lines to characterize the

timing of the most important agricultural activities at the scheme. In the final feedback session, the farmers eventually made a list of their demands to the "government" and we encouraged the management committee to attend to some of the issues.

At both schemes, the individual visits to the farmers on their farms or at their homes, played an important part in the needs assessment. At Hoxane, the team was divided into several groups which then went to the different areas on the scheme and selected farmers at random for the informal interviews. A formal questionnaire was not used, however some basic information was collected and collated. After the first few visits, the feedback was that the farmers preferred the team to make notes and they were not opposed to the idea of a formal survey. It was the teams intention to collect detailed information from a large sample of the farmers and 29 of the 70 participated in the survey. The base-line data collected is age, gender, number of family members, farm size, crops, implements, etc. as well as the main crop planted and any specific problems encountered. It was noted that although at the large group meeting all the interactions were translated, when we spoke to the farmers one on one, many of them could communicate quite well in either English or Afrikaans.

### **2.3 Results of the Participatory Needs Assessment**

The purpose here is to discuss the use of various participatory techniques as well as the interpretation of the information, so the format to be used is divided according to technique used, together with needs expressed. The initial contact with the community or farmers is of vital importance. The correct protocol must be followed such as permission from or visits to the Headman/Kgoshi/Chief and/or the local tribal or local government or civic structures. It is of course preferable if one or more of these structures originally invited you to the area and that representatives of these groups can be part of the team during the PRA. Much of a participatory needs assessment is conducted in small groups which hold meetings with existing interest groups or working groups such as soccer, sewing, schools or gardening. It is also important to conduct some of the investigation with people of influence in the

community or key informants as they must in no way feel threatened by the presence of the team.

### 2.3.1 Long-term trends of crops

Long-term trends and changes in agricultural systems on the irrigation schemes has been largely influenced by the development initiatives of the government. For instance, at Olifants there were major changes when the area was included into Lebowa, and then again specific changes in the crops grown when the area was re-developed and the irrigation scheme upgraded. There was a change from multi-cropping where several crops seed was broadcast together to a mono-cropping farming system for commercial production of cash crops such as wheat and cotton. It appears that the number line representation (Fig. 2.1) of the long-term trends worked reasonably well, as long as additional columns and rows can be added as further aspects may need to be related back to the dates. The idea to represent the change in agriculture by a series of pie charts could have worked better if more time had been taken to obtain the dates of critical changes (Fig. 2.2). The significant times when change was made need to be identified from the general time line first, then a pie chart could be used to give more detail about specific aspects, such as cropping systems.



Fig 2.1 Long-term trends in agricultural practices at the Olifants-Arabie scheme – a number line representation.

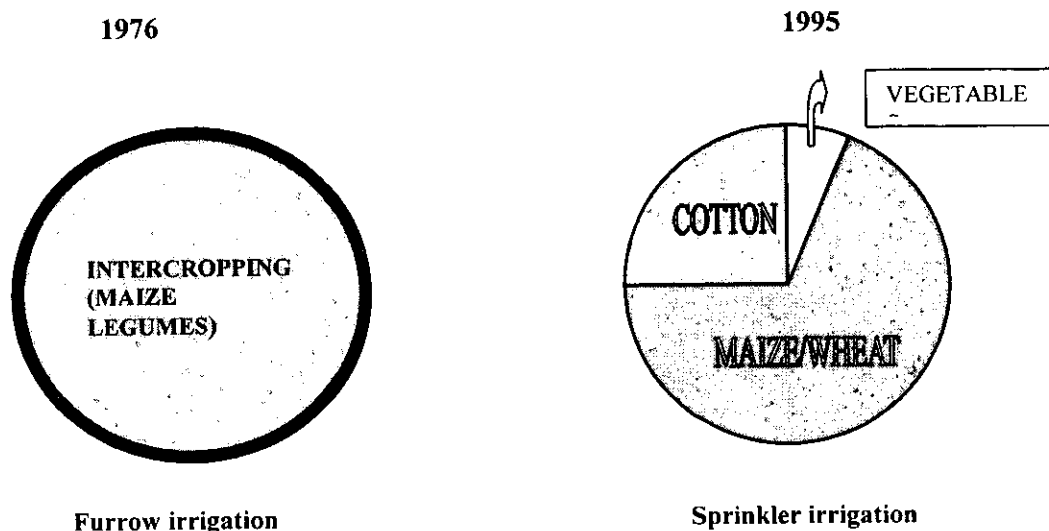


Fig. 2.2 Changes in agricultural cropping practices by two pie charts.

### 2.3.2 Venn diagrams to illustrate institutional structures

The relationships between the various role-players at each village or each irrigation scheme were different and so they were illustrated using the Venn diagram with different size and circles to represent the different organizations (Fig. 2.3). It was interesting to hear the interaction between the group members as they each discussed their own view of the relationships and importance of the various role-players. Sometimes the concept of the Venn diagram is difficult to explain and can best be taught by an example of a family situation which all those present can usually understand, as the circles are similar to the rondawals and the arrangement of the kraal. In both these situations, the usual role-players were present, namely government departments, NGOs, community leaders, churches etc. The Venn-diagram was specifically built around the needs of the farming activities. The current issues are highlighted by the presence of circles representing the kgoshi/induna/chief and the allocation of land. The other organizations that are vital to the agricultural activities include the Department of Agriculture including the co-ops which were represented by a large circle near to the middle of the diagram. Organizations that are periferal to farming activities such as schools and clinics are illustrated further from the center.

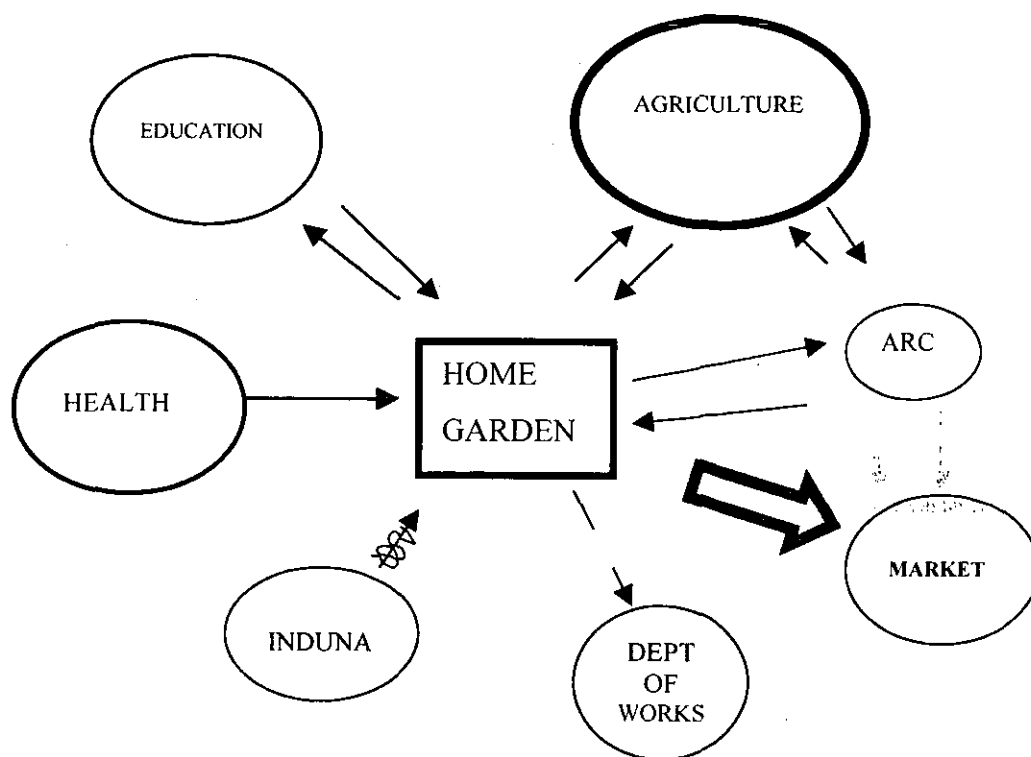


Fig. 2.3 A Venn diagram to illustrate the institutional structures that have an influence on home gardens.

### 2.3.3 *Seasonal calendar for maize production*

Usually farmers have a very good understanding of the timing of field operations for cultivation of a specific crop. However, scientists need to have their preconceived ideas about the ideal situation banished, as they learn from farmers about the local situation. This is a valuable exercise as it gives farmers confidence that they do know a great deal about their own farming system and also as it provides opportunity for the team to catch a broad outline of all the usual activities that farmers perform. At a later stage these activities and the reasons and logic for the methods and procedures used can be investigated in more detail, whether due to cultural factors or environmental limiting factors or other reasons. The seasonal calendar from Hoxane shows that green maize is planted in mid-winter as it is under irrigation in a subtropical area and then they can gain a competitive advantage by supplying the market very early in the season (Fig. 2.4). It did, however, stimulate a number of questions amongst the scientists and farmers and therefore a maize cultivar trial was initiated at the first opportunity, and was planted on three different farmers' fields (see chapter 3).

## MAIZE

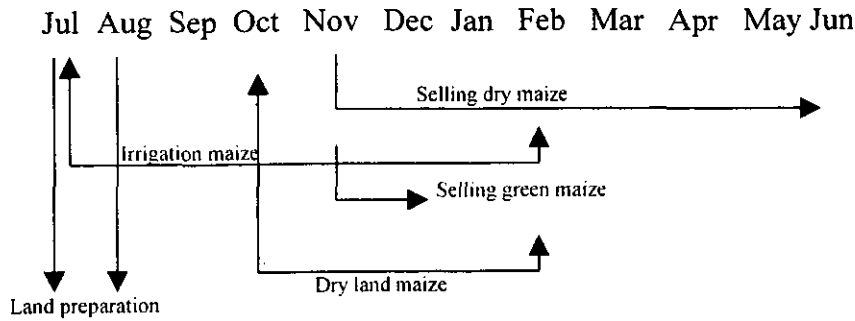


Fig. 2.4 A seasonal calendar showing activities during the maize season at Hoxane Irrigation Scheme as drawn by PRA group 1.

### 2.3.4 Matrix ranking to record preferences

When specific detailed information or a series of questions need to be answered, then the matrix ranking method can be used. At both these irrigation schemes it was necessary to gather information about the variety of crops that are grown and the breadth and depth of the agricultural knowledge base. A crop ranking matrix was first done as a learning exercise with the team and it was good to see that local extension staff knew their farmers reasonably well. A matrix was also used to distinguish between the primary use of crops grown, whether they are crops for re-sale or for use by the family. It appears that maize is grown in both areas as a staple crop to be eaten as both green maize and to be stored for the rest of the year. At Olifants, maize is planted in summer and wheat and cotton for resale in the winter (Fig. 2.5). At Hoxane, there are a wide variety of crops grown with tomatoes and maize at the top of the list. These are followed by cabbage mainly for re-sale on local and regional markets, and pumpkin, whose leaves and vines are largely harvested as a green vegetable. The level of the local knowledge about pests and diseases can also be assessed by use of a matrix ranking exercise.

(a)	Maize	Wheat	Cotton	Tomato	Spinach	Cabbage	Onions
Food (own)	1			2	3		
Selling	3	2	1				
Pests			3	1		2	

(b)	Tomatoes	Cabbage	Okra	Beans	Green	Onion	Beetroot	Spinach	Pumpkin	Sweet	Butternut	Potato	Maize	Groundnut	Mango	Hugo	Cassava	Banana	Peaches	Lichi	Sugar cane	Chicken	Cattle/Pigs	
1.Importance	1	4	5	6									2	3										
2.Diseases	1	2		4					5		5		3											
3.Fertilizer	1	3											2											
4.Water	1	3											2											
5.Eat	1	4		3		5							2											
6.Price	1	4	3										2		5									

Fig. 2.5 Two examples of matrices for the ranking method describing the use and importance of the various crops (a) at Olifants and (b) at Hoxane.

During the construction of these matrices two methods or contrasting principles can be used. Firstly, one of consensus where the group agrees to place a single vote on the matrix. Secondly, each person in the group can be given a number of seeds or stones with which to vote, then the block with the highest score will be the most popular. To use the matrix method, it is best to talk at length with some key informants so that the correct line of thinking or approach is used. Then a critical issue can be addressed by allowing the group to form their own headings for both horizontal and vertical columns. At first it will also be rather strange for them to be expressing themselves in this way, and so some time needs to be taken to explain it in simple terms and to be sure that the translators have given sufficient detail. It is also good to try to find out whether the consensus or individual voting method will be most acceptable to the locals. It was found that the farmers were really interested in the final outcome of the matrix ranking and asked for a report back after several groups went through the same exercise. The method of matrix ranking can be used to evaluate or assess the results or preferences of an on-farm trial or to survey the local farmers opinion of new versus old cultivars or pest problems or methods of holding farmers days. The possibilities are endless, where there are several options to be chosen from then the matrix method can be used. The information obtained from these ranking exercises provides a basis for the decisions as to what needs to be addressed and the priority order.

### ***2.3.5 Labour analysis and daily time schedule***

On the Olifants scheme, the farmers are mostly women and they work in the fields under the control of the former Lebowa Agricultural Corporation. The irrigation scheme is run along the lines of an estate and farmers do not play a role in decision making. This was causing much unhappiness and major problems in all areas at the time of the PRA. The people consider that they work rather largely as labourers who move irrigation pipes at prearranged times and have no opportunity for application of individual management skills, as shown by the daily time schedule. All the farmers, mostly women, have precisely the same program each day as they must all move irrigation pipes while the centrally controlled pumps are switched off (Reardon, 1993). This is definitely one of the major difficulties and complaints at this part of the irrigation scheme, as it has limited the peoples opportunities and their personal development.

The tasks performed were also carefully divided according to both gender and age groups (Fig. 2.6). The tasks such as maintenance of the cattle kraal are strictly performed by the males and tasks such as cooking and weeding are usually performed by women. The children and youth also have a full daily program although they are often required to work in the fields moving irrigation pipes despite missing some classes. The children also work in the field during harvest time. The labour analysis worked very well as a group exercise as the tasks are mostly divided along cultural traditional or tribal lines and so there is consensus in the large group. Under these circumstances, the daily time schedule could also have been done in a work group situation as the farmers work in teams moving pipes and must perform this task at specific strictly limited times.

MEN'S WORK	WOMEN'S WORK
Milking	Cleaning
Building	Fetch water
Fishing	Food preparation
Hunting	Washing
Livestock herding	Collect wood
Kraal maintenance	Pick vegetables
Leisure	Child care
Meetings	Group Activities
Employment (income)	Leisure

Fig. 2.6 A list giving the division of labour between the men and women in the community at Olifants during the PRA.

### ***2.3.6 Mapping of natural resources and infrastructure***

The mapping exercises are always fun and can be used as an icebreaker. However despite it being relatively easy and enjoyable, the map offers a large amount of information for the team that may be on its first visit to an area. The infra-structure such as roads, electricity and telecommunications can be illustrated quite clearly. Rivers and pipelines or canals supplying water are also of vital importance. The people can also usually supply a wealth of information on the good and problematic soils or presence of rocks or poorly drained soils. This exercise worked well in both situations (Fig. 2.7). When one group visited a school, they also were able to involve all the children in a large agricultural class in a map drawing exercise. Under this situation, one of the team did however supply a list of the features that should be shown on the maps.

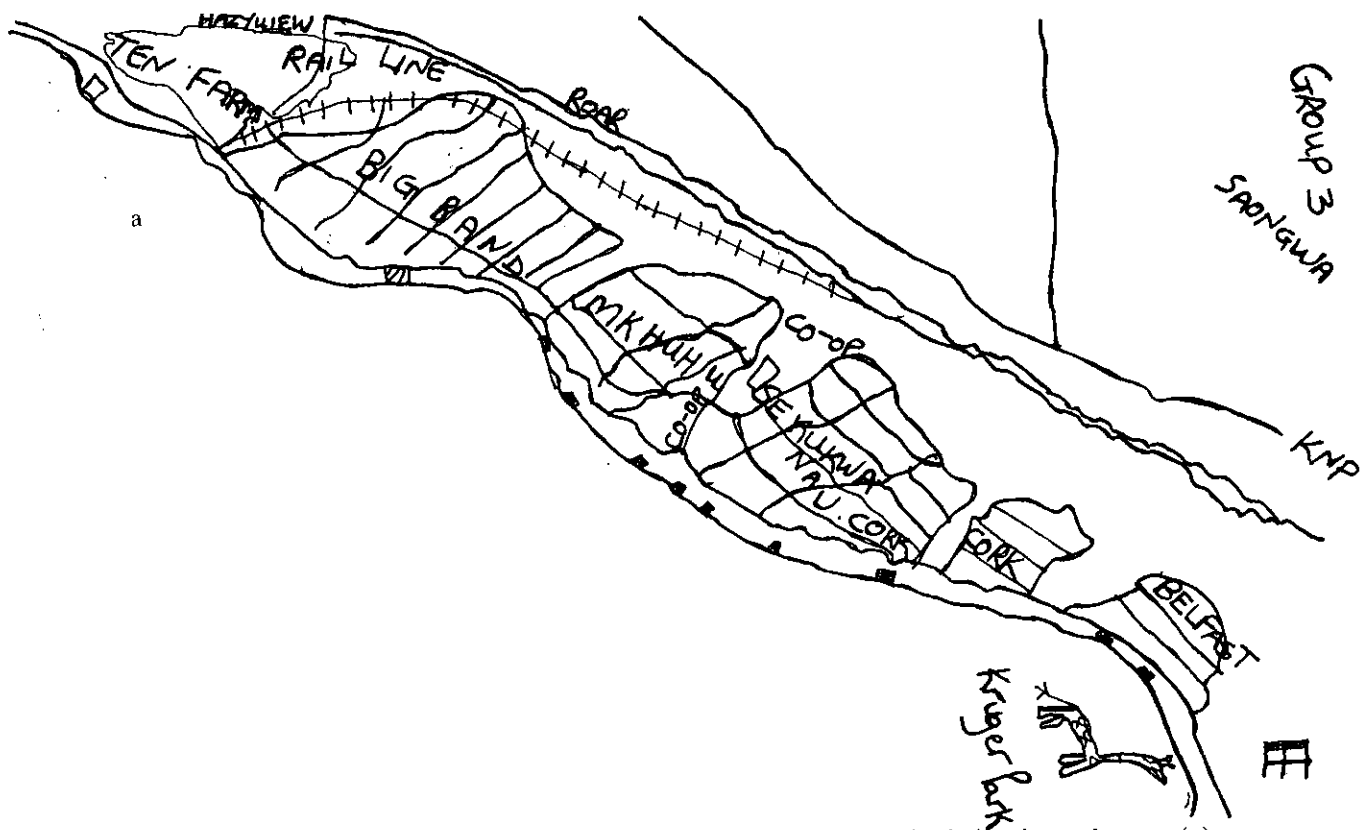
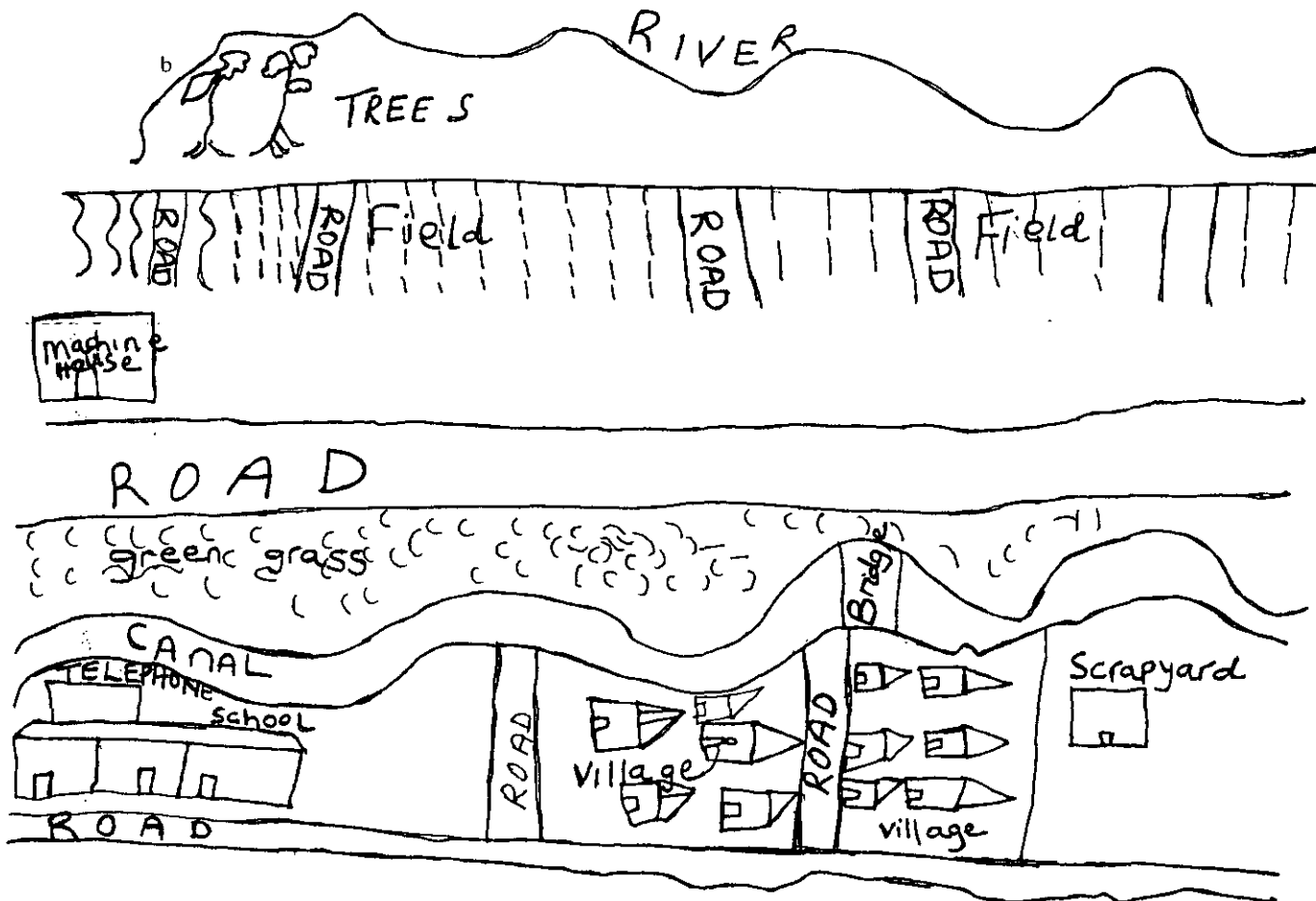


Fig. 2.7 Two examples of the mapping of resources on the irrigation schemes (a) Hoxane (b) Olifants.



### ***2.3.7 Informal farm / home visits***

Even though much of the needs assessment was performed in groups it was still most beneficial to conduct some personal individual visits to the homes or farms of the people concerned. It is not always easy to be sure that some segment of the population is not being excluded from the group discussions due to cultural values or other reasons. Even if some of the group discussions were held in single gender groups, one may not be able to glean all the true information due to personal rivalry or group pressure or submission to the usual leaders in the community. Therefore individual visits in some homes are always worth the time and effort spent, as the people can always speak more freely in the privacy of their own home. They also feel really important and are glad to welcome visitors to their home or fields. It is important though to have some sort of method or strategy to select farmers or houses. A transect can be plotted across the area and then a visit made at a selected interval as the team moves through the area. Alternatively, farms can be selected at random from a map of the whole area and then specific appointments made to talk with those farmers. The team concentrated on speaking to farmers and their wives or husbands if present, but it appears that it could also be beneficial to address the needs of labourers who work on farms at Hoxane.

Results from the unstructured open-ended survey conducted at Hoxane indicate that the average age of the farmers is 57.8 years and they are predominantly men who have been in residence on the farm for 17.8 years. The average family size is 9.1 people on a farm size of 11.1 ha with 4.8 ha under irrigation at present. They employ on the average 3.8 additional people per farm and the average labourers wage was R 123.60 per month per labourer in 1995. Only a third of the farmers have transport (Fig. 2.8) to take their produce to local or regional markets, so this is an area that can be addressed by the co-op or it is an opportunity to develop agriculturally related industries and transport businesses. About two thirds of the farmers own a tractor (Fig. 2.8) although a number had considerable maintenance problems such as obtaining spares and/or financing for the repairs. One of the farmers has already seized this opportunity and he and his son run a tractor repair workshop on the

irrigation farm. Other farmers must hire tractors (Fig. 2.8) from their fellow farmers and often have to delay soil preparation as a result. A large number of the farmers also own cattle ranging from 0 to 33 head and a few have goats and chickens. A third of the farmers use some sprinkler irrigation while most use predominantly furrow irrigation methods or basin irrigation around fruit trees (Fig. 2.8). Base line data could be used later on to assess and evaluate the adoption rate of technology that is introduced and the effectiveness of technology transfer that is in progress.

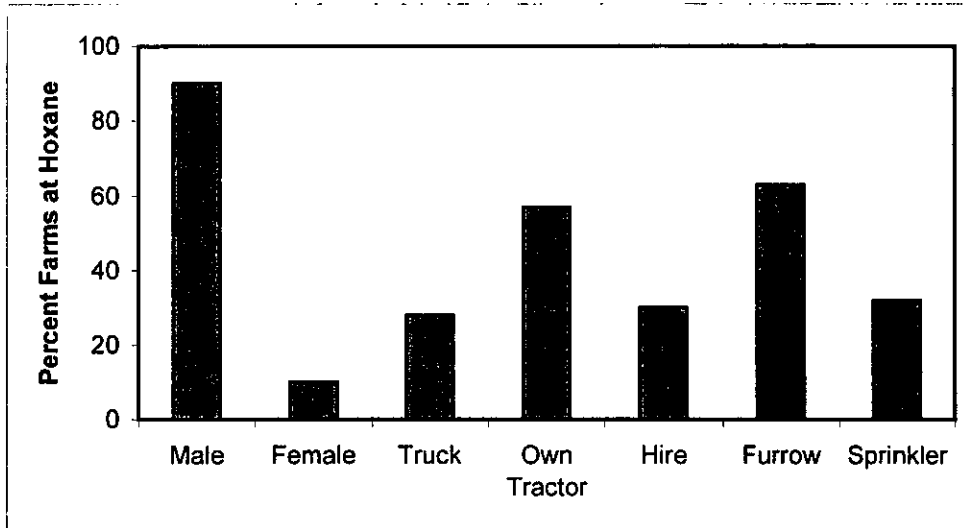


Fig. 2.8 (a) A bar graph showing the percentage of farmers that are male and female at Hoxane. Also illustrated are the use and ownership of tractors and furrow or sprinkler irrigation.

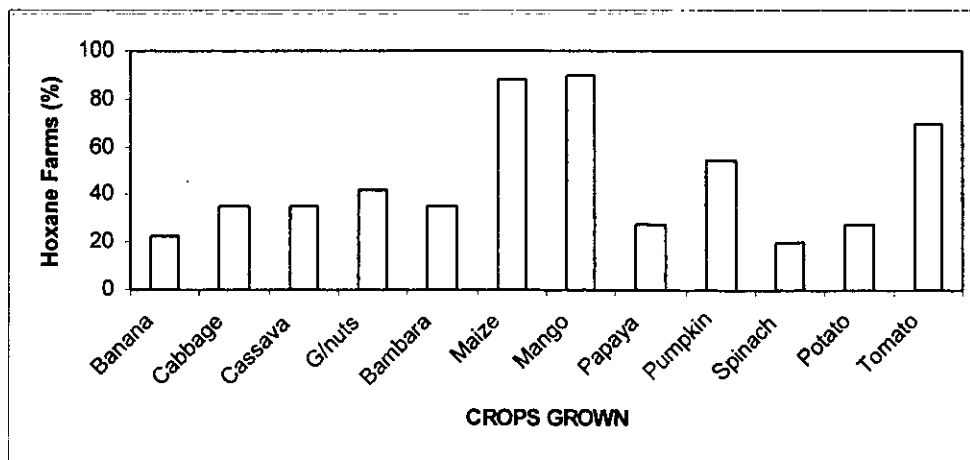


Fig 2.8 (b) The crops grown at Hoxane and the percentage of farms on which they are grown

## **2.4. Conclusions**

Most of the farmers still want to plant their own staple food crop namely maize, as in the past there have been severe food shortages, and so household food security is high on the list of priorities. However a number of the progressive farmers at Hoxane are now easily able to supply enough food for their own families and so they tend to look to being able to provide for further education of their children and to improve their farm implements. From these needs assessment studies one of the main points was the fact that the wealth of research information that has been readily available to the white commercial farmers was totally inaccessible to these farmers, whether it was due to physical distance or language or high scientific level of presentation. These aspects now need to be addressed by the extension staff together with the research scientists.

In general, the participatory techniques worked well and provided some structure to discussions and informal interviews with farmers. Once the concepts behind the techniques have been mastered, they can be used under a wide variety of conditions to assess the needs in general. The methods were also used successfully to answer specific questions as to crops grown and determine the most limiting aspects of the farming systems. Once these needs have been identified then the key role-players and community leaders can prepare a project proposal or business plan to guide the long-term development of the area. This can then provide for a strategy for the development of the farmers in particular and the area in general. This is followed by specific actions that take the project along the road and provide the necessary ongoing development and training for the area along the lines specifically identified.

Although much of the information collected in this participatory fashion is not readily converted into hard numbers, many of the trends or choices that face farmers can be highlighted and clarity can be brought into the factors that influence the further discussions. There are still many possibilities in the use of the data collected in such a manner to develop some social cause and effect flow charts. If for instance the different groups in the community may rank or grade the importance of various crops

in a different order, it could be interpreted as different priorities and needs in different sectors of the population. These differences once emphasized can then be used to develop different meaningful projects to meet the variety of needs in the community.

## Chapter 3

### ON-FARM TRIALS

#### 3.1 Introduction

The process of setting up participatory on-farm trials is a lengthy one, which must involve many role-players. The most successful projects are usually those where members of the community or a group of farmers initiated the process, as then the desire to move forward is motivated from the farmers themselves. However, this is not always the case as often it is either the researchers or extension staff that initiate the process. Whichever way, it is important that it is an inclusive process – with as many of the role-players involved in the project as possible. The linkages between agricultural extension officers and other government officials are vital, as farming activities are often dependent on operations of other government departments (Merrill-Sands, Kaimowitz, Sayce & Charter, 1990). The local government or tribal authorities and other local leaders must also be included for the smooth running of the project. Often this coordination at an official level can run parallel to the interactions at the level of actual farmers in their fields.

Once the initial needs assessment has been completed then the process can move into the specific planning of the project and on-farm trials. It is good to report back to a whole community meeting at this stage. All the role-players and all farmers can again be drawn into the process to avoid unnecessary conflict or accusations that certain groups or individuals were not included in the decision making. If a smaller committee can be formed for the specific project then all the better, so that the whole community then gives that committee the authority to go ahead with their best interests at heart. This allows a small working group to be formed with farmers that are really prepared to participate and work together with extension staff and researchers.

During the specific planning phase for the on-farm experiments it is important to build-up confidence amongst the farmers and commitment to the specific objectives

of the project. The selection of farmers and treatments is crucial and a difficult phase as this is when the real practical participation and commitment to the hard work of agriculture is apparent. Most farmers have tried and tested various methods during their years of crop production and so the concept of experimentation is not foreign to them, although the formalization and methods of measurement may be foreign to them. Time needs to be given to explaining the need for the various measurements and the importance of the documentation of the steps taken throughout the trials (FAO, 1993). The processes need to be decided on a consensus basis where all participants will agree to the need for comparisons of various treatments that will be included in the trials.

The selection of the farmers for the trials is a vast topic with many different methods and pros and cons for different systems (Bembridge, 1991, FAO, 1988). The requirement for different levels of participation for different types of trials is vital to consider when establishing these on-farm trials. For instance packets of seed of 5-6 varieties can easily be handed out to a large number of farmers to plant according to their own methods, if only the yield and personal preferences are to be recorded. However, to conduct a detailed irrigation scheduling trial where the soil water content and amount of irrigation applied has to be measured, requires either a major commitment from the farmer or a larger control by the research team. It is all these kinds of decisions that need to be made by the group consisting of farmers, extension officers and researchers to enable the on-farm trials to run smoothly and address the concerns of all parties. This requires a process of relationship and confidence building as well as commitment to a long-term project, and usually cannot be bought, but only develops on a personal level between the team members.

On-farm trials have been conducted in various localities in the lowveld of South Africa, in Mpumalanga and Northern Provinces (Walker, 1999). Due to some of the constraints described above all, of the projects have to some extent been both a success or failure during different seasons.

## **3.2 Methods and Management of Trials**

### **3.2.1 Hoxane Irrigation Scheme**

Hoxane is an irrigation scheme where there are approximately 70 small-scale farmers on the Sabie River between Hazyview and Kruger Gate of the Kruger National Park. They are farming sub-tropical tree crops (mangoes, avocados and citrus); field crops (maize and groundnuts) and vegetables on plots of between 5 ha and 15 ha. The former Gazankulu Development Corporation upgraded the irrigation scheme during the 1980s with funds from the Development Bank of Southern Africa.

The Agricultural Research Council (ARC) in conjunction with the Northern Province Department of Agriculture (NPDA) initiated a technology transfer project in January 1995. The technology transfer took the form of a monthly training session in English with the extension officers of the whole area. Farmers training days were also held where a specific topic of interest was addressed and farmers were divided into small groups and they then visited each stall and lessons were translated into the local language, Shangana. This project was based on FSRE principles and so a series of on-farm trials was planted during 1995 (Walker, 1995a).

From the needs assessment it was apparent that maize played an important role in the farming practises and was harvested as green mealies and sold locally to the residents of Mkhuhlu. The most pressing problems were with insect pests and diseases on all the crops planted. The most important and widely grown cash crop is tomatoes, and mangoes are the most important subtropical fruit crop. The researchers from the various ARC institutes then agreed to develop some demonstration trials to address these expressed needs. It was decided to use sections of the farmers fields for the demonstration trials and so volunteers were requested to speak to the extension staff. Later, however, the extensionists suggested some of the better farmers that could be asked to participate.

On-farm trials have been conducted at different levels over at least three seasons, with varying degrees of farmer involvement ranging from – just the use of the land to

farmer managed trials. The maize cultivar trials were planted by Dr John van den Berg of the ARC Institute for Grain Crops in Potchefstroom during late July 1995 at three farms. An extension officer visited the farms weekly and the researcher visited monthly including two training visits, one during the season when the use of a simple method to apply an insecticide for the prevention of stalk-borer was demonstrated and a second visit at maturity, together with a small group of farmers.

The tomato and cabbage trials were planted by Jaco Smal and Uli Gernholz of the ARC Roodeplaat Vegetable and Ornamental Institute and Emile von Maltiz of the ARC Plant Protection Research Institute. Initially there was a major setback when a wind storm destroyed the seedlings. The pesticide and spacing trials were laid out and planted by the researchers and extension officers in three farmers fields. The various sprays for use in the pesticide trial were issued to the farmers, consisting of a range from commercially available sprays to home-made mixtures. The researchers visited the trials on a monthly basis and a mid-season field visit was arranged to which all farmers were invited.

The groundnut cultivar trials were planted by Phonnice du Toit of the ARC Institute for Grain Crops in Potchefstroom during November 1995 at three farms. The extension officer visited the farm weekly and the researcher visited monthly including a farmers field visit. Unfortunately these trials were damaged by the heavy rain and floods during January and February 1996.

In general, the management of the trials was hampered by the poor communications infrastructure between researchers and extensionists. Some of these trials were successful in achieving the objective to introduce farmers to different cultivars as only one or two of the cultivars performed well. These cultivar type demonstration trials were repeated through several seasons for tomatoes, cabbage and sweet potatoes. The pesticide trials were not successful as there were numerous problems with the routine spraying of crops and researchers were never certain whether the correct spray had been applied or to which plots. In one situation the farmer did not use any of the treatments but sprayed with his own spray on all the different treatment plots so that the field would look beautiful and clean for the farmers day. Obviously there was

some lack of understanding of the real objectives and a serious breakdown in communication in this case. A groundnut cultivar trial was washed away during an unusual heavy rainfall season (January – February 1996) – although the farmer had not conducted the weeding as arranged.

Following much further discussion, a further season of trials was initiated in which all the decision making was left up to the farmers with a little guidance from the extension staff. However, even though the farmers study groups selected the participating farmers, some of them withdrew at planting and others during the season, and only one crop of tomatoes was successfully harvested. One problem was that although they weighed the fruit, a record of the plot numbers was not made and so effectively there was no yield data available. The farmers however proceeded to plant one of the most successful tomato and sweet potato varieties in the following season. So, despite the fact that the researchers have no data – some of the farmers adopted new cultivars for their commercial production as a result of the on-farm trials. This could therefore be considered as a successful adoption of new technology as a result of the trials.

### ***3.2.2 New Forest Irrigation Scheme***

Following the decision to do the irrigation on-farm trials at New Forest Irrigation Scheme, the necessary negotiations began. An initial meeting was held between the director of the Department of Agriculture of Northern Province (NPDA) and the project leader. The next step was for the ARC project team to meet with the Department of Agriculture officials at Tulamahashe government offices.

The New Forest Irrigation Scheme consists mainly of two groups of farmers, namely small food plots planted mainly by pensioners, and emergent farmers with approximately 1.2 ha plots. It was decided not to involve the women who are mostly old age pensioners who work on the food plots as it would not be possible to use these plots for experimental purposes. So a meeting was scheduled with a farmers representative committee from the other group of farmers. At this meeting of farmers,

extension staff and researchers, the selection of farmers to participate in the trial was made.

Several of the committee members expressed interest and commitment to the on-farm experiments and other farmers who would willingly participate were identified. The project team (both ARC and NPDA) then visited the various farms to discuss which piece of land would be available. They also visited the homesteads in the town to identify cattle manure that could be used from cattle kraals adjacent to the houses.

Following discussions with the group of extension officers working on the irrigation scheme it was decided to conduct farmer-managed trials to investigate the effect of different fertilization methods on the yield and water use of irrigated maize (Lee, 1993, Yoganathan & Van Averbeke, 1996). The farmers requested that the experiments be conducted on maize as it is the predominant crop and provides food security for the community at large (Heisey & Mwangi, 1996). Tomatoes and cabbage are also planted on a large scale but not by all the farmers, and they felt that it would exclude parts of the community if the experiments were conducted on those crops.

There was agreement on the aim to investigate the differences in yield and water use under different fertilization management treatments. The most commonly used fertilization method is a small handful of cattle manure applied at planting. Alternatively, inorganic fertilizers are applied when the budget allows (Heisey and Mwangi, 1998). It was agreed that one of the treatments would be the farmers own usual methods. As there were often shortages of water on the irrigation scheme, it was also decided to look at an option of using a mulch to limit soil surface evaporation (Walker, 1995a; 1995c, Walker, 1999). Therefore the 4 treatments applied at each of the farmers fields were as follows:

- a) normal or usual method of fertilization as applied by the farmer
- b) mulch and inorganic fertilizer
- c) inorganic fertilizer at recommended amounts
- d) cattle manure

The practical operational tasks were then assigned to extension and research staff. The Department of Agriculture undertook to arrange the delivery of the kraal manure and the ploughing and soil preparation for the irrigation farmers. Four plots, each 10 x 10 m, were laid out within a single levy at each farm. Soil analysis was conducted for the top 20 cm layer and subsoil samples (Appendix 1). There were numerous delays each step of the way and particularly with the soil preparation operations but finally the maize seed was planted and irrigation water applied.

Many of the operational difficulties were due to lack of equipment and budget allocation by the NPDA. So, although the extension staff were enthusiastic and willing to cooperate, there were continually practical drawbacks that limited the progress of the project. Some of these problems can be attributed to the transition phase between the former homeland government and the Northern Province government. In addition, there were numerous problems that were peculiar to the Bushbuckridge area, as there was dissension as to which of the new provinces (either Mpumalanga or Northern Province) should have jurisdiction over this area.

The neutron probe access tubes were inserted by a team from ARC and NPDA, one in each of the plots at each farm. However, due to lack of transport, particularly during 1996/97, few weekly readings were taken by NPDA staff.

The basic agronomic operations, including cultivation, irrigation, weeding and insecticides, were conducted by the farmers themselves as it was a "farmer managed" trial. However, during the first season, few of the farmers applied control measures for stalk borers and so much of the crop was damaged by insects.

The harvesting of dry maize cobs was again done by the whole team, namely farmers, NPDA and ARC. These cobs were weighed in the field and then a subsample transported to Pretoria to be oven dried for biomass calculations.

It was the intention of the project team to plant a vegetable crop during 1997 as an on-farm trial, however due to the unrest and strike-action which lasted at least 3 months,

it was impossible to plant the tomato trials. All of the government departments were on strike concerning the transfer of the area from Northern Province to Mpumalanga, and so very few crops were planted at New Forest Irrigation Scheme. Therefore the maize on-farm trial was repeated at the same farmers, during the second year namely 1997. The treatments remained unchanged, except that no additional cattle manure was applied.

### **3.3 Discussion**

#### ***3.3.1 Hoxane Irrigation Scheme trials***

The maize and groundnut cultivar trials appear to have been well received and each had a successful mid-season field visit at the trial with several farmers attending and asking many questions. There were some problems however with the crop being harvested before the final visit by the researchers and so no good cultivar preference evaluation was possible. There were similar responses to the tomato and cabbage trials, however the management of the spray programme was not at all successful. Extreme results were where the weekly spraying was not done at all or where the farmer used his own chemicals to spray all the different treatments equally.

Overall the management of the trials left much to be desired. This was of course a first for both researchers and extensionists and so it turned out to be a learning experience. Both the extension and research technicians were inexperienced in running on-farm trials and both offices are short-staffed or overworked. There were also problems due to insufficient funds for transport or a shortage of vehicles which resulted in poor management of the trials. Due to the distance from the research institutes to Hoxane and the work load of both researchers and extension officers there was often a breakdown in communication.

There were also some administration problems in the Department of Agriculture, despite the fact that the supervisor was co-operative and enthusiastic about the project. Initially there were three extensionists working on the irrigation scheme, however one was transferred and not replaced. The officers were also expected to perform the duties for

the on-farm trials in addition to their other duties and they were not given recognition for this extra work load or time and transport spent on the project.

The content of the trials was not always well thought through by the researchers or discussed at length with either the extension officers or the farmers. The demonstration of the maize cultivars appeared to be acceptable and serve the purpose intended as almost all the farmers plant maize on part of their farm. The vegetable trials however appear to be misdirected as they did not really serve the commercial farmers who are further advanced nor did they serve the subsistence farmers as the spray programme was not simple enough. Therefore care must be taken to ensure that inappropriate products or technologies are not used in demonstration trials. During our discussions prior to the trials we did not include the farmers themselves so the local knowledge was excluded during the planning phases. Some of the potential information from the trials was not collected due to lack of equipment or infrastructure and this should have been anticipated during planning (Walker, Shabangu, Ngomane, De Wet & Smal, 1996).

There was no real selection of the farmers to participate in the trials. To ask for volunteers was unfair as they did not have a good idea what level of commitment was needed. To ask for people to be nominated by the committee or the extension officers is not good for internal politics or other possible favouritism. Much more time and effort needs to be put into the selection of farmers to participate in on-farm trials. There were also false expectations from farmers involved in the trials as not enough time and effort was made to explain to them how the trials would work, so they expected the government or ARC to provide all the labour and capital equipment for all the operations on the farm.

### ***3.3.2 New Forest Irrigation Scheme trials***

#### ***3.3.2.1 Field operations***

The second attempt at irrigation on-farm trials was at New Forest Irrigation Scheme. As already described there were many stumbling blocks to be overcome. Therefore, the overall impression of the practical management of the field operations is not a good one. It proved to be extremely difficult to manage the trials at New Forest Irrigation Scheme. However, the process and difficulties will be discussed and the results will be given by way of an illustration of what was actually achieved.

The processes of setting up such a set of on-farm trials is highly involved and in this particular case complicated by the logistics of being 5 hours drive from ARC offices in Pretoria. Many of the operations needed the goodwill and cooperation of the department and although the spirit was willing, often it was most difficult to coordinate and motivate the necessary transport, implements and manpower at the same time. The extension staff selected the farmers and approached them to be involved in the trials and to arrange for the use of a piece of land. There were many delays in arranging for the NPDA tractors to plough the fields and for the delivery of fertilizer and kraal manure to the field. This necessitated the staggered planting of the maize crops at different farmers and even replanting in one case. The insertion of the neutron probe tubes was a mammoth task plagued by problems of lack of transport and the necessary equipment at the site. However, the fields were planted between 3 and 24 October 1996 and one plot finally in December 1996. The monitoring of the soil water content was begun immediately, however it was only conducted at sporadic intervals due to lack of transport for the extension officers resulting in only 8 readings over the growing season. The dry maize was harvested on 19 and 20 February 1997.

The main factors contributing to the difficulties experienced in the New Forest on-farm trials were as follows:

- distance from home base (Pretoria to Tulamahashe);
- poor cooperation between ARC and NPDA at top management level;
- lack of previous experience in rural on-farm trials;

- lack of good operational telecommunications;
- poor cooperation from some specific farmers and extension personnel;
- poor irrigation infrastructure at scheme level;
- strike action from all government departments in the Bushbuckridge area;
- delay in delivery of agricultural chemicals (fertilizers and pesticides);
- delay for repair of equipment;
- lack of available transport at field site.

If we consider the 1996 maize trials, there were many lessons to be learned during the seed bed preparation stage, including unavailability of tractors or ploughs and delays in delivery of fertilizers to the field sites. These factors caused one of the farmer's fields to be planted more than 2 months after the others, resulting in this data not being comparable as a replicate of the other farmer's fields. During the crop growth and development, delays in delivery of pesticides and poor telecommunications allowed stalk borers to cause extensive damage in many of the farmers fields and throughout the on-farm trials.

There was also some misunderstanding between some of the farmers or workers and the extension and research staff. This resulted in delays in the weeding operations when the crop was waist high in the vegetative stage. The effects of high weed density was clearly seen in several of the farmers fields across all treatments. Another problem encountered was the stealing of maize cobs during green mealie phase. This theft continually presented itself as a problem throughout the on-farm field experiments at New Forest Irrigation Scheme as well as other distant rural sites.

### ***3.3.2.2 Water content measurements***

Although much time, effort and expertise were used, the calculation of a water balance on the experimental plots eluded the team. The experience gained during this on-farm trial with irrigation treatments in developing agriculture must be taken seriously when venturing into future such projects. This type of trial is very time consuming and skilled labour intensive and still often the results sought after are not obtainable. Sometimes, one could imagine if it was a qualified persons sole task to

attain the objectives – then it must be possible. However, following this experience at New Forest, there are many, many other circumstances beyond any individuals control that could not be changed no matter how much skill or time are spent on the problem. Thus, the water balance part of the project was aborted due to unforeseen circumstances beyond the control of the project team.

As the farmers were applying the normal amount of irrigation to all the treatment plots, it will be assumed that they received equal amounts of water during the season. During the second season, the team went to great lengths in inserting V-notches and plastic lining into the furrows at the edge of the experimental field. However, even though the amount of water applied was measured on several occasions, these data are difficult to apply to the rest of the fields or to the rest of the season. Neither the extension staff nor the technician nor the farmer was able to accurately time the run off water per treatment plot. So this again is a failed attempt at measuring or estimating the water applied per irrigation as required for objective 4.

Some difficulties were also encountered at the initial insertion of the neutron probe access tubes, due to stony ground at the deep layers of the soil. Several tubes had to be inserted twice to ensure good straight tubes in each of the 4 treatments at each farmer. The extension staff were cooperative and willing to do the readings each week, however after 2 – 3 weeks a serious problem arose. The government transport supplied by NPDA was withdrawn and so measurements were discontinued. Another difficulty with the water balance was that as some of the farmers cannot read and write it was difficult to record irrigation application data. As the extension staff were not able to visit each farm every day, even the day of irrigation is uncertain. This means that no water balance could be calculated for the on-farm trials, despite the extra time and effort made by the research team during the second year. The data for the second season was better than the first season, but it was still inadequate for a complete water balance to be made. This is a severe drawback to the validity of the on-farm experimental data as no water-production function could be drawn up for the various treatments or across different farmers' fields. This means that one of the

primary objectives of the on-farm field trials was not able to be met, but, as described above, it was beyond the control of the research team.

During 1996 maize season, the water content measurements were recorded as ratios from the neutron probe and the results from Nukeri and Mashele are shown in Fig. 3.1(a) and 3.1(b). Consider firstly the water content versus depth at Nukeri's farm on day 34 and 98 after planting (dap). It appears that the addition of kraal manure had the effect of retaining more water in the top layers of the soil. On 34 dap the kraal manure plot has a water content 5 % higher at 15 cm depth than the other treatments (Fig. 3.1 (a)).

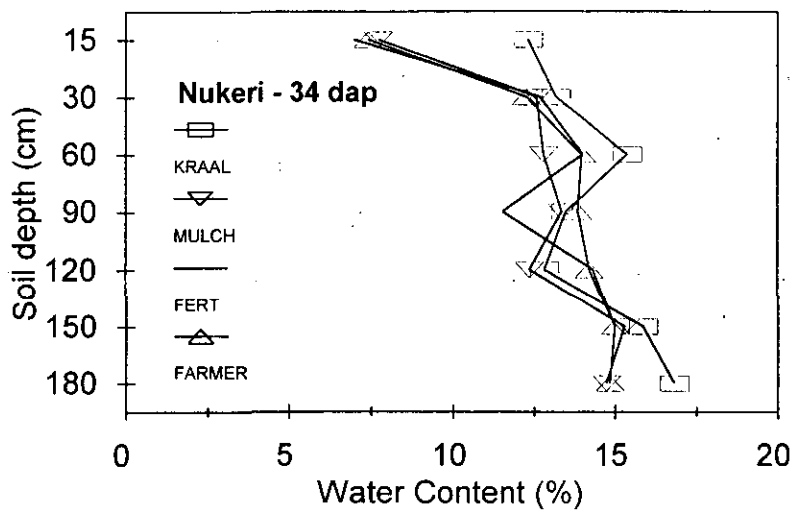


Fig.3.1(a) Soil water content measurements across treatments at various depths at Mr. Nukeri's farm on 34 days after the maize was planted.

On 98 dap the effect is not as large, but the kraal manure treatment is constantly at a higher water content until a depth of 90 cm (Fig. 3.1 (b)).

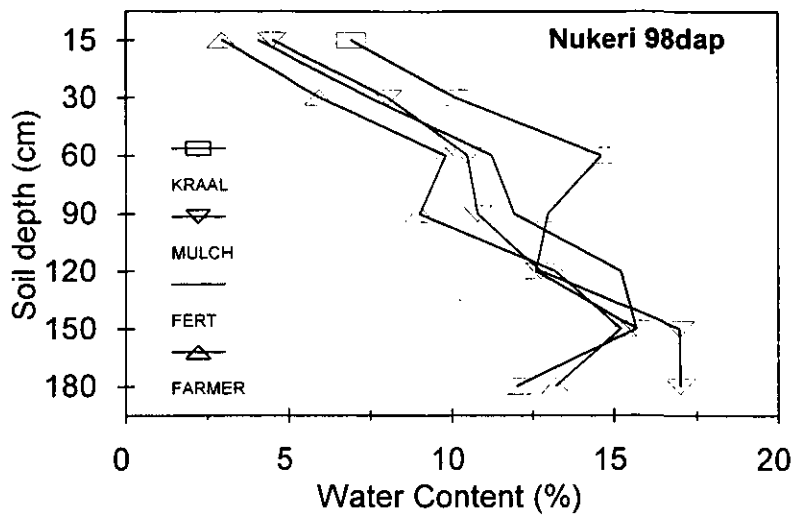


Fig.3.1(b) Soil water content measurements across treatments at various depths at Mr. Nukeri's farm on 98 days after the maize was planted.

In another example at Mashele's farm on 40 dap the kraal manure and mulch are at a higher water content than the other 2 treatments at 15 cm and then the mulch treatment maintains a higher water content down the profile to a depth of 90 cm (Fig. 3.2 (a)).

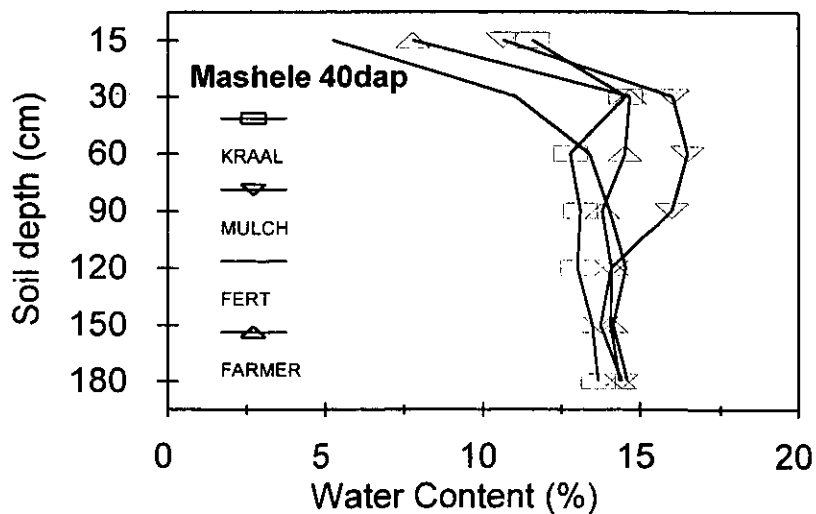


Fig. 3.2(a) Soil water content measurements across treatments at various depths at Mr. Mashele's farm on 40 days after the maize was planted.

On 98 dap again the kraal manure treatment has a higher water content in the top layer and the mulch at 60-90 cm depth (Fig. 3.2 (b)).

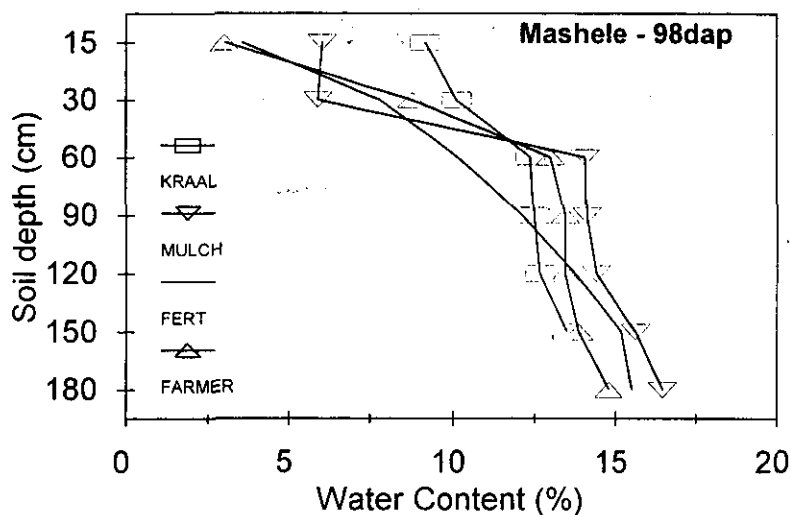


Fig. 3.2(b) Soil water content measurements across treatments at various depths at Mr. Mashele's farm on 98 days after the maize was planted.

The changes in soil water content with time during the season are shown in figures 3.3(a,b,c,d) for Nukeri's farm and in figures 3.4(a,b,c,d) for Mashele's farm. At Nukeri, under the kraal manure treatment it is seen that the surface layer steadily dried out through the growing season. After the second reading (26 dap), there was little change from 60 cm down in the profile on the kraal manure treatment compared to the other treatments where there were changes of 5 % between 26-98 dap at a depth of 30-90cm.

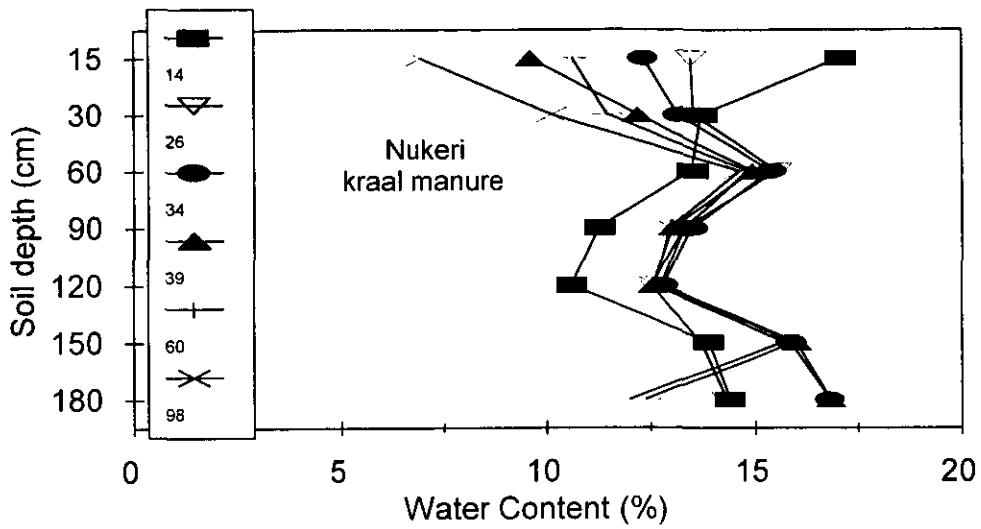


Fig. 3.3(a) Changes in water content with time (dap) through the season for the kraal manure treatment at Mr. Nukeri's farm.

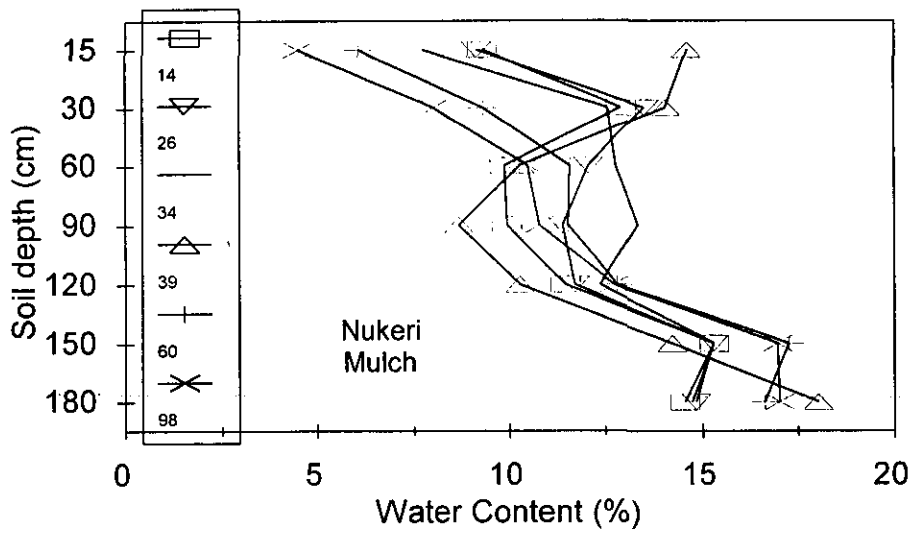


Fig.3.3(b) Changes in water content with time (dap) through the season for the mulch treatment at Mr. Nukeri's farm.

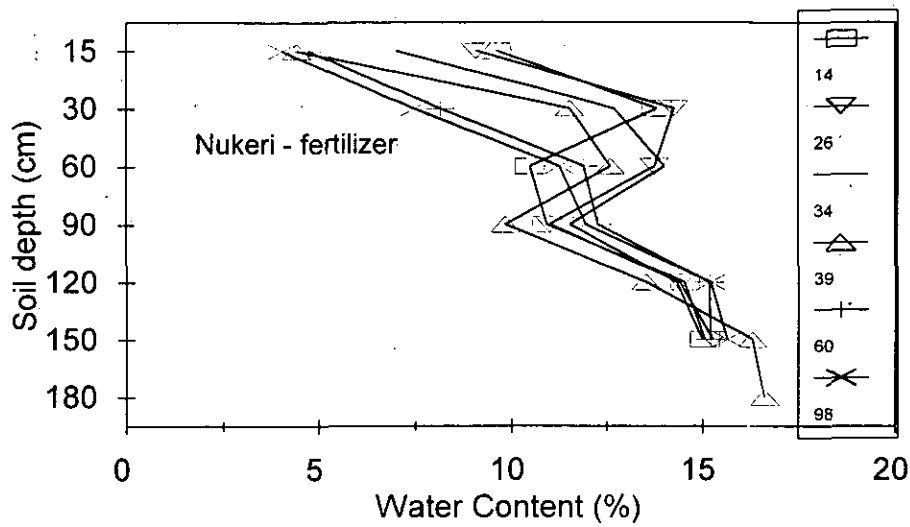


Fig.3.3(c) Changes in water content with time through the season for the fertilizer choice treatment at Mr. Nukeri's farm.

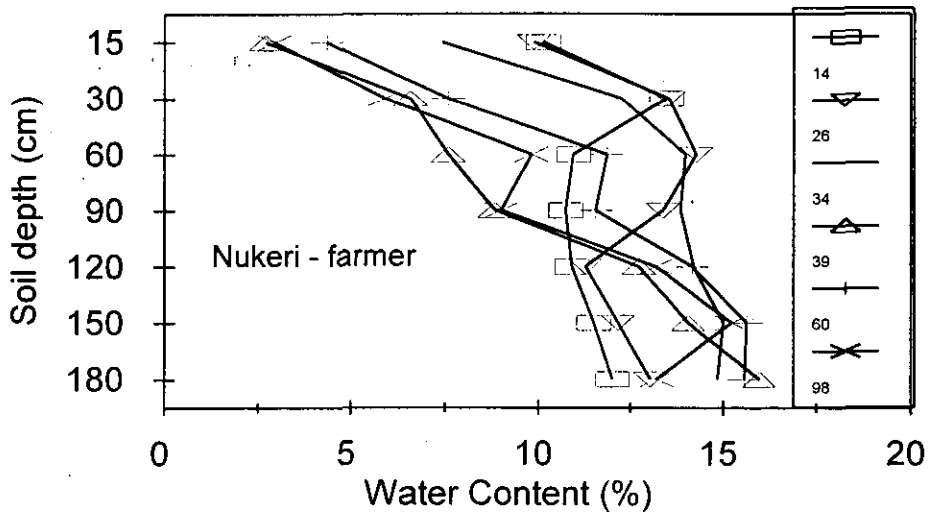


Fig.3.3(d) Changes in water content with time through the season for the farmer's own treatment at Mr. Nukeri's farm.

On Mashele's farm in the kraal manure treatment, the water content in the top layer is higher throughout the season than under the other treatments and again the farmers own normal practices gave the most depletion of water in the surface layers (Fig. 3.4(a,b,c,d)).

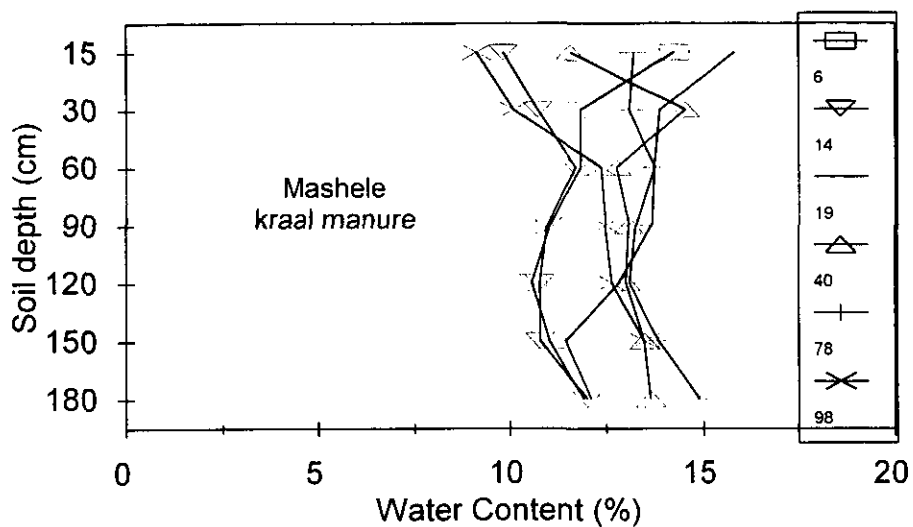


Fig. 3.4 (a) Changes in water content with time (dap) through the season for the kraal manure treatment at Mr. Mashele's farm.

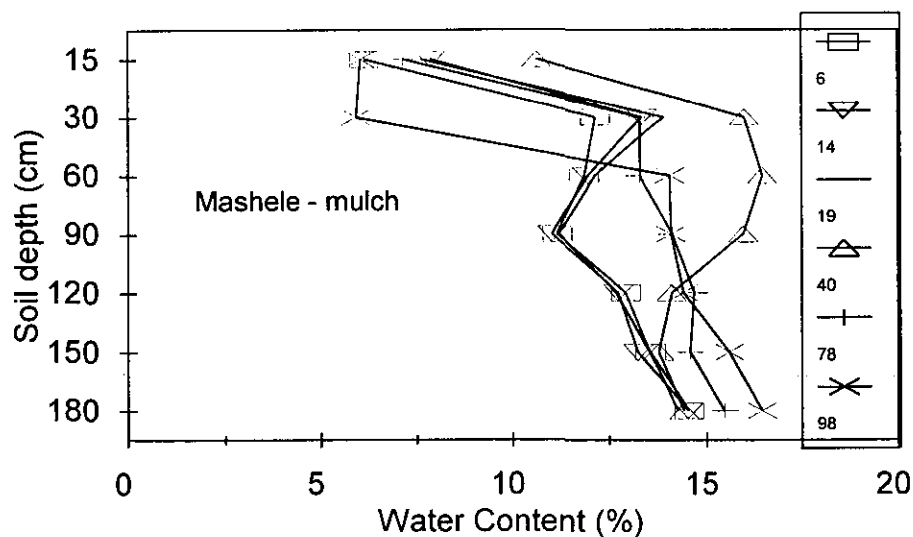


Fig. 3.4(b) Changes in water content with time (dap) through the season for the mulch treatment at Mr. Mashele's farm.

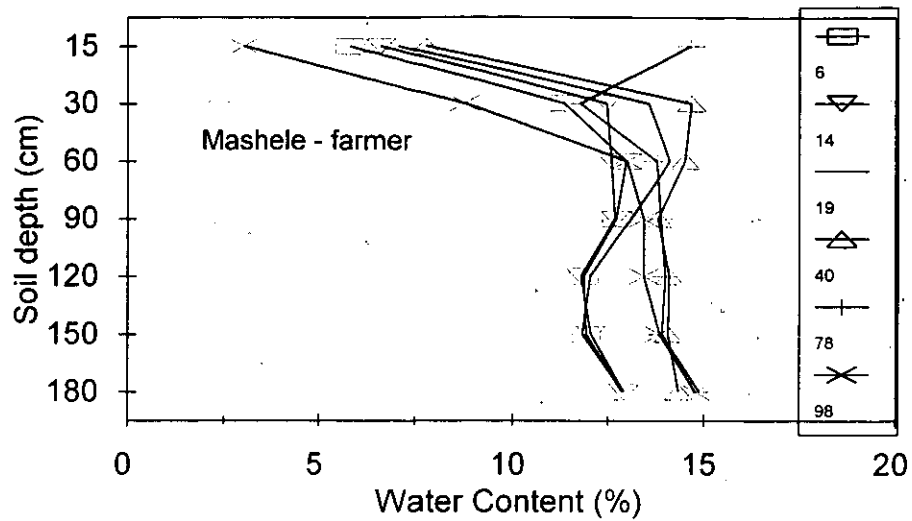


Fig. 3.4(c) Changes in water content with time (dap) through the season for the farmers choice treatment at Mr. Mashele's farm.

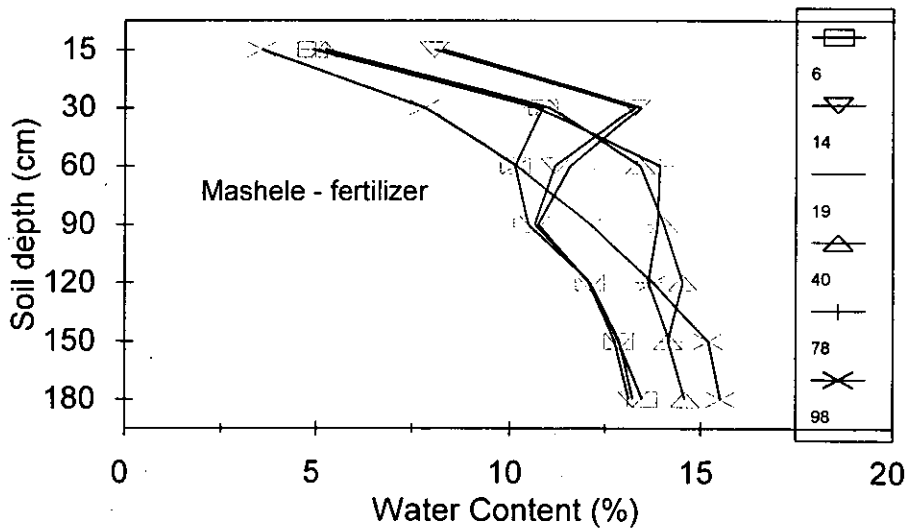


Fig. 3.4(d) Changes in water content with time (dap) through the season for the fertilizer treatment at Mr. Mashele's farm.

### 3.3.2.3 Final maize yield

The final maize yield data for 1996/97 for each farmer's field are presented in figure 3.5(a).

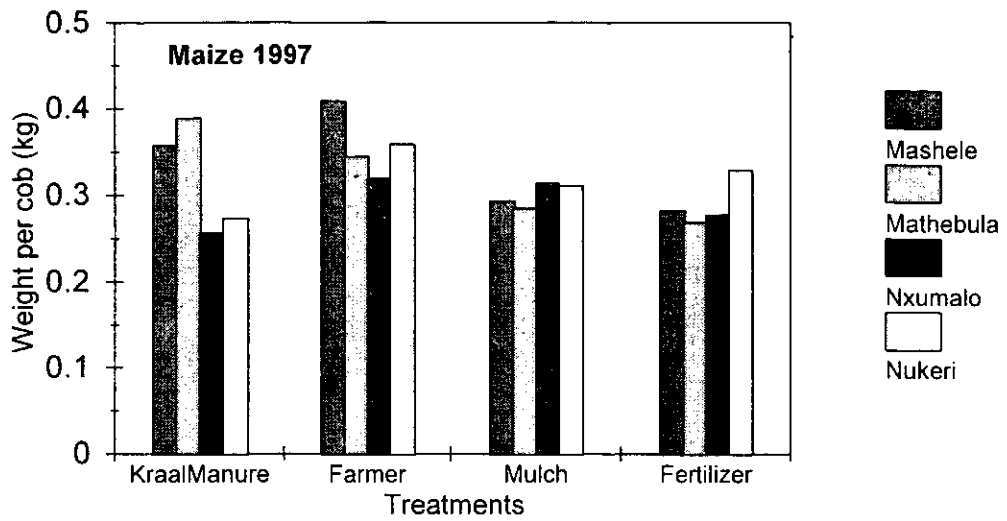


Fig. 3.5(a) Maize yield in mass per cob for the four treatments on the farmers fields for 1996/97 season.

The yield (kg per cob) as measured in the field with a spring balance Fig. 3.5(b).

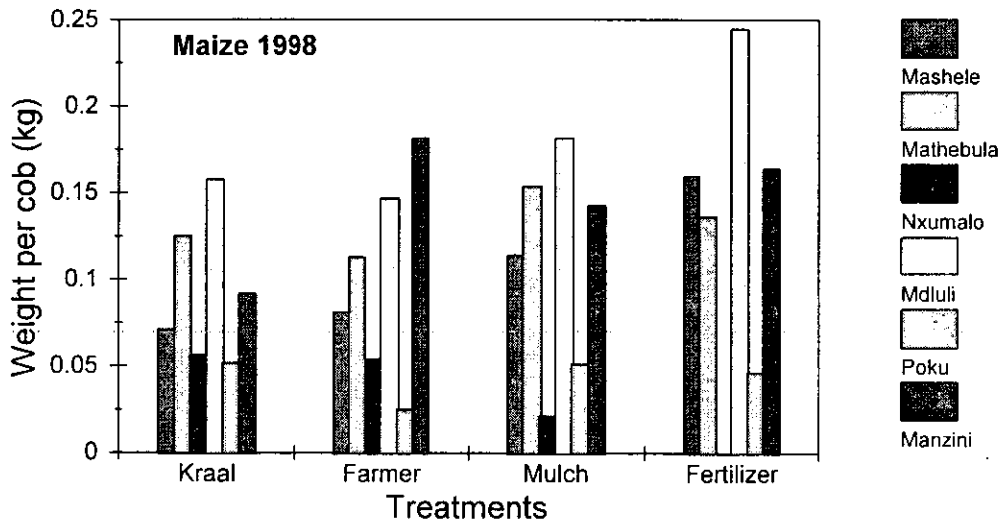


Fig.3.5(b) Maize yield in mass per cob for the four treatments on the farmers fields for 1997/98 season.

This is represented by field mass per cob as some of the cobs were stolen from the various treatments and so a total mass per land area could not be used. From the four farms that were harvested (in 1997) it is noted that none of the treatments is consistently above the others at every farm site. However, at Nukeri, Nxumalo and

Mashele's farms the farmers own treatment gave the highest yield. Only at Mathebula's farm did the kraal manure treatment give the highest yield. It can be seen that at the different farmers' fields, the different treatments gave a variety of yield values (Walker, 1999). From 1997/98 season, four farmers obtained reasonable yields and two very low yields due to neglect of the trials. Under the poor conditions (Nxumalo and Poku) the kraal manure gave the highest yield, of the others, two of the farmers own treatments were highest, one fertilizer treatment and at Mdluli's the mulch and kraal manure treatments were both high (Fig. 3.6). Sub-samples of the maize cobs from each plot were dried in the oven and then a good dry mass was calculated for each treatment on each farm. The differences between the 2 seasons are noticeable and yet cannot be explained agronomically. Most of the reasons have already been discussed and were beyond the control of the project team. During both seasons the differences between the different farmers are much larger than the differences between the treatments on a single farm. There are also no visual trends between treatments. Therefore it is difficult to make a conclusion about the maize yields on these trials, as management factors appear to have an overriding effect.

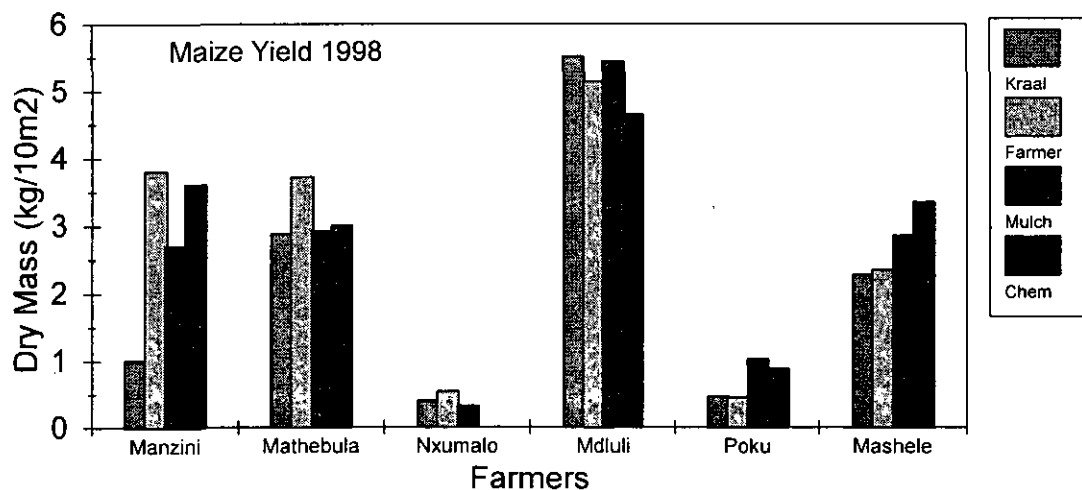


Fig.3.6 Maize cob dry matter yield for 1997/98 season for each farmer and treatment.

Mrs. Mdluli produced an average of 5 kg per 100 m<sup>2</sup> across the various treatments. Some of the other farmers had extremely low yields such as Nxumalo and Poku. If all

the farmers' fields are assessed, no one single treatment produced the highest yield at all of them. The farmers' own method was however highest at both the Manzini and Mathebula trials.

The total number of plants per row (Fig. 3.7(a)) was reasonably consistent and so no conclusions can be drawn about detrimental effects of either the mulch or manure on plant population.

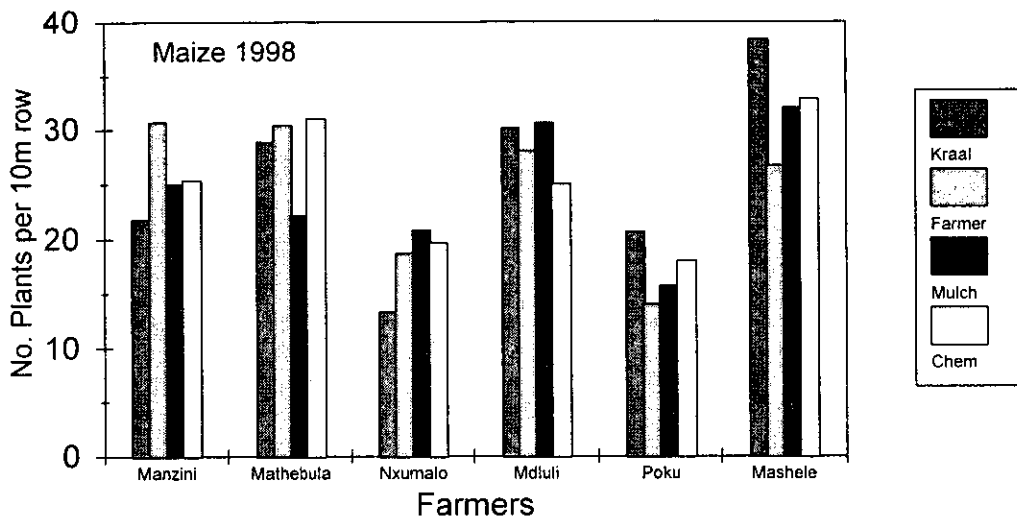


Fig. 3.7(a) Details of the farmers plots showing the number of plants per row.

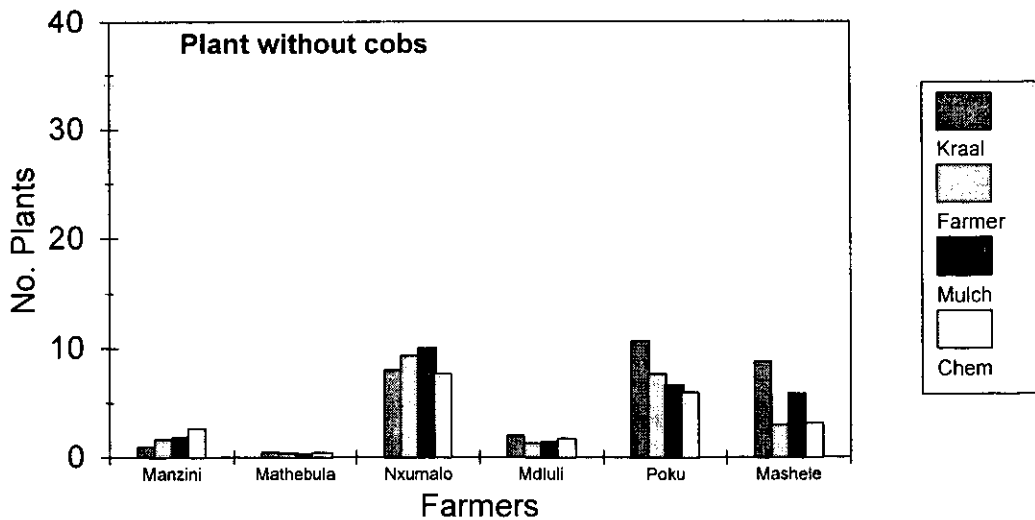


Fig. 3.7(b) Details of the farmers plots showing number of plants where no cob was formed.

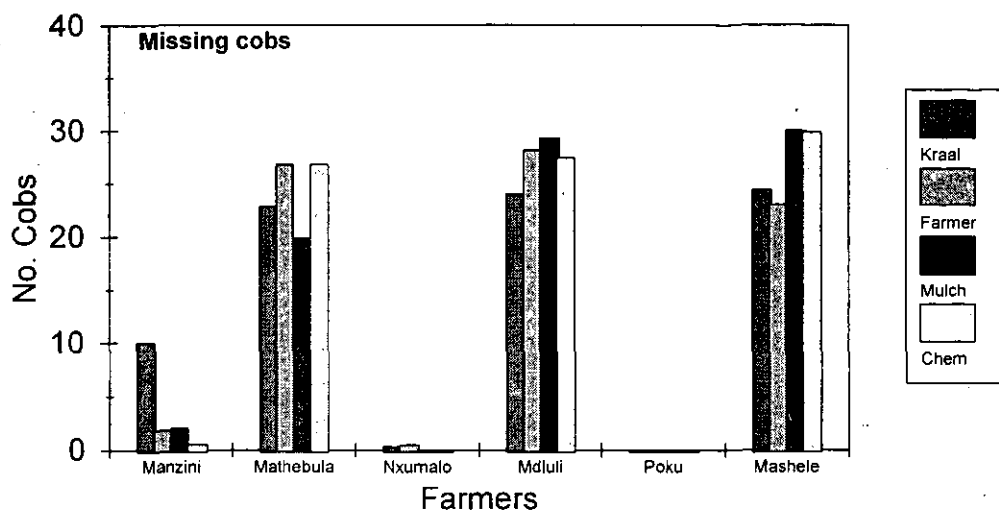


Fig. 3.7(c) Details of the farmers plots showing the number of cobs missing (stolen) at harvest time for maize 1997/98 season at New Forest.

It is interesting that at the two farmers (Nxumalo, Poku) who neglected the trials the number of plants per row was also reduced. The number of plants without a single cob (Fig. 3.7 (b)) was also high which indicated that the problems were present throughout the season. The number of cobs missing (Fig. 3.7 (c)) presumed stolen, was highest at the farmers field which produced the best yield, some of which were also near the public road.

#### 3.3.2.4 Farmers opinions

During the first season of on-farm trials, there appears to have been a lack of enthusiasm or commitment from the participating farmers. Several of them did make an effort, but were quickly despondent as other factors prevented the trials running smoothly. During the second season, it appeared that there was a renewed enthusiasm and even somewhat of an urgency to participate. This change in attitude could have been due to the overall decline in the local economy due to the prolonged civil servants strike action. A competition for the best trial plots was also advertised and perhaps provided some incentive for hard work on the trial plots. At least one of the farmers, Mdluli, also transferred responsibility for the trial to his wife. She then committed herself to work hard in the trial plots during weeding and pesticide

activities as well as for the irrigation each week. Another incentive could have been the lessons learned from the previous season - as farmers were able to sell the produce at the end of the trial and this was definitely to their own benefit.

A farmer's information day was held each season which included a visit to 2 or 3 of the maize on-farm trials. These farmers days were well attended and the difference between some of the treatments at 1 or 2 of the farmer's fields was striking. However, the difference between the state of the crop in the various farmer's fields was also blatantly obvious. The farmers then helped with the decisions for the awards. During 1997, Mrs. Ndluli's crop was obviously outstanding and of a considerably higher standard than the other farmer's fields. This was also borne out by the final yields (Fig. 3.6) from 3 of the treatments being almost twice as much as that harvested from the other farmers fields and up to 10 times that of the poor fields. The farmer's days were a huge success and provided an encouragement to both researchers and extension staff to keep on persevering with the on-farm trials. The farmers were mostly encouraged by the good yields and challenged to improve their general farm operations. They were challenged and shown that a high maize yield is possible under the conditions prevailing at the New Forest Irrigation Scheme. Once they had seen it with their own eyes in their colleague's fields, they knew for sure that they could also produce such a good crop next year. Throughout these on-farm field experiments, the currently used varieties have been utilized, also the standard row spacing and planting density was retained as used under the general farmer practice. These factors could also be changed to increase production of green maize under irrigation. However, this project was aimed at obtaining the water use information under the prevailing conditions in the developing agricultural situation. Therefore, it was decided not to change the standard practice factors of cultivation during this project, so as to illustrate that the results attained are within the reach of the average farmers working their own field at New Forest Irrigation Scheme. It appears that this objective was achieved, as many farmers were interested to see Mrs. Ndluli's fields and hear her comments that she thought that the kraal manure treatment was the best. The actual yield data show that there was little difference between the farmers, mulch

and kraal manure treatments, and only the chemical fertilizer treatment had a significantly lower yield per land area or higher per cob (Fig. 3.5 & 3.6).

### **3.4 Lessons Learned and Recommendations**

Some of the problems encountered in the on-farm trials will be ongoing practical problems for the farmers in the area. Some of them, however, were peculiar to the particular season and hopefully will not influence agriculture on a long-term basis.

The NPDA staff members have been exposed to practical on-farm field experiments as a method of technology transfer. This has definitely formed a positive impact on several of them and been a major capacity building exercise. At least one of the extension staff had attended a Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) training session about on-farm trials. The experience that they were all able to gain through the hands-on activities together with the ARC-researchers has provided them with a firm base on which to build. It is hoped that some further on-farm experimental trials will be conducted in a similar manner by the NPDA extension staff.

There are many lessons to be learnt from the first year of on-farm trials, despite what appears to be a year of failures. Both the extensionists and the researchers have followed the steep learning curve and will address many issues more carefully and fully prior to the next set of on-farm or demonstration trials. These experiences have taught us that the introduction of technology can speed development but it must be appropriate technology and so research and technology development needs to be continued.

As far as the administration of the project is concerned, co-operation and support needs to be negotiated at both the grassroots level of people that are interacting with the extensionists and those who are in the supervision positions. After this series of trials we were better able to understand the amount of time and infrastructure needed to support them and these must be included in the detailed project plan. It must be kept in mind that there needs to be agreement at all the various level of both organisations and with

the farmers themselves. The need for recognition for the extension staff involved in the trials needs to be addressed as a matter of urgency (Walker, *et al*, 1996).

A serious component that was lacking in the preparation and planning for these trials was a series of training and explanations to all the role-players of the principles behind an experiment, the reason to run the trials, the expected outcome and the consequences of the results. Perhaps a system of "twinning" extensionists and researchers for the duration of the trials would benefit both groups and allow a better understanding and value for the tasks that the other performs. A detailed action plan with dates and duration time and task allocation should be prepared and then the trial may be able to run more smoothly. To facilitate the breakdown in communication between the researchers and the extension officers it is suggested that a set time is chosen when they will communicate with each other each week, whether by phone or fax and that each will be responsible to report progress to the other.

Even though a needs assessment was done at the beginning of the project, it is still necessary to arrange specific discussions with the farmers to address the topics proposed for the trials. It will be worth the time spent in these discussions to be sure that the topics that are the focus of the trials are of specific interest to the farmers. This will also help the farmers to participate and learn from the trials. A suggestion is that study groups are formed for farmers to meet on a regular basis in small groups and discuss their farming activities with experts in that field of interest. The technologies should be discussed in detail with the farmers and extension staff so that the local knowledge and other innovative suggestions can also be incorporated into the plan.

The whole question of what method to use in selecting farmers to take part in the trials remains an unsolved problem. Somehow a system and method needs to be worked out so that it becomes a win/win situation where farmers, extension and research will benefit from the trials. Possibly if study groups are formed and topics are of specific interest to farmers themselves, they will be more willing and committed to the trials. Several of the younger farmers are already producing on a commercial scale and these farmers should

be included in the selection as they are most probably the early adopters and are already innovative in their farming methods.

Despite all the problems encountered during the course of these trials, both the extensionists and the researchers have learnt a lot about the management of off-station trials. Perhaps a few of the lessons learnt could have been learnt from text books on the subject, (FAO, 1993; Mettrick, 1993; Norman *et al.*, 1994; Okali, Sumberg and Farrington, 1994; Schönhuth and Kievelitz, 1994) however they are now part of our own experience and can be avoided during the next on-farm trials. Just because the trials were not an overwhelming success according to standard norms, it is no reason not to continue along this road to try to expose and adapt the principles of FSRE for technology transfer to small-scale farmers.

The preparation prior to the on-farm trials is of vital importance for their success. This should begin up to a year before the proposed trials, as a relationship of trust must be built up between researchers, extension staff and farmers. The linkages and personal contacts must be to the mutual benefit of all parties involved. This often means that researchers or their supervisors think that they have been sidetracked onto less important issues. The value systems of each group must be kept in mind during this time and effort must be made to embrace or at least understand some of the aspects that may appear foreign initially. The planning phase must include more than the normal planning of an experiment as all the role-players must be incorporated as soon as possible in the planning phase discussions. Often this requires some basic introduction to experiments and their overall purpose, which could be given to a large group of farmers and community members. The participating members will work out the specifics of the actual on-farm trials that will be conducted at a later stage.

Throughout these negotiations a commitment to cooperation must be made by all groups concerned. It is good if this commitment to cooperation can be made at the highest possible level and on all relevant levels in all the structures, government, farmers' unions etc. This enables the support for the project to come from the head of the organization as an instruction to those actually working together, failing this

members of the team are often transferred or given other priorities for work by their supervisors.

The logistics of a cooperative project are difficult and so the best possible communication channels must be used. A good policy is to set a regular or routine time for telephone contact or actual visits at the beginning of the season and then to stick rigidly to those communication times even if it appears that there is little to say. If this is established early in the project then it can be used successfully when any unforeseen crises arise.

The question of what actually becomes the specific objective of the on-farm trial is of vital importance. The farmers must be allowed to discuss at length the purpose of the experiment and the possible advantages that can come out of a successful project. From experience, it appears that if the farmers feel in any way that the researchers or extension staff can veto the decisions made at the group meetings, then they lose faith in the process and become disillusioned. This often results in failure of one or more of the farmers' trials. It cannot be overemphasized that the frame of reference of the farm community must be carefully understood and the trials must fall within their priorities.

The next step is the selection of farmers for actual participation in the planting of crops on their fields. This is a most difficult stage of the decision-making and can make or break the whole process. There are many theories of the best methods to use; however it appears to differ from area to area and depends largely on the underlying level of commitment and cooperation between the parties. Sometimes a group of enthusiastic farmers can form study groups and then they select the participants from within their own group. The selection of the farmer is not only for the physical operation of the experiment, but also for the acceptance of the results by the rest of the farming community. When introducing new methods to the farmers, there will be early adopters and sometimes these people will even be rejected by the rest of the community as culturally they are seen to be getting ahead of the rest of the people. Sometimes the extension officers' selection also leads to accusations of favouritism

and this needs to be avoided. If the leaders of the farm community can be involved in this part of the decision making it will be most beneficial to the success and transfer of information collected during the project.

### **3.5 Technology Transfer**

During the on-farm trials there are many opportunities for technology transfer to the rest of the farm community (Walker, 1995a). This action would have begun with the initial contact, as the farmers are always ready to ask questions and discuss alternatives. It is good to hold a farmer's information day during the on-farm trials, so that the farmers can visit the trials and interact with the rest of the team (Bembridge, 1991). It provides a good opportunity to assess the reaction to the preliminary results and allows all the farmers to assess the state of the trials. It enables the farmers that are not directly involved with the trials to view the fields and make their own interpretation and decisions of whether it could fit into their farming system.

After several seasons of on-farm trials the results and recommendations can be collated and distributed to the farm community in general. Some of the farmers will already have begun to use the various options that were included in the trials. Further surveys or discussion groups can also gauge the adoption rate of any new techniques with the farmers. In this way the farmers are learning from each other and not only directly from extension staff or researchers.

### **3.6 Conclusions**

Although much work has been done over the years at experimental stations, little has been successfully transferred to the practical reality of small-scale farmers. Some of this lack of technology transfer can be overcome by using on-farm trials where the farmers participate in the decision making as to the most appropriate treatments to use in their area and to meet their most pressing problems. The trials are then carried out in the farmers' own field and they are actively learning throughout the project. Much time and effort must be given to the cooperation and communications to allow this type of project to run smoothly. However, it is worth the effort when the farmers in

the area adopt different technology or adapt their usual methods slightly to increase productivity and sustainability.

In some areas on-farm trials have become more common, but still the benefit appears to be localised to the farmers that can actually visit and view the trials. This always seems to be only a few people compared to the masses of farmers that need to be reached. Other methods need to be used to transfer the knowledge gained from the on-farm trials to farmers at distant localities. Modelling could provide this opportunity if the social and economic aspects of the farmers' choices and opinions could be included together with the physical constraints to crop production. The type of data collected during a participatory rural appraisal should be able to be included as it often represents the consensus agreed upon by the farmers in that area. If some of these factors can be numerically measured and the influence of them on the crop production systems assessed then they would enhance a purely physical model driven by constraints of weather and soils.

## Chapter 4

### GUIDELINES FOR ON-FARM TRIALS

#### 4.1 Introduction

Following the difficult learning curve of the project team during the process of conducting the on-farm trials, it was decided to formulate guidelines from the teams experiences and available literature for future projects. Most of the available literature applies the principles of on-farm research to simple applications such as introducing and testing various cultivars or pest control methods. During this project the on-farm research principles were applied to the more complex problem of optimization of available natural resources under irrigated maize production.

On-farm trials were used to meet the original aims (4 and 5) of the project to evaluate water use on small vegetable plots and to establish demonstration trials. The on-farm trials are conducted within the framework of the FSRE methodology (FAO, 1993), the focus being on the farmer at the center of the farming system which must be a viable economic proposition. In farming systems research the inputs and outputs to and from the farm should be assessed and brought into consideration. The level at which the farmer wants to work and generate income is also a factor. The farming system then must be sustainable at several levels – environmentally, economically and socially or culturally (Herzog and Gotsch, 1998). The FSRE approach is basically problem driven and relies on participation of all the role-players (FAO, 1993, Mettrick, 1993). Research staff are drawn from many disciplines and must work together in an FSRE team to promote wide scale adoption of new or improved technologies. One of the principles is that the process is iterative in that the cycle can be repeated many times, each with an improvement or gaining of ground. Basically the FSRE methodology consists of the following stages: (Auerbach, 1995)

- (1) Diagnostic stage – this is where the main farming systems are identified by a multi-disciplinary team which includes farmers and other key role players from the area (Nyemba, 1997). This includes identification of problems and possible ways of solving them. Participatory rural appraisal is often used during this phase.
- (2) Applied/adaptive research stage is where new technology is developed on-station and at a basic scientific research level where high technological solutions are developed. The farmers are not usually directly involved, but the research is focused on solving problems identified during stage 1.
- (3) On-farm adaptive research phase is where the newly developed technology is implemented at a farm level. This often takes the form of testing existing technologies in the farmers fields under farm and local conditions. There are several types of on-farm trials – named according to the origin and management style. They range from farmer initiated and farmer managed through farmer initiated and researcher managed to researcher initiated and researcher managed.
- (4) Evaluation of the newly tested and introduced technologies needs to include both qualitative and quantitative methods. This is a time when feedback and acceptability by the farming community can be integrated with the quantitative scientific and economic results of the research.
- (5) Dissemination or adoption stage. Following the on-farm evaluation the technologies can be transferred to a wider group of farmers via study groups, farmers days, co-operatives, local NGOs and extension and health workers. This will then lead to the technology being widely used and in time adopted by the farming community if it truly is appropriate to their needs.

#### **4.2 Diagnostic Phase**

On-farm trials are seen within this context of FSRE and applied within a holistic view of sustainable agriculture in a particular region. The process can be repeated for a specific area of concern and interest with specific role-players who want to address a specific problem. During the diagnostic phase the farmers identify a specific question or problem which will then encourage ownership of the process of technology development. Care

must be taken by the multi-disciplinary team not to present their own hidden agenda during this process of problem identification. The recommendation is that the diagnostic phase is conducted using the participatory techniques as described in detail in chapter 2. During the description of the current farming system and identification of the natural resources potential of the area, limitations and problems will become obvious. Care must be taken by the researchers not to look for quick fix solutions, but they must rather present unbiased information about a variety of options to address the shortcomings that have been identified.

### **4.3 Farmer Selection**

Before the new technologies can be introduced on a large scale they should be tested at the farm level under local constraints by farmers themselves. However, to implement this, a sample of farmers must be identified to perform the on-farm trials. This process of farmer selection must not be underestimated as it can make or break the on-farm trials. There are a number of different approaches to the on-farm trials and they have direct implications in terms of the selection of participants. Aspects such as equity, social development, empowerment and sustainability need to be considered (Okali *et al*, 1994).

It is vital that the farmers that are selected to participate in the on-farm trials are representative of the farmers that have identified the specific problem and are the potential beneficiaries. Farmers participating in the trials should cover the same range of ages, gender, locations, access to land and resources (i.e. livestock, farm size etc.) and wealth groupings as the target community in the area. It is crucial that the selected farmers are acceptable within the broader community, so that the adoption of the results will not be hampered. Often the innovative farmers will more easily try the new technologies and also share the results relatively easily with the rest of the community.

A further criteria which is vital yet not easy to evaluate is the commitment of the particular farmer to the project. As was seen in this project, several farmers showed a lack of commitment and so their fields were neglected during the season. The selection of farmers is a sensitive issue and should be approached with caution. The assistance of

extension staff and local farmers' representative committee members should be enlisted before a final selection is made.

As the purpose of the on-farm trials is to enable effective development, refinement and transfer of the technology to the local community, the farmer selection is critical. There are two main options – firstly to select a good representative of the farm community or secondly to select an “innovative individual”. The representative individual should be in good standing with the rest of the community and be respected and trusted by them. The representativeness should be along the lines of the common agricultural practice in the area and typical family size and situation. Otherwise the results obtained by him/her would be questioned or doubted or carry no weight. If the on-farm trials are initiated within a study group then often the members will appoint or elect someone from their own ranks to be the participant. This is a very crucial stage in the on-farm trials and there should be a balance between influence of the locals and outsiders. The selection of the “innovative farmer” sometimes can be influenced too greatly by those in authority or from outside the area. Someone must be identified who is “research-minded” and willing to take some extra risks or venture out into a new area. The final selection can be made by a committee or group which includes researchers, extension workers and farmers. The decision should follow a visit to the various farms and assessment of the commitment of the individual to the trials for a full cropping season.

#### **4.4 Planning the Trials**

Once the problem and the possible options for remedial action have been identified, the group must discuss the on-farm trials in detail. The various options must be formulated into treatments or comparisons that can be tested in the field and often have to be simplified to a single variable. For the evaluation of new cultivars this is relatively simple, but most other solutions are more involved or complex. The farmers, researchers and extension staff must all agree to treatments that will be tested. This is not always a simple matter as each farmer has his/her own opinion about the best solution to the specific problem. Often modifications of the trials need to be considered at this stage and “trade offs” can be made between scientific rigour, statistical requirements and practical

trial layout. There must be agreement by consensus and researchers or extension staff must not override the farmers opinions. Different fields at various farmers will often become the replications and so all the farmers must agree to include the full range of treatments to be tested at each site. Detailed discussion must also involve specific tasks for each of the groups – farmers, extension and research groups - including weeding, soil preparation, measurements and time frame etc. The format of the final evaluation should also be discussed and agreed upon so that the farmers know exactly what is expected of them and how the results will be measured. This process will often take several visits before all the details can be finalized, particularly if it is necessary to use an interpreter. The planning should include a detailed time framework with specific tasks, dates and the name of the person responsible for each operation.

#### **4.5 Implementation**

This is the actual operational phase where the crop is planted and treatments applied and the final assessment made (eg. yield harvest). During the planning phase the decisions need to have been made as to who is responsible for which part of the operation. If it is a farmer managed trial, then others must not interfere with the general agronomic practices which that specific farmer is using. This is precisely one of the objectives of on-farm trials: to evaluate the technology under local farmers field conditions and management practices. Often if there are quantitative readings to be made either the extension or research staff need to perform them, unless the farmer is paid as a technical staff member to do them, but many lack the literacy and numeracy skills needed.

During the implementation phase there are many pitfalls. Care must be taken that there is good communication between the farmer and extension staff. Extension staff must be available to the farmers if they encounter problems or need advice that pertains to the trials. There must also be good communication channels between extension staff and researchers. Often the trials are in deep rural areas and so transportation and communication infrastructure is not always operational. As was the case in the present study, this can present a major problem if a routine contact period is not used. In the

detailed plan, it must be clear which persons are responsible for which tasks and the permission of their superiors must also be granted.

#### **4.6 Evaluation Phase**

The methods used to evaluate the on-farm trials must be discussed during the planning phase. Evaluation should include both qualitative and quantitative methods. Participatory techniques can again be used for the community assessment of the trials to form the basis of the qualitative analysis. The matrix method is particularly useful for this type of evaluation, where different treatments can be evaluated in the light of different parameters. The group will decide which important aspects of the trial need to be evaluated. For example, a comparison of labour required for different treatments or acceptability of the taste of the various cultivars can be assessed. The visual observations throughout the season by the group of farmers can be noted during farmers days or study group visits arranged at various critical stages during the season. The quantitative evaluation methods must be simple and straight forward so that they can be easily performed in the field. Often the mistake is made by researchers to try and perform intricate or detailed analysis at a farm level, which leads to frustration and failure to achieve the original goals set for the trial. Care must be taken to include the participating farmers in the quantitative evaluation, so that they are aware of the proceedings involved when the results are finally available.

#### **4.7 Presentation of Results**

This must occur as soon after the evaluation phase as possible and preferably before the next planting season. The farmers can quickly become discouraged if they feel that their fields have been used for an experiment and results were never communicated to them. The information from one season must also be explained in great detail so that farmers are in a position to make their own decisions regarding the next growing season. Often researchers are reluctant to show results which have not been through all the necessary statistically analysis and replications. However, the farmers were intimately involved in the trials and can remember the visual and qualitative evaluation results. After one or two seasons the results can be disseminated to the wider farm community in the adjacent

area. This type of technology transfer can include the farmers also in the type called “farmer to farmer”. The results must preferably be presented in a pictorial format, so that those who are illiterate will also be able to understand. The use of diagrams or graphs is often most useful, however the number of variables must be kept to a minimum. It is also good if the diagrams or pictorial representation can be displayed at the Department of Agriculture’s office for all interested parties to see. This also provides some recognition to extension staff and to farmers themselves for their involvement in the trials of the past season.

#### **4.8 Conclusion**

On-farm trials form an integral part of the cycle of introduction of adaptations to an existing farming system. Options to be tested at the on-farm level must have been evaluated in detail on the research station and shown promise for a significant improvement of the sustainability of a local farming system. On-farm trials are not a simple matter and there needs to be sufficient funding and commitment to the process and methodology from all concerned – farmers, extension staff, researchers and funders. The process cannot be hurried along or forced onto the community. To maintain commitment and ownership of the trials care must be taken to proceed diligently through all the phases. The success of on-farm trials is based on a person to person commitment and trust that is developed during the whole process. Care must be taken to recognize the different frames of reference of the farmer, extension staff and researchers. The challenge then is to be able to understand and enter into the farmers value system. From this perspective the on-farm trials can be implemented and evaluated. The ultimate evaluation of success of a certain technology is the number of farmers who have actually adopted the introduced technology and use it on a regular basis in their own fields during subsequent years.

As already stated, ideally the on-farm trials should follow detailed experiments on the research station. However, in the present project the on-station trials needed to run concurrently with the on-farm trials. The objectives for on-station trials, namely to test the effect of various locally used soil management methods on the crop water use of

multi-cropped vegetables, were decided during the proposal stage of the funding for this project following preliminary field investigations. The detailed needs assessments in this project highlighted similar questions (chapter 2) with respect to water requirements of crops on irrigation schemes. However, the major crop of interest at New Forest Irrigation Scheme was maize, being the staple food of the area and having a high value on the local market. During the participatory needs assessment, the mapping exercise also allowed one to identify natural resources that were available in the area. Therefore, during the discussions with farmers in the planning phase of the on-farm trials, kraal/cattle manure and grass or reeds were identified as materials locally available. These materials were then included in the on-farm trials as major treatments which could influence the crop water use. In keeping with the participation principles and specific farmer requests, the crop used in the on-farm trials was maize and not vegetables. However, the on-station trials were already being conducted at Roodeplaat and so that crop choice was not changed. The treatments were however adjusted to include mulch and kraal/cattle manure in the later years experiments as will be seen in chapter 5.

Therefore, in this report, the project does not always show enough cohesiveness, however, that is one of the disadvantages of conducting a participatory type project with on-farm trials where the choices of the community must be taken into consideration and respected at all times.

## Chapter 5

### ON-STATION VEGETABLE IRRIGATION TRIALS

#### 5.1 Introduction

There are continual requests for information from engineers for planning and design purposes for water use of vegetables under irrigation. As there has been a shift in emphasis for some researchers in South Africa to development of the previously disadvantaged communities, the demand has been increasing for this information. As one travels around the rural areas, it is observed that the people seem to manage to cultivate vegetable under severe conditions and with very little water (Crosby, 1996). So the challenge was put - how much water do multi-cropped vegetables really need?

This part of the project was designed to collect yield and water use data over both summer and winter seasons for multi-cropping vegetables under irrigation at the ARC experimental farm at Roodeplaat, near Pretoria. The experiments included the range of vegetable crops usually grown by households in a backyard type garden. The method of application of water was also to simulate the use of a bucket into a short-furrow or furrow-basin that is widely used (De Lange, 1994). The objective was to generate yield-water production functions for multi-cropped vegetables under different frequencies and amounts of applied water, but not under water stress conditions. This would then form the basis for further investigations and for use in planning water supply and potential vegetable production at small household or community garden scale.

In the rural areas, the people often have access to animal manure - from cattle, goats or chickens. Following a period of maturing of the manure ("sweating") it is then applied to the fields. The effect of these applications of manure on the water production function was also investigated.

Some form of soil covering is also used to limit the soil surface evaporation following wetting by rain or irrigation. The effect of this type of natural mulch was also measured during the irrigation experiments (Kiome and Stocking, 1993, Obi and Ebo, 1995).

## 5.2 Material and Methods

The field experiments were conducted at ARC-Roodeplaat at the ARC-ISCW experimental site. The soil is Hutton type (Soil Classification Working Group, 1991) (soil analysis Table 5.2.1) and the long-term weather data is given in Appendix 2. The soil preparation followed standard procedures and fertilizer was applied at the normal recommended rate for vegetables to ensure adequate growth and production.

Table 5.2.1 Soil chemical analysis from on-station trials at Roodeplaat 1997 for each treatment.

Lab no	Treatment	P	K	Ca	Mg	pH	R	TotalN
1	Depth (cm)	mg/kg	mg/kg	mg/kg	Mg/kg	Water	Ohms	%
		2	3	3	3			4
M667	B20	58,98	562	158	278	7,68	2800	0,054
M668	B40	58,44	555	145	263	7,66	2900	0,054
M669	D20	45,98	607	154	212	7,44	2800	0,047
M670	D40	30,71	560	151	254	7,45	2500	0,056
M665	K <sub>a</sub> 20	52,41	569	154	432	7,52	2200	0,054
M666	K <sub>b</sub> 40	37,14	622	184	379	7,40	2300	0,053
M671	K <sub>b</sub> 20	52,82	386	680	161	7,38	-	0,060
M672	K <sub>b</sub> 40	42,23	410	555	154	7,34	-	0,053

Treatments: B – no mulch soil plots; D – mulch plots, K – kraal manure plots. For kraal manure plots: a - before application; b - after application. Depth: 20 – 0-20 cm, 40 – 20-40 cm. Method used: 1)ARC-ISCW Reference Report No. 2 GROND97/98 752) Bray 1; 3) Ammonium Acetate; 4) Digestion.

The vegetables were planted during both summer and winter seasons in multicropping plots. The irrigation treatments varied slightly between the different seasons and as the project developed over time. Basically, a 10 or 20 mm irrigation amount was

given either twice a week or weekly or every fortnight. The CPN treatment was irrigated when the neutron moisture meter readings indicated that the soil water content was at the 50% depletion level. See table appendix 5A for specific labels for each season and for plot layouts for various years.

The following crops were grown during the different seasons (Table 5.2.2): Cowpeas (*Vigna unguiculata*); Tomato (*Lycopersicon esculentum*); Swiss Chard (*Spinacia aleracea*); Cabbage (*Brassica oleracea*); Beetroot (*Beta vulgaris*).

The other cultivation practices that are somewhat different under these circumstances include the use of cattle manure and a mulch covering the soil surface between the crop-rows. These two treatments were introduced into the field experiments as the project progressed after the PRA had been conducted. The kraal manure was rotavated into the soil following application. The mulch was applied after transplanting of seedlings and covered the soil throughout the season.

During the first pre-project summer season, the various methods of water application were investigated. The treatments included standard dripper lines and dripper tapes as well as by buckets in a basin. The distribution of water in the soil under the dripper lines was found to differ significantly from typical irrigation used in small-scale agriculture, therefore in the following years plots were all irrigated using the bucket method or a hose pipe with a flow meter. This method proved to be easily managed by the labourers and still provide an accurate measure and control of amount of water added to each plot during each irrigation application.

**Table 5.2.2 Details of the crop cultivars and seasons when they were planted.**

Season	Crop	Cultivar	Transplant date	Harvest dates
Winter 1995	Beetroot	Detroit Dark Red	*	13/09/95
	Swiss Chard	Ford Hook Giant	*	28/08/95
Summer 1995/96	Cowpeas	Renoster	*	*
	Swiss Chard	Ford Hook Giant	*	31/01/96 05/03/96
	Tomatoes	Redox	*	16/02/96
Winter 1996	Beetroot	Detroit Dark Red	01/08/1996	25/10/96
	Cabbage	Drum Head	01/08/1996	04/11/96
	Swiss Chard	Ford Hook Giant	01/08/1996	26/09/96 18/10/96 07/11/96
Summer 1996/97	Cow peas	Renoster	21/10/1996	03/02/97
	Swiss Chard	Ford Hook Giant	21/10/1996	04/12/96 06/01/97 22/01/97 10/02/97 04/03/97
	Tomatoes	Redox	21/10/1996	23/01/97 30/01/97 06/02/97 13/02/97 20/02/97 28/02/97
Winter 1997	Beetroot	Detroit Dark Red	29/07/1997	10/11/97
	Cabbage	Drum Head	29/07/1997	24/11/97
	Swiss Chard	Ford Hook Giant	29/07/1997	18/09/97 06/10/97 20/10/97 03/11/97

\*data not available

The soil water content was monitored with a soil moisture neutron probe in each plot each week throughout the growing season. The water use was calculated for each plot by the water balance method using the difference in soil water content between consecutive weeks values, plus the amount of rain and irrigation. The seasonal water use for each plot was then calculated as the sum of the weekly water use. The water balance was calculated for the root zone (0 - 45 cm) and for the whole profile (0 - 150 cm).

The crop yield was weighed in the field to give a fresh mass, representing the marketable fresh mass of vegetables. A sub-sample was oven-dried to enable the evaluation of the dry matter produced. The spinach was harvested approximately every fortnight depending on the prevailing weather conditions. The data was stored and manipulated in Quattro Pro and Excel files. The statistics were performed on the yield and water use across the irrigation and cultivation treatments using SAS statistical package.

### **5.3 Results and Discussion**

The soil water data was diligently collected each week through all the seasons. Due to the large volume of data, it would be unrealistic to present each replication in some form of graph or table. Only representative graphs will be shown to illustrate the necessary points for the discussion and conclusions to be drawn.

#### **5.3.1 *Soil water content between rows***

During the first investigative season, the comparison was made between the irrigation with drippers and water application with buckets. The data is shown in Fig. 5.1(a & b). Under drip irrigation more water was depleted from the upper three layers (to a depth of 60 cm) by the end of the season than under the bucket method. The water content at the deepest measuring point only changed slightly through the season under the drip treatment, whereas with the bucket irrigation there was water extraction from 120-150 cm depth. Therefore, it was decided that the drippers could not be used to simulate the use of short furrow irrigation in the rest of the experiment.

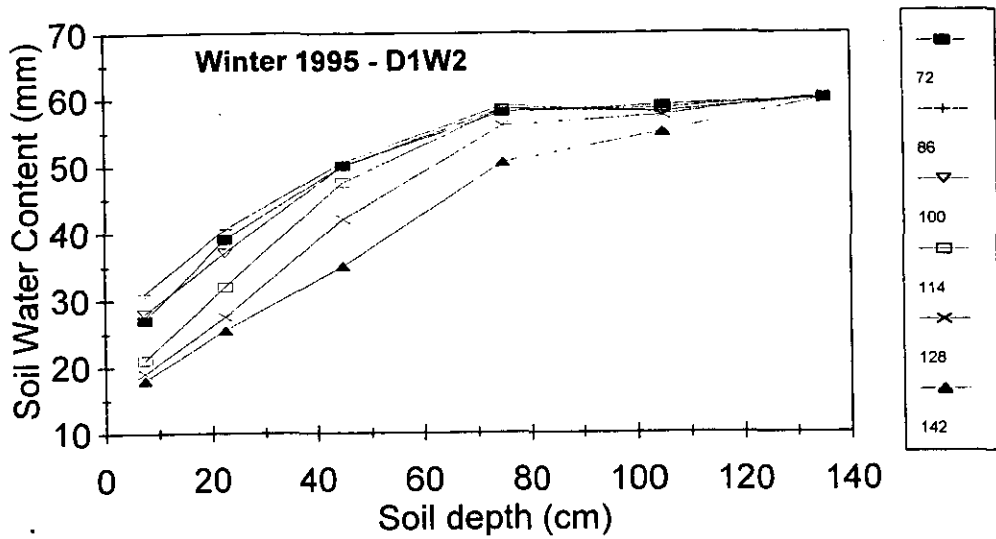


Fig. 5.1(a) Variation of water content through the season with depth for dripper treatment (D1) irrigated at 10 for every fortnight (W2)

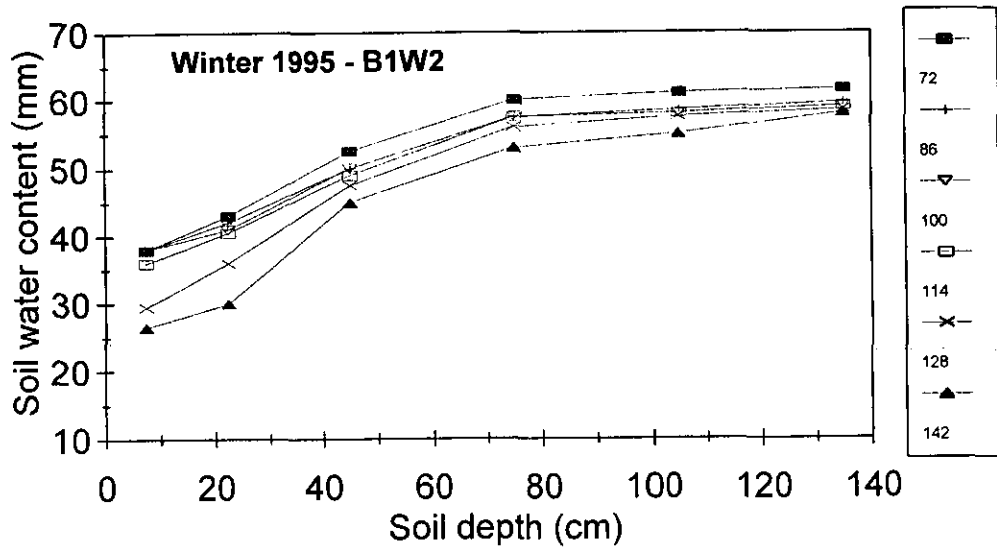


Fig. 5.1(b) Variation of water content with depth for bucket treatments irrigated at 10 mm every fortnight.

During the second season an investigation was mounted to look at the water distribution between the two crops in a single plot. Two tubes were placed between

the rows and two tubes were placed in each of the two crop rows. The detailed data set shows that there are few if any differences between the water use between and within the row. This can be attributed to the fact that the between row width is relatively small and that the roots of the two crops are quickly integrated together and therefore extracting water evenly from the whole plot. These observations are made within the assumptions of the accuracy of the instrument being used namely the neutron probe monitor and taking the measurements on a weekly basis.

The trend of water use from different depths with time for the different irrigation treatments can be seen from the water content versus depth graph. For instance, consider the weekly dripper treatments where 20 mm and 10 mm were applied respectively (Fig. 5.2(a,b)) and compare with the fortnightly 10 mm dripper treatment (Fig. 5.1 (a)).

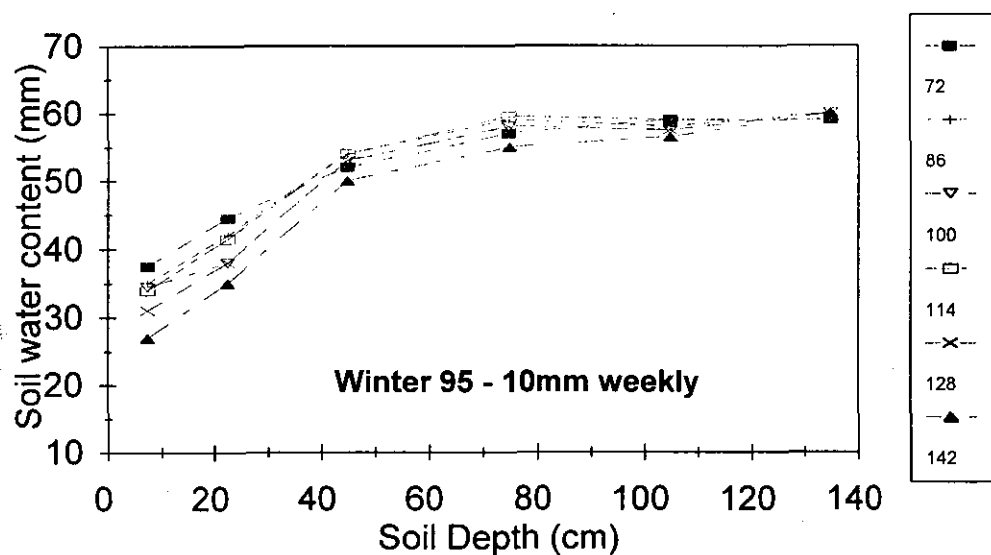


Fig. 5.2(a) Comparison of soil water content for 10 mm weekly dripper irrigation treatments.

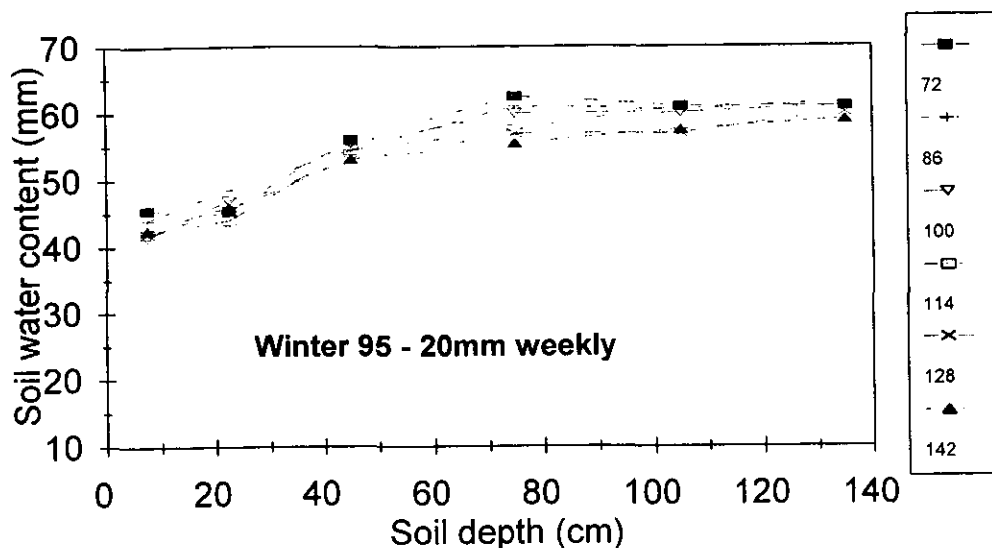


Fig. 5.2(b) Comparison of soil water content for 20 mm weekly dripper irrigation treatments.

In the dripper 20 mm weekly treatment (Fig. 5.2 (b)) the soil water content at all depths remained unchanged whereas with the 10 mm weekly treatment, the top layers of soil were progressively dried out during the season (72-142 dap). In the dripper 10 mm fortnightly treatment (Fig. 5.1 (a)), there is also an obvious drying out of the soil during a 60-day period from 72 to 142 dap. Therefore the drying out of the soil is clearly noticeable in the top 3 layers and also shows slightly at the 80 cm layer on 142 dap for both the 10 mm treatments. The vegetable crops were obviously in need of more than 10 mm per week as shown by the little depletion in the 20 mm per week treatment.

### 5.3.2 Total soil water content (TSWC)

During winter 1996, the comparison was between mulch and no mulch treatments. A combination of irrigation treatments were ranging from 20 mm weekly, either in 1 application or in 2 applications (S120 and S1102) to fortnightly irrigation of either 10 mm (S210) or 20 mm (S220) (Fig 5.3(a,b)).

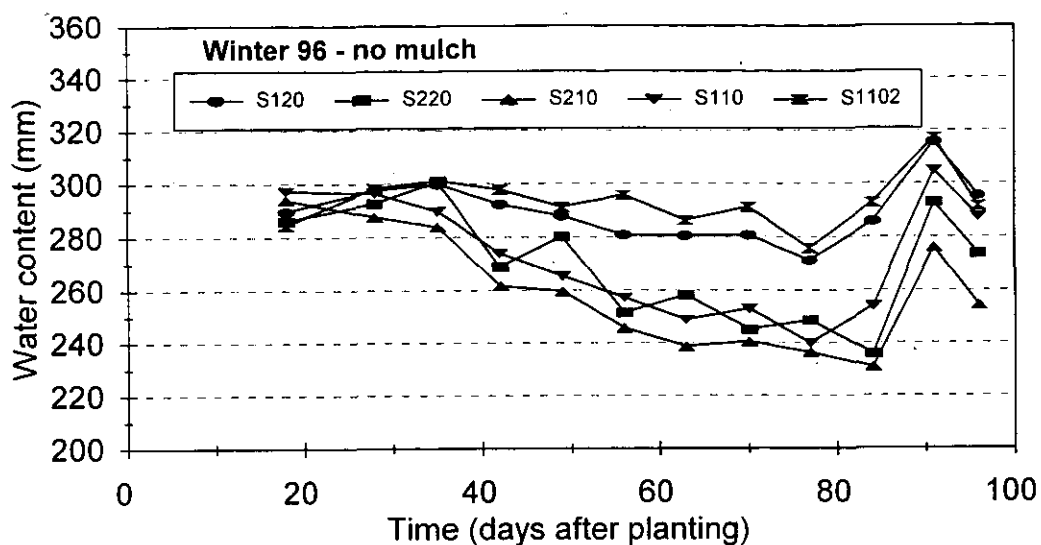


Fig. 5.3(a) The total soil water content for the no mulch treatment (S) in winter 1996 for all the treatments (120 = 20 mm weekly, 110 = 10 mm weekly, 1102 = 10 mm twice weekly, 210 = 10 mm fortnightly, 220 = 20 mm fortnightly).

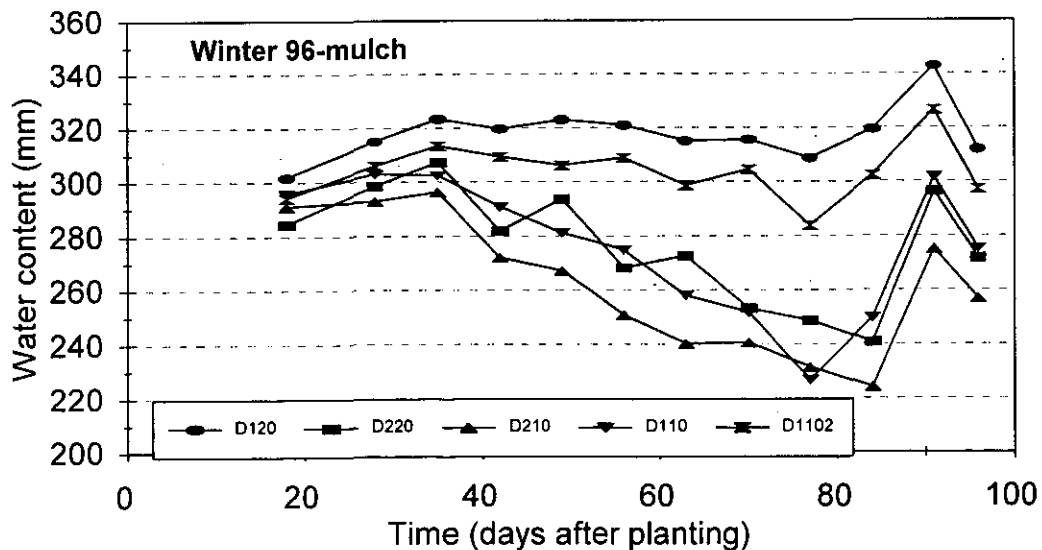


Fig. 5.3(b) The total soil water content for the mulch treatment (D) in winter 1996 for all the treatments (120 = 20 mm weekly, 110 = 10 mm weekly, 1102 = 10 mm twice weekly, 210 = 10 mm fortnightly, 220 = 20 mm fortnightly).

The mulch well-watered treatments remained at a high value of profile water capacity throughout the season namely 300 - 320 mm. The no mulch treatments receiving

weekly applications were consistently lower than the mulch treatments and remained around 285 - 300 mm. This gave a difference of about 25 mm soil water between the mulch and no mulch treatments.

There were consistently lower values of TSWC for the treatments receiving water on a fortnightly basis (220 to 245 mm). This then gave a difference of about 65 - 80 mm between these treatments and the well-watered treatments. The fact that it rained just prior to harvest (84 and 91dap) means that the crops recovered somewhat and the final soil water depletion was not as low as it had been prior to receiving that rainfall.

The 1996 winter season clearly shows that under well-watered conditions the mulch served to conserve water in the profile and maintain a higher TSWC than without mulch covering layer. However, under the infrequent irrigation (only every 2 weeks) the mulch did not serve this purpose. It would appear that the mulch is limiting the soil surface evaporation from the frequent irrigations when the soil surface is wet a larger proportion of the time. But that under the infrequent irrigation interval, this does not substantially effect the total profile water content.

During winter 1997 (Fig. 5.4(a,b,c)) similar results were found, but a cattle manure treatment was also included. The weekly irrigated mulch treatments (D1201, D-CPN) maintained a higher TSWC throughout the season (approximately 280 - 300 mm). This was higher than both the no mulch and cattle manure weekly irrigation treatments which maintained approximately 260 - 280 mm level.

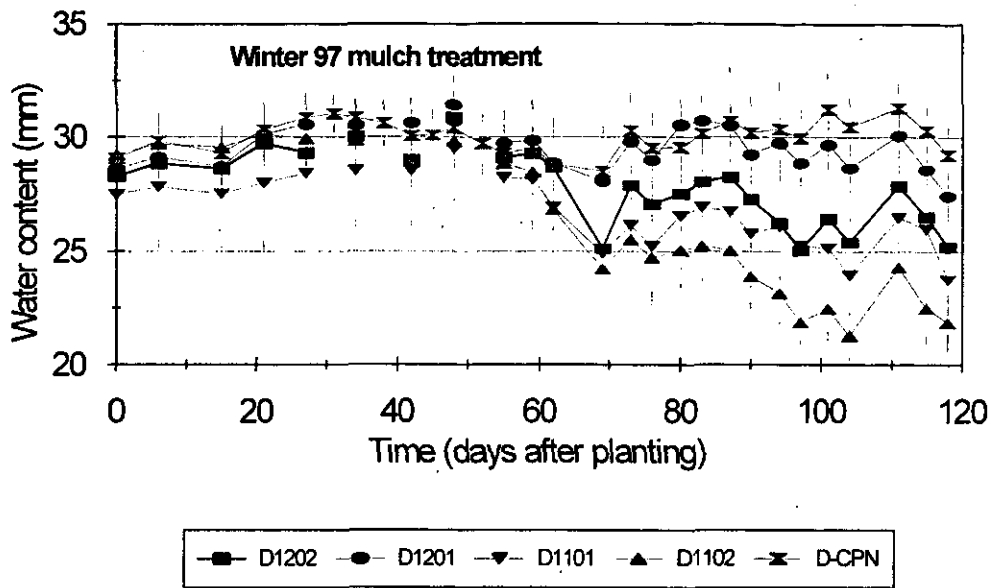


Fig. 5.4(a) Total soil water content for the mulch treatment (D) during winter 1997 from the soil water depletion (CPN) and the 20-mm weekly irrigation treatments.

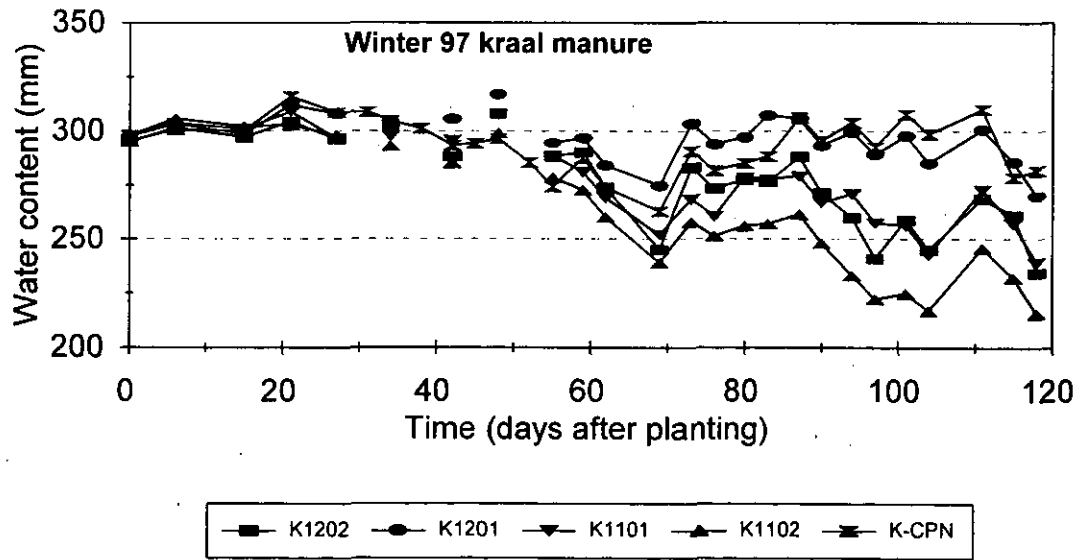


Fig. 5.4(b) Total soil water content for the kraal manure treatment (K) during winter 1997 from the soil water depletion (CPN) and the 20-mm weekly irrigation treatments.

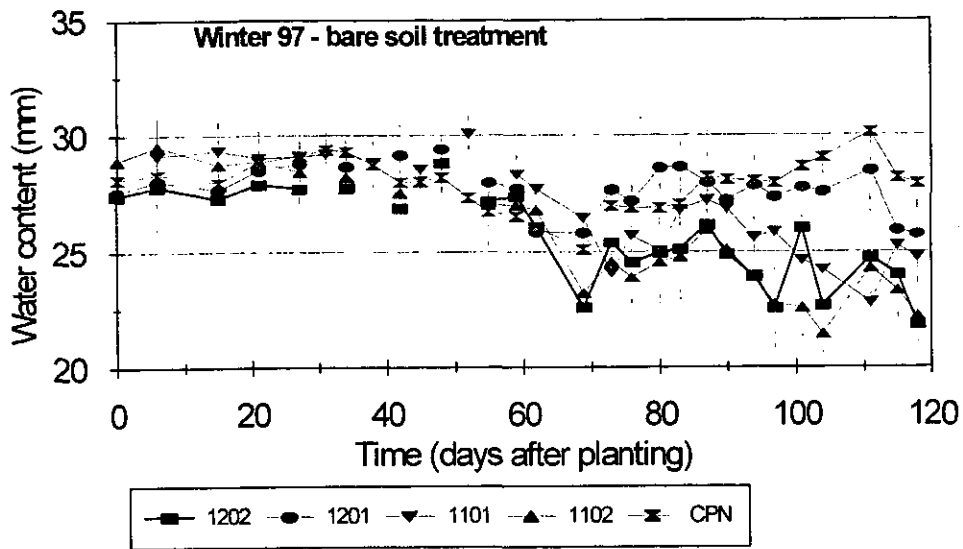


Fig. 5.4(c) Total soil water content for the no mulch soil treatment during winter 1997 from the soil water depletion (CPN) and the 20-mm weekly irrigation treatments.

The mulch treatments receiving 20 mm in each 2 week period (D1202 and D1101) had consistently higher soil water than similar kraal manure (K1202 and K1101) and no mulch soil treatments (1202, 1101), although the differences were smaller (20 mm). The irrigation treatments receiving only 10 mm every two weeks had consistently lower soil water and progressively depleted the soil profile during the growing season, down to values around 210 - 215 mm. This gives a depletion of 70 to 85 mm lower than the well-watered treatments. Again, there were only slight differences between these treatments of mulch, kraal manure or no mulch. The soil surface only remains wet for a comparatively short time of the season as these treatments only received 8 irrigations and so the soil surface was probably only wet about 13 % of the time compared to over 30 % under the weekly irrigation.

During summer 1996/97 similar experiments were conducted (Fig 5.5(a,b,c)) but are unreliable due to rainfall and higher potential evapotranspiration rates.

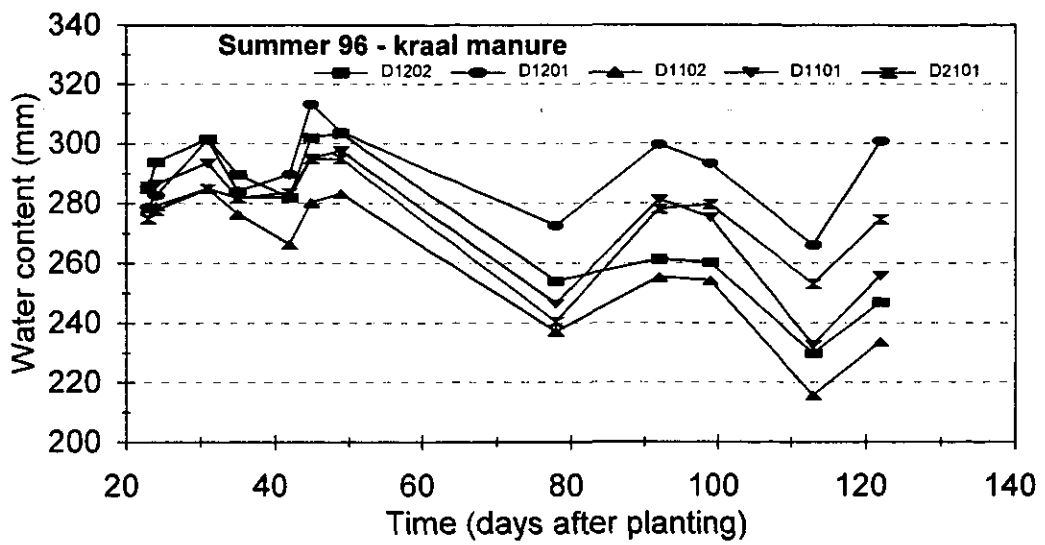


Fig. 5.5(a) Total soil water content versus depth for the summer 1996/97 for the kraal manure treatment.

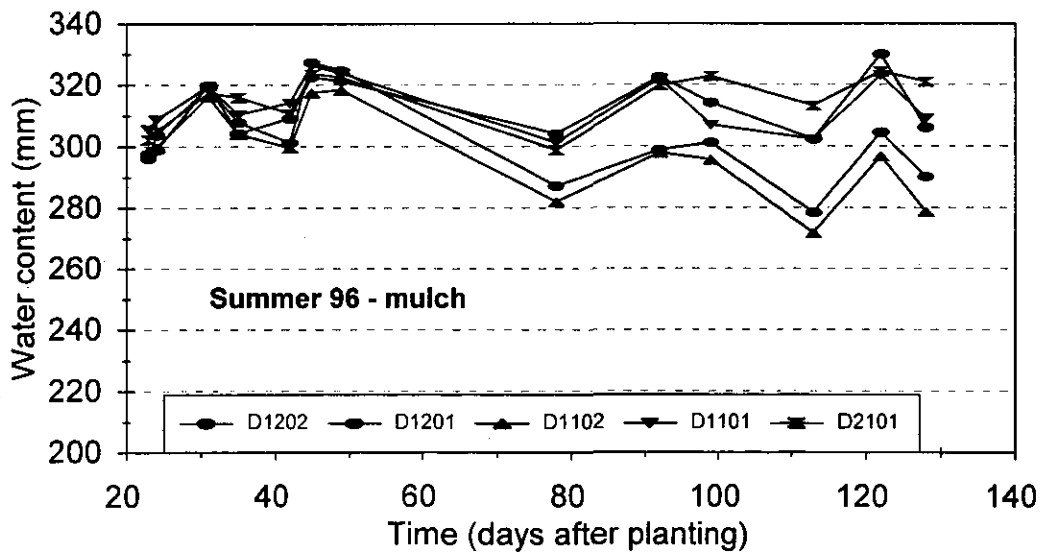


Fig. 5.5(b) Total soil water content versus time after planting for the summer 1996/97 for the mulch treatment.

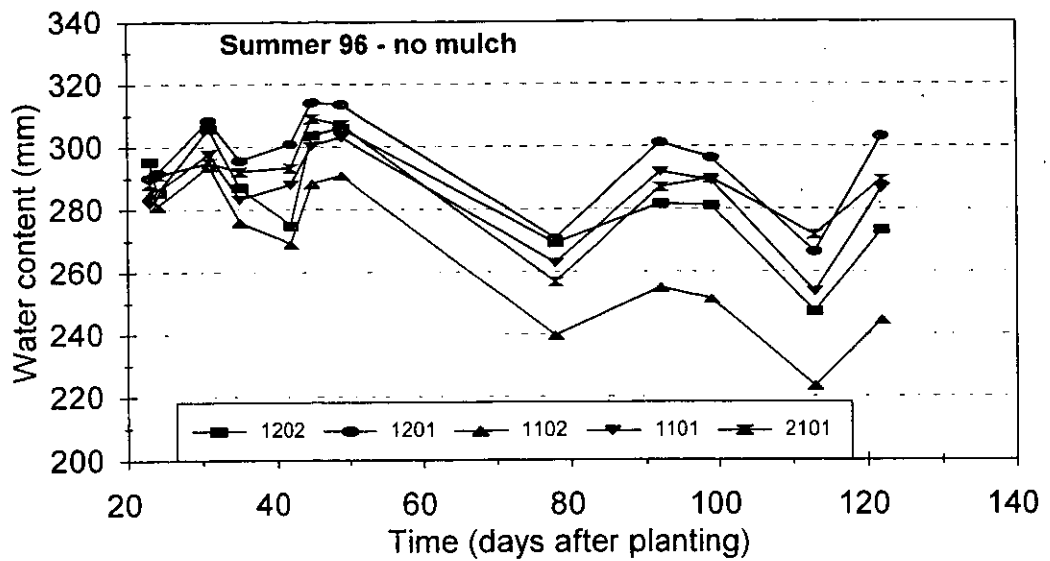


Fig. 5.5(c) Total soil water content versus time after planting for the summer 1996/97 for the no-mulch treatment.

Here it appears that all mulch treatments were consistently wetter than the rest of the treatments, regardless of the irrigation regime and remaining in the range 270 - 300 mm. Both the treatments receiving 20 mm weekly with kraal manure and no mulch remained in the 265 - 300 mm range. The no mulch treatments receiving 20 mm over a 2 week period were usually wetter than kraal manure treatments receiving the same amount of water. As expected the kraal manure and no mulch treatments that only received 10 mm every 2 weeks gave the driest soil profile values around 215 to 220 mm. It appears that during the summer the treatments that received 2 applications of 10 mm a week (2101) were consistently drier than those receiving only one application of 20 mm (1201). This would be explained by the increased soil surface evaporation and shallower water penetration by the frequent application of smaller amounts of water.

Again the differences between the maximum depletion of the driest treatments and the well-watered treatments was about 80 mm. The difference between the depletion on the mulch and no mulch treatments was about 45 mm.

### 5.3.3 Volumetric soil water content at various depths

The representation of the water content as a volume per volume for each soil layer that was measured from 0 to 135 cm will assist in discussing and explaining the water use data. The winter 1996 season will be used as an example and discussed in detail. For the treatments that received 20 mm per week, whether in one application (1201) or two applications (2101) it was seen that the top two layers remain wet throughout the season (Fig. 5.6(a,b,c,d)).

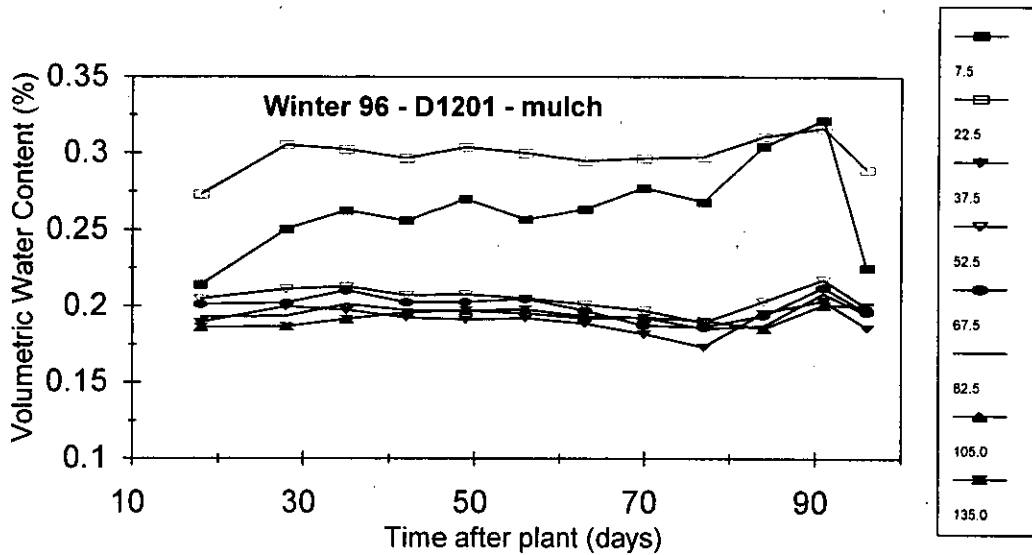


Fig. 5.6(a) Volumetric water content for each depth (cm) versus time for winter 1996 on the mulch (D) 20 mm weekly (120) irrigation treatments.

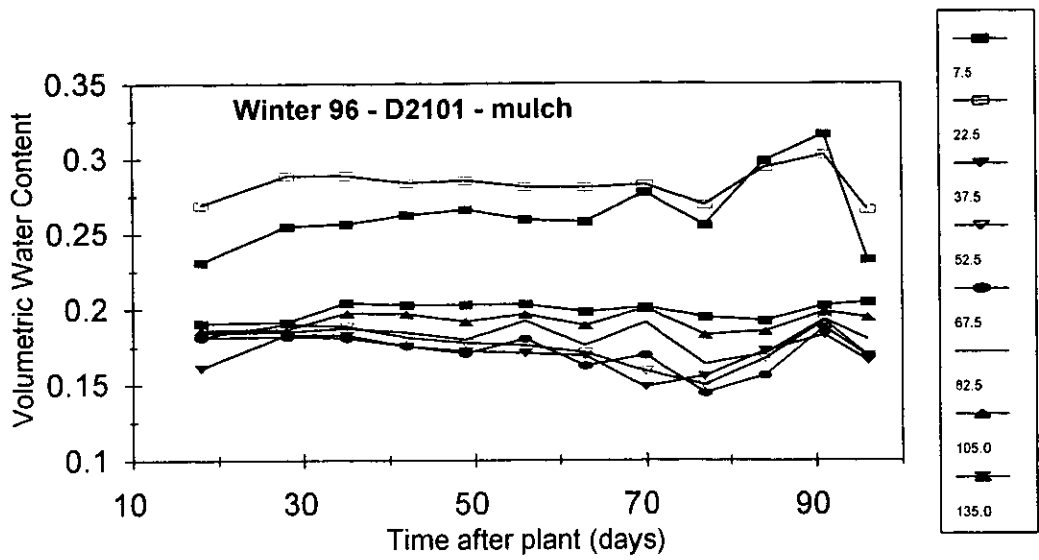


Fig. 5.6(b) Volumetric water content at each depth (cm) versus time (dap) for winter 1996 on the mulch (D) 10 mm twice weekly (210) irrigation treatments.

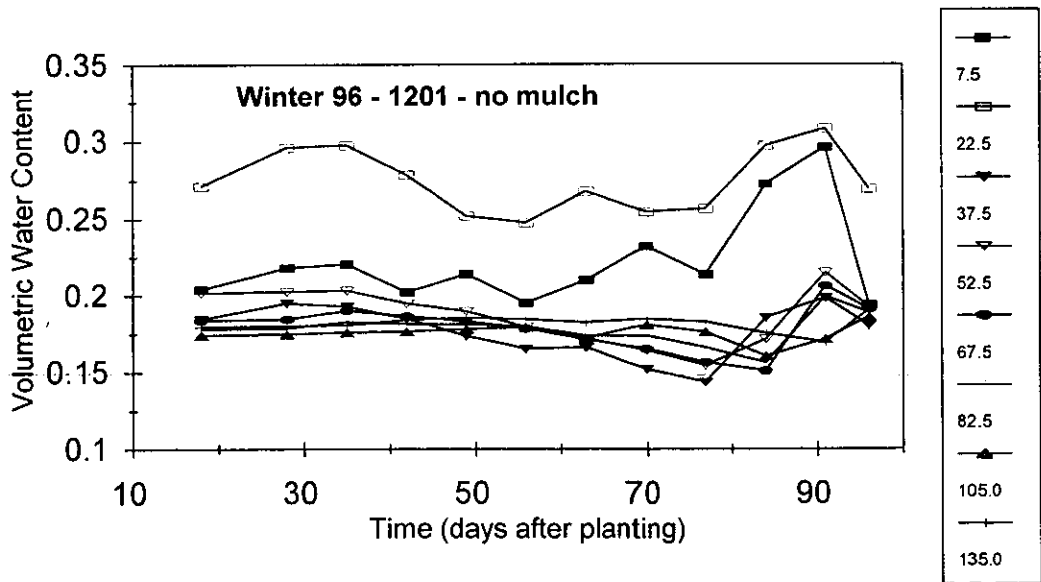


Fig. 5.6(c) Volumetric water content at each depth (cm) versus time (dap) for winter 1996 on the no mulch treatment receiving 20 mm weekly (120).

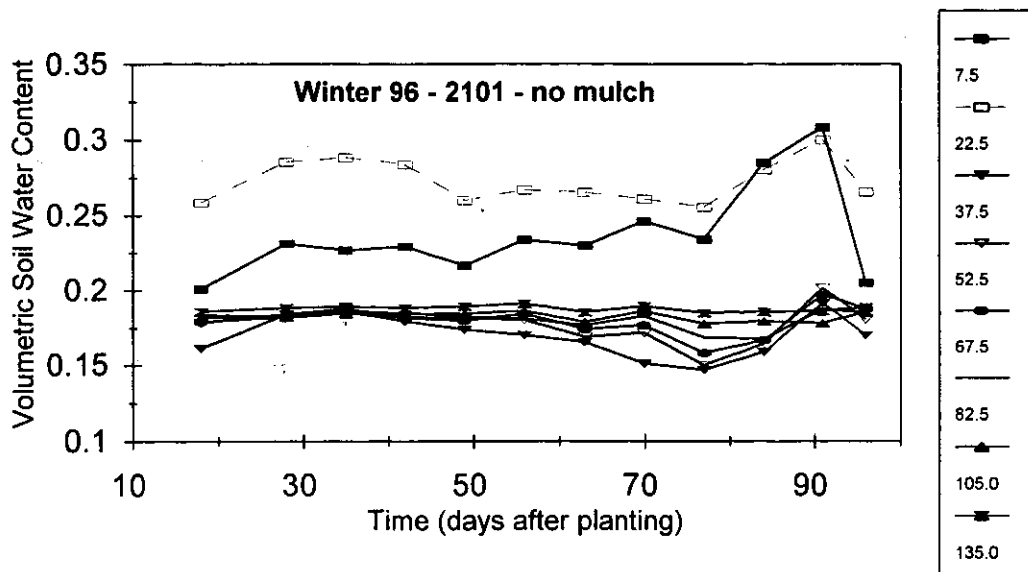


Fig. 5.6(d) Volumetric water content at each depth (cm) versus time for winter 1996 on the no mulch treatment receiving 10 mm twice weekly (1102).

This was true for both the no mulch and mulch treatments. The volumetric soil water at the deeper layers showed the least variation among the other treatments and illustrates that most of the water was supplied as needed by the plants. A reasonable consistent soil water content was maintained in each layer throughout the season.

The no mulch and mulch treatments that received 10 mm each week or 20 mm each fortnight have similar trends to each other (Fig. 5.7(a,b,c,d)).

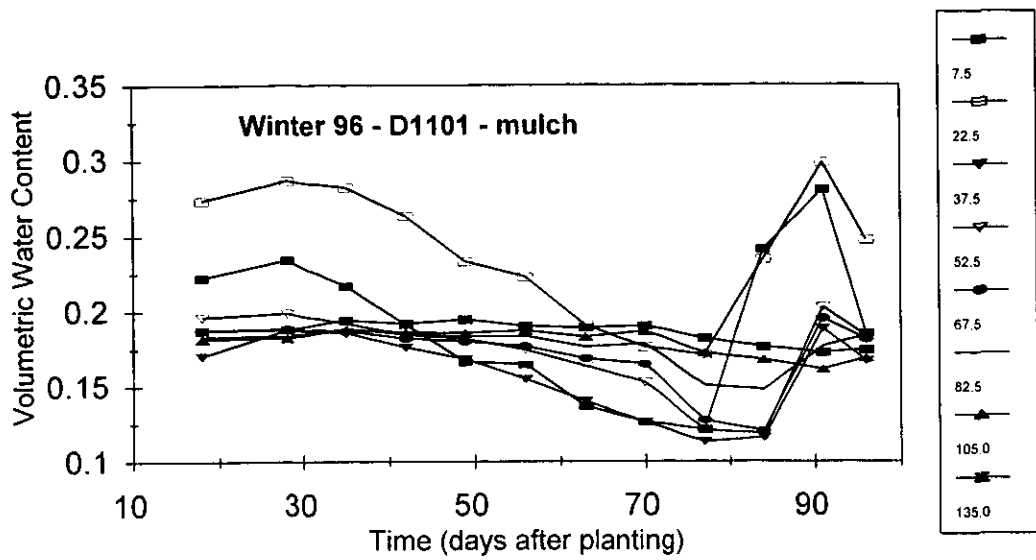


Fig. 5.7(a) Volumetric water content versus time for all the depths for winter 1996 on the mulch 10 mm weekly irrigation treatments (110).

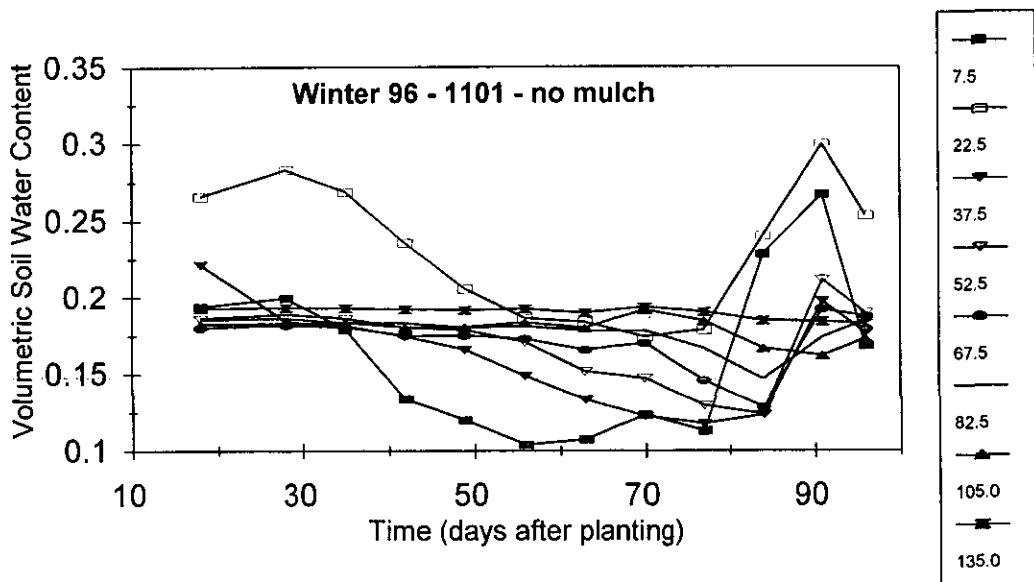


Fig. 5.7(b) Volumetric water content versus time for all the depths for winter 1996 on the no mulch for 10 mm weekly (1101) irrigation treatments.

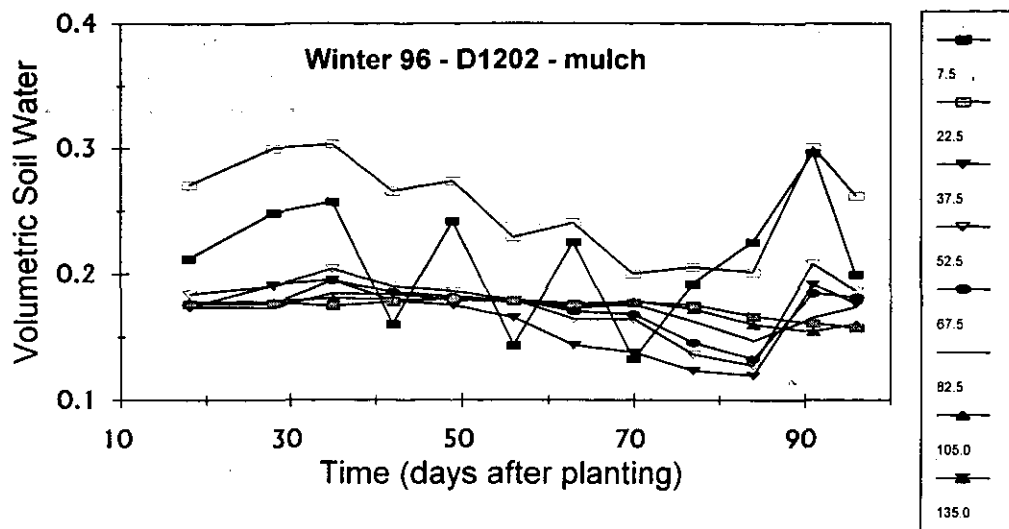


Fig. 5.8(a) Volumetric water content versus time for all the depths for winter 1996 on the mulch the 20 mm fortnightly (1202) irrigation treatments.

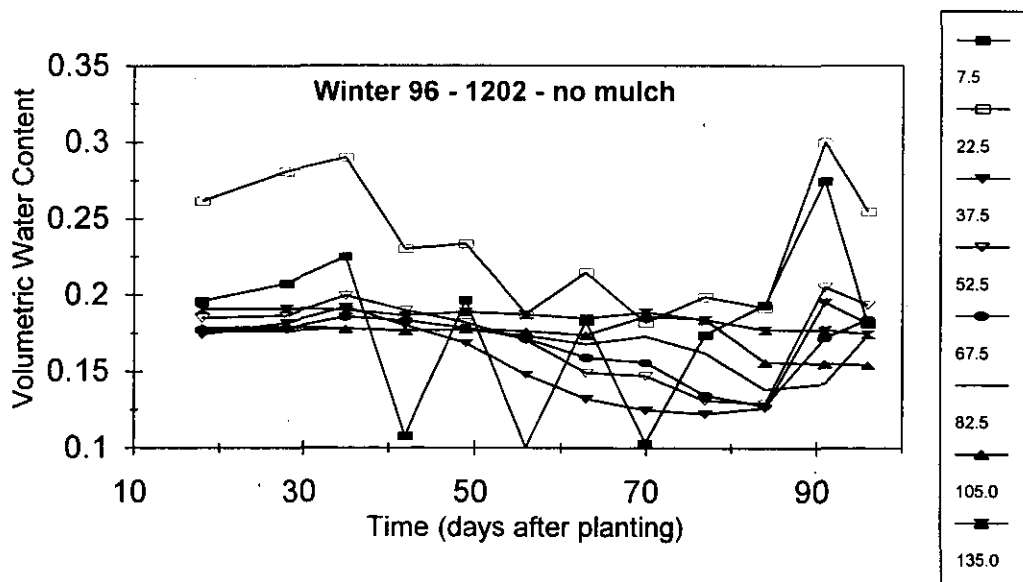


Fig. 5.8(b) Volumetric water content versus time for all the depths for winter 1996 on the no mulch for 20 mm fortnightly (1202) irrigation treatments.

The top two layers (0 - 15 cm and 15 - 30 cm) steadily decline during the season until the heavy rainfall received late in the season. The next two layers also show the depletion through the season as this forms the main part of the root zone (to 60 cm). As the amount of irrigation water applied is not sufficient to supply all the evaporative demand, the soil water is steadily depleted here also.

If one looks at the treatments receiving 20 mm every fortnight, (Fig. 5.8 (a & b)) then the effect of this water application is clearly seen in the top soil layer as the values zigzag each week. A slight pattern can also be seen in the second layer centered at 22.5 cm. It can also be clearly seen that the soil water in the third and fourth layers (centered namely at 37.5 and 52.5 cm) were showing a steadily decline in water content following the root and full canopy development (after 50 dap). This again indicates that the amount of water applied during the irrigations was insufficient to supply the needs of the crops.

The treatments receiving only 10 mm every 2 weeks (Fig. 5.9 (a & b)) show a combination of the patterns discussed above. There is a steady decline in the top 2 layers during the first 40 days of the season. The soil surface layer shows a zigzag pattern between the irrigated and dry weeks until the heavy rainfall is received. It is again interesting to note that the top layer is consistently drier than the second soil layer (15 - 30 cm). The layer 30 - 45 cm is steadily depleted during the season and to a greater extent than the next 2 layers (45 - 60 cm and 60 - 75 cm). The pattern is also noteworthy that the shallower layers are depleted earlier in the season and to a greater extent than the deeper layers. Towards the end of the season (approximately 80 dap but before the rainfall) it was noted that water was extracted by this treatment from the soil layers 75 - 90 cm and 90 - 120 cm.

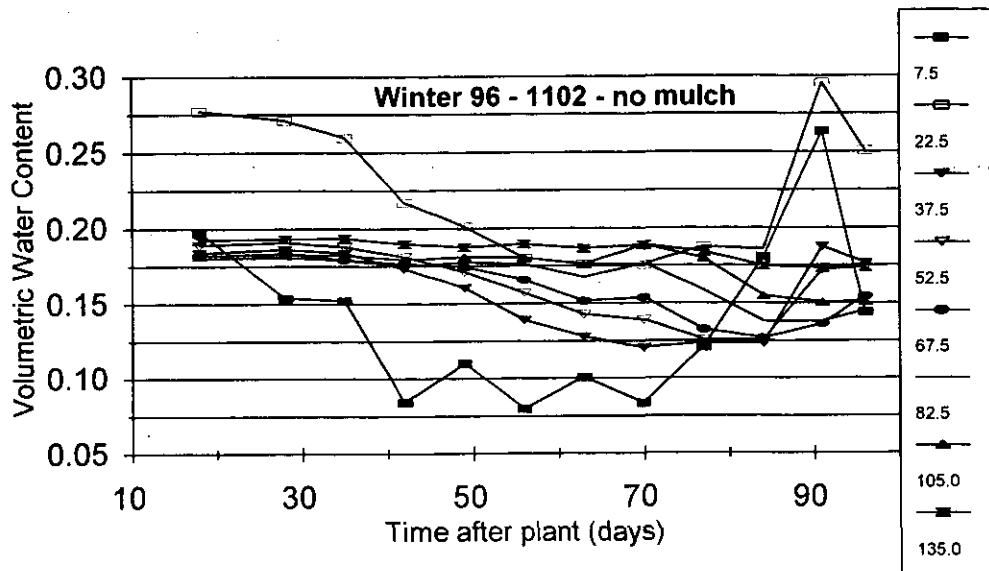


Fig. 5.9 (a) Volumetric water content versus time for all the depths for the winter 1996 on the no mulch treatments with 10mm fortnightly irrigation treatments.

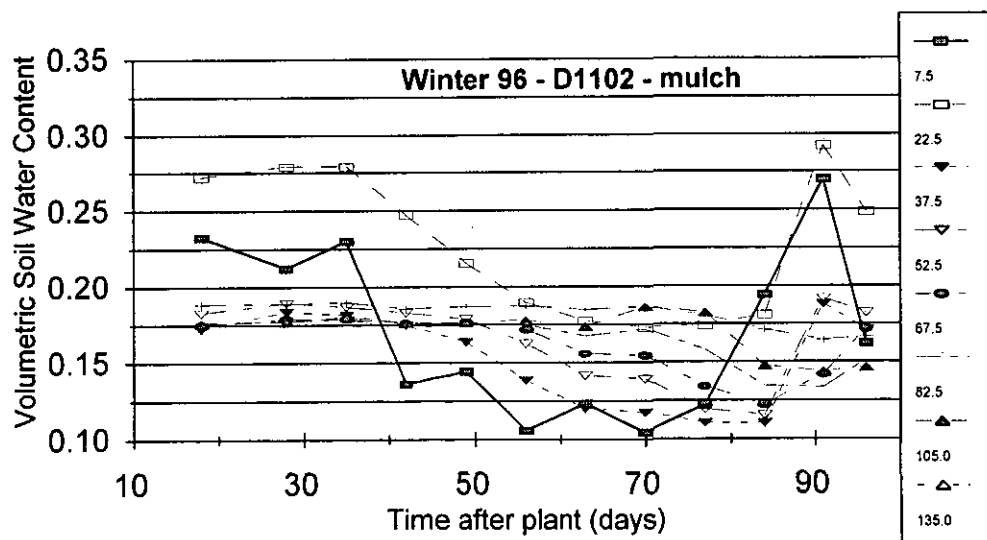


Fig. 5.9 (b) Volumetric water content versus time for all the depths for the winter 1996 on the mulch treatments with 10mm fortnightly irrigation treatments.

### 5.3.4 Cumulative water use through the season

The cumulative water use with time through the growing season is used to monitor the total amount of water used with growth and development of the crop. The comparison was made between the measurements within one plot between the water use measured within the beetroot and within the cabbage crop row (Fig. 5.10(a)). It

appears that the final total water use from the crops is similar, although the rate from the cabbage increased later in the season.

During winter 1996 there were clear differences between the treatments in the amount of water used by the inter-cropping combinations. Under both the mulch and no mulch treatments (Fig. 5.10(b)) the plots that received 20 mm per week (either in one (120) or two (1102) applications) had a higher water use. The final value being greater than 300 mm but with no significant difference between these two treatments. The next two treatments that received 20 mm over a two-week period either as one application (220) or as two applications (110) also showed similarities for the cumulative water use during the season. They ended for mulch and no mulch with just less than 250 mm being used. The remaining treatment (210) which received only 10 mm each second week lagged behind the other treatments, particularly noticeable after 70 days after planting. This resulted in a total of 200 mm being used through the season.

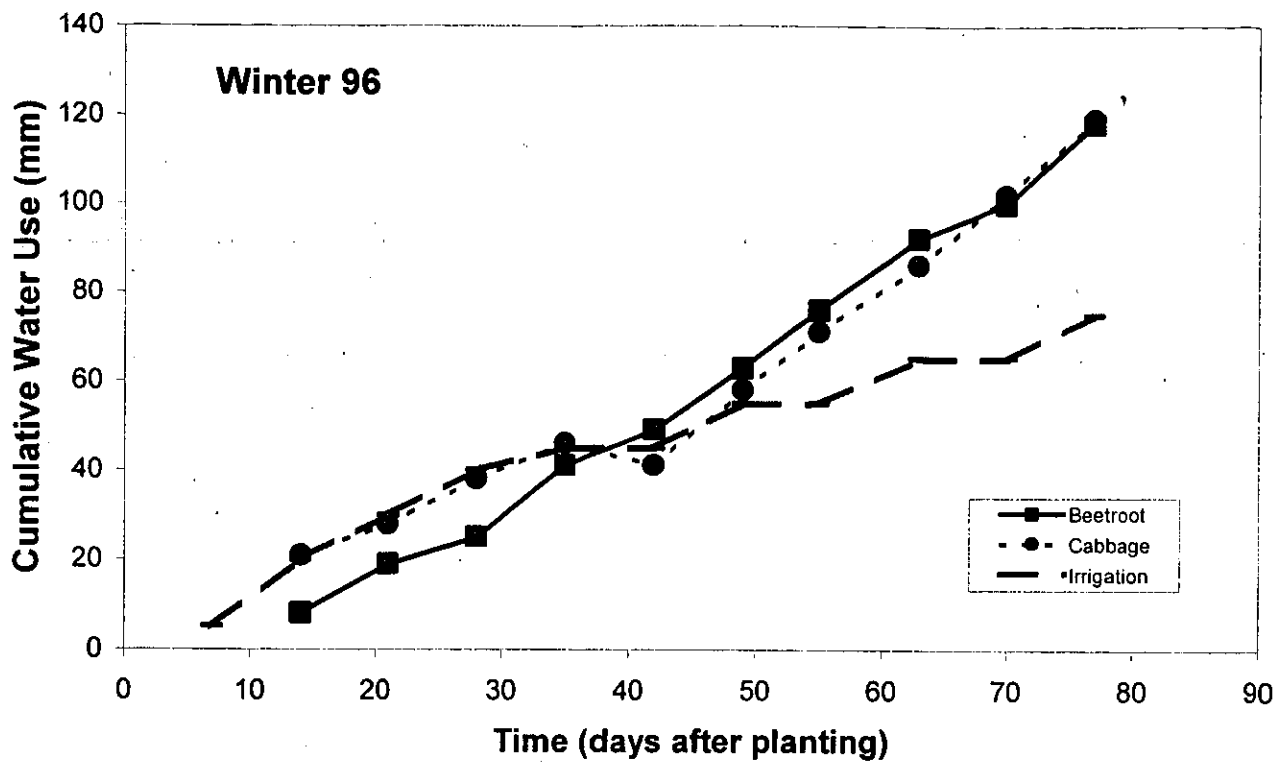


Fig. 5.10(a) Cumulative water use for winter 1996 for the fortnightly 10mm plot to compare the measurements taken in the beetroot row and in the cabbage row.

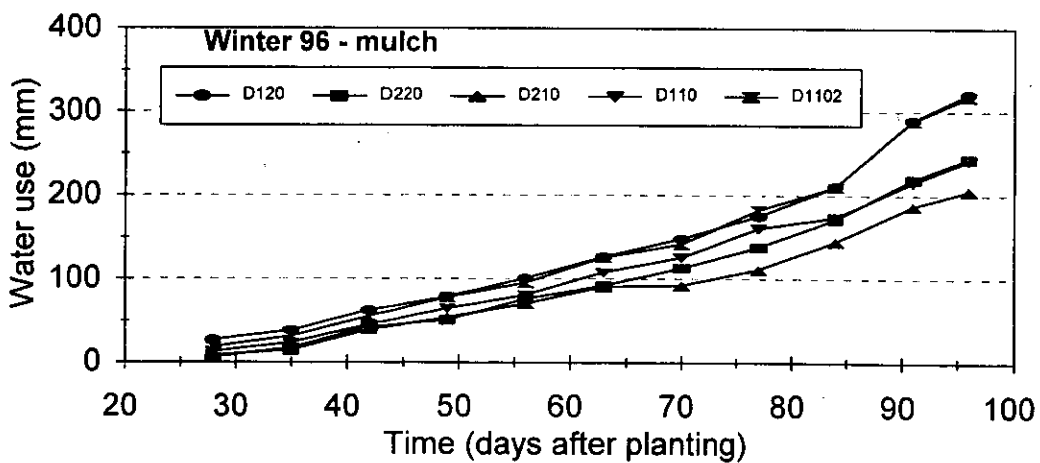


Fig. 5.10(b) Water use versus time during the winter 1996 season for the mulch treatments over the range of irrigation treatments.

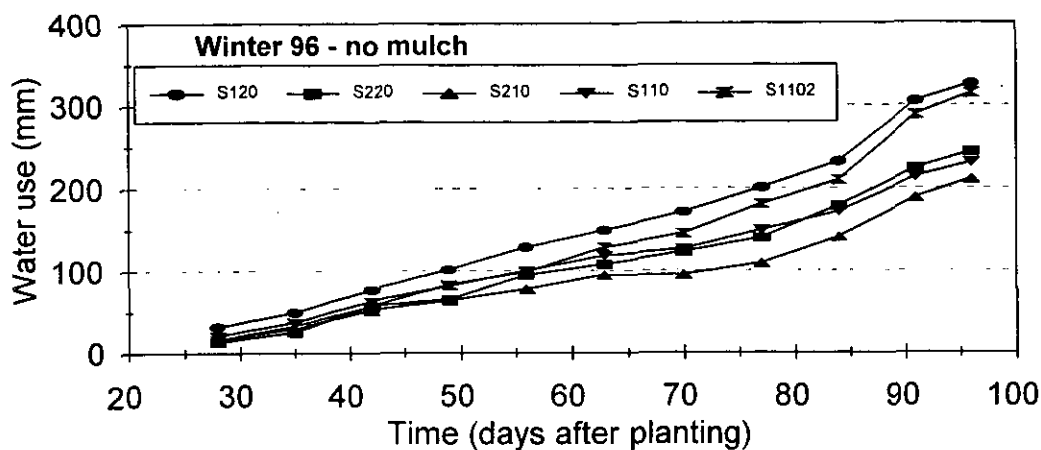


Fig. 5.10(c) Water use versus time during the winter 1996 season for the no mulch treatment over the range of irrigation treatments.

During summer 1996/97 there are no differences between the water use of the different treatments before 90 days after planting (Fig. 5.11(a,b)). Following this, there were only minor differences. The weekly application of 20 mm (1201) uses slightly more water - just about 600 mm under all treatments. The other irrigation treatments are bunched together as a result of the rainfall received during the season and they all use between 450 and 550 mm water. The fortnightly 10 mm treatment (1102) does remain consistently lower than the others during the second half of the season but is not significantly different.

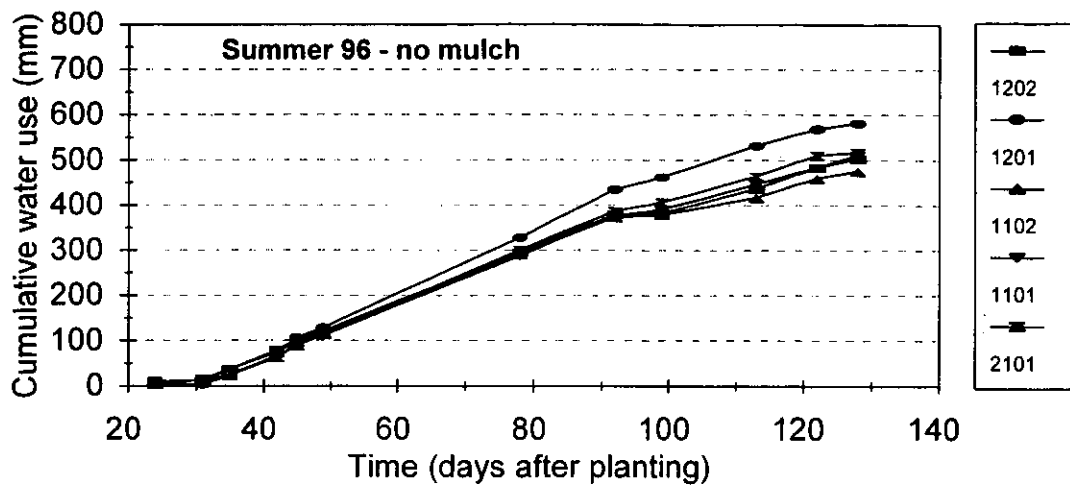


Fig. 5.11(a) Water use versus time during the summer 1996/97 season for the mulch treatment over the range of irrigation treatments.

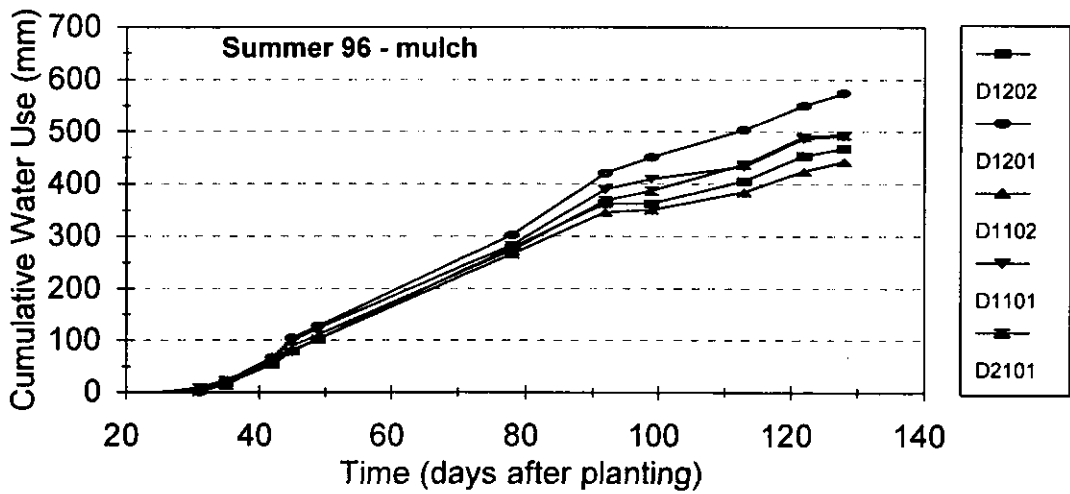


Fig. 5.11(b) Water use versus time during the summer 1996/97 season for the mulch treatment over the range of irrigation treatments.

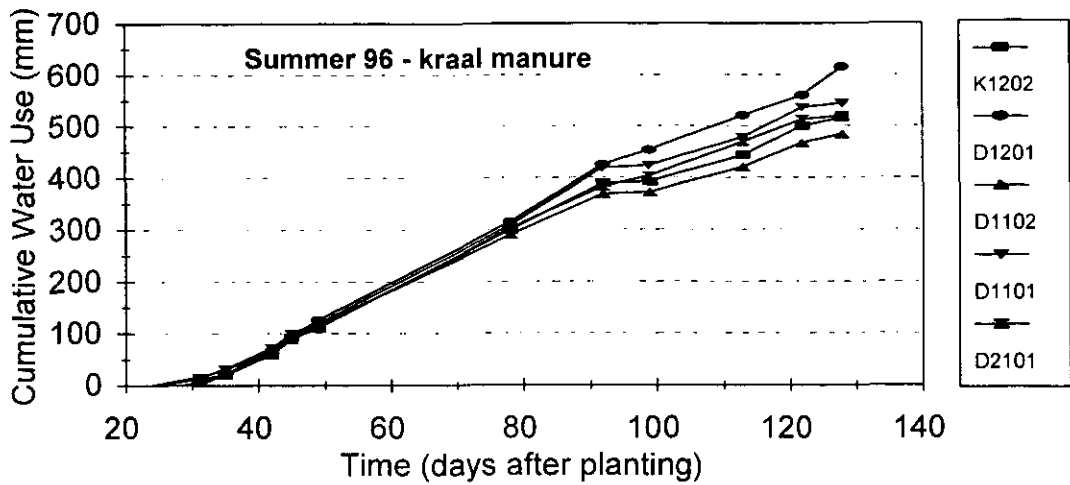


Fig. 5.11(c) Water use versus time during the summer 1996/97 season for the kraal manure treatment over the range of irrigation treatments.

The winter 1997 shows the same results as winter 1996 with the weekly 20 mm (1201) application using more water than the other treatments - at 450 mm (Fig. 5.12(a,b,c)).

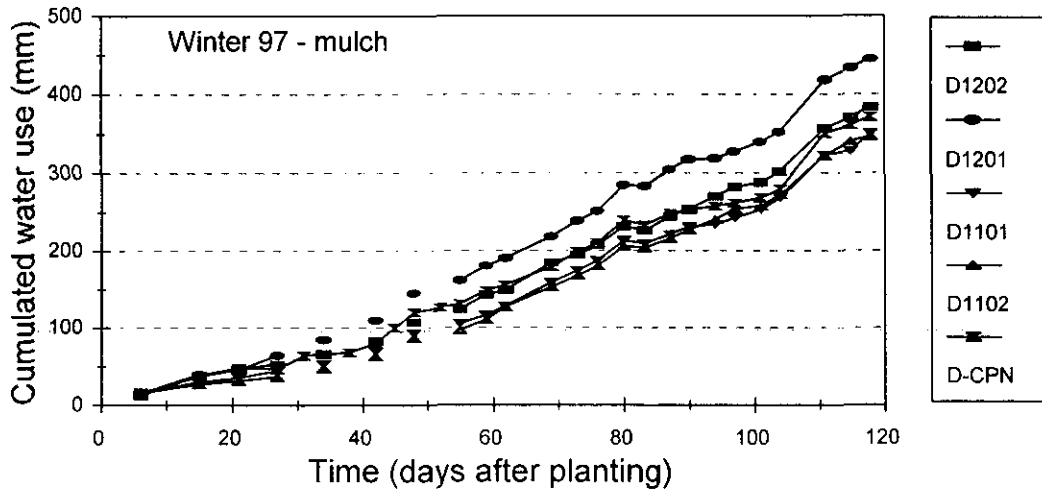


Fig. 5.12(a) Water use versus time during the winter 1997 season for the mulch treatment over the range of irrigation treatments.

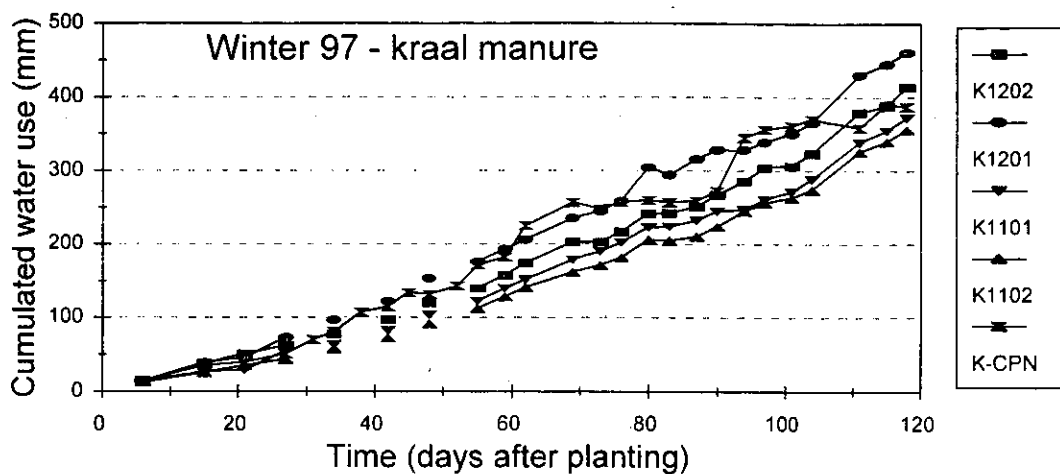


Fig. 5.12(b) Water use versus time during the winter 1997 season for the kraal manure treatment over the range of irrigation treatments.

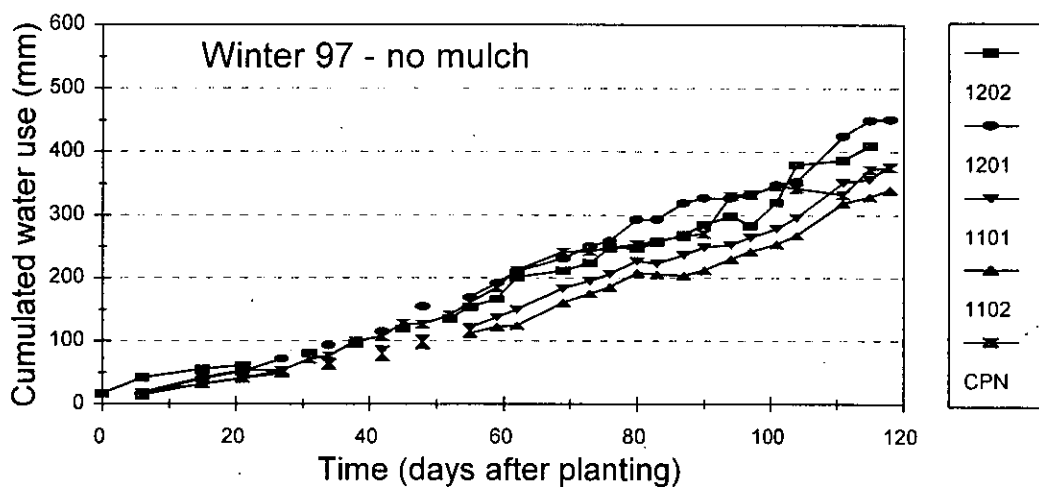


Fig. 5.12(c) Water use versus time during the winter 1997 season for the no mulch treatment over the range of irrigation treatments.

Again the water use is similar during the early part of the season and the slight difference are noticeable between day 50 and 60 after planting. Again the fortnightly 10 mm (1102) application treatment lags behind the others in all three of the

treatments, no mulch, kraal manure and mulch. Similar results were observed by two plots growing a sole crop of cabbage or Swiss Chard ( Fig. 5.13(a,b)).

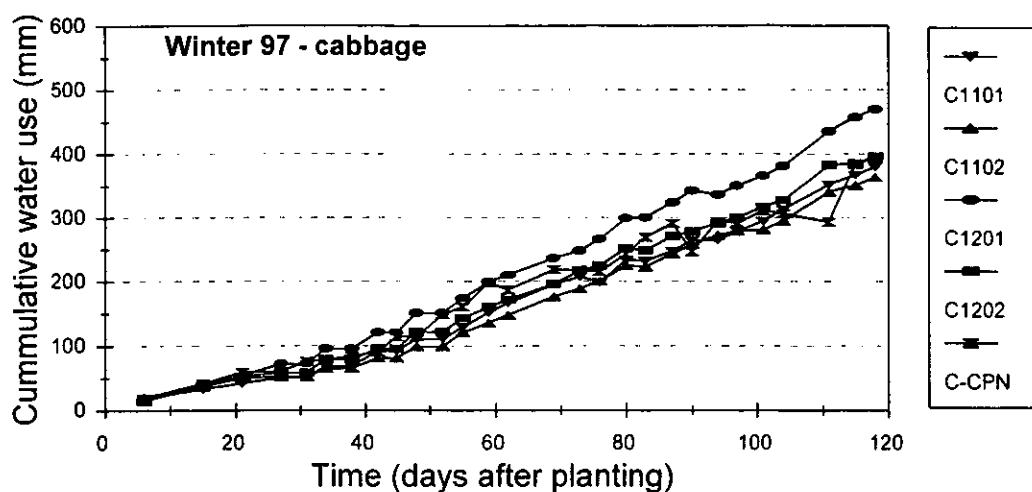


Fig. 5.13(a) Water use versus time during the winter 1997 season for the single crop plots of cabbage.

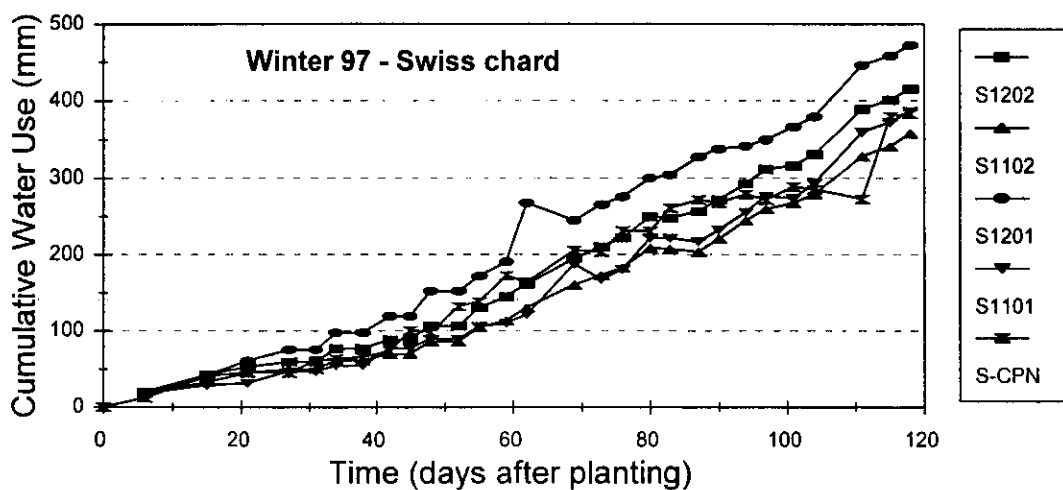


Fig. 5.13(b) Water use versus time during the winter 1997 season for the single crop plots of Swiss chard.

### **5.3.5 Water Use-Yield Production Functions**

Usually in an experiment an attempt is made to achieve as wide a range of water use and yield values as possible. However, in this case the concern was not for the water logged or droughted crops. Attention was rather given to the application of water within the normal range but including a range of combinations of frequency and amount of water usually applied. As has already been discussed under the volumetric water content section, much water from the profile was also used by the crops receiving the lower range of irrigation. This then is the main reason that there are no wide ranges of yields and water use, but rather a focused concentration within a narrow range.

There are some trends that can be seen in the data but the differences are not significant. Consider summer 1996/97 (Fig. 5.14 (a, b & c) which shows the tomato, swiss chard and cowpea yield values for each of the specific replication plots. For the tomato, there appears to be a slight trend to higher yields with higher water use for the kraal manure treatments. In a smaller fashion the mulch treatments tend to be on the lower yield and water side. For the Swiss chard yields, there is a slight trend to lower yields and water use under the mulch treatment. However, the kraal manure did not perform better than the others. For the cowpea, yields on the mulch plots appear slightly high despite the lower water use. This is probably due to the drought resistant characteristics of cowpeas.

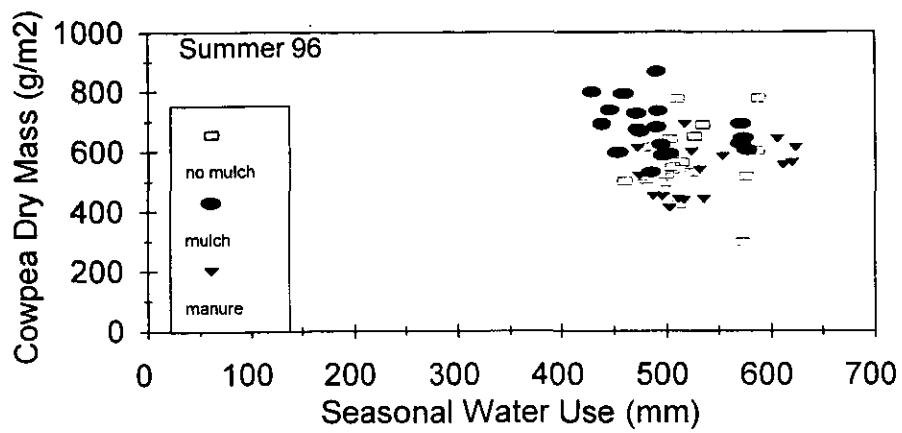


Fig. 5.14(a) The water – dry matter production functions for the summer 1996/97 season for cowpeas.

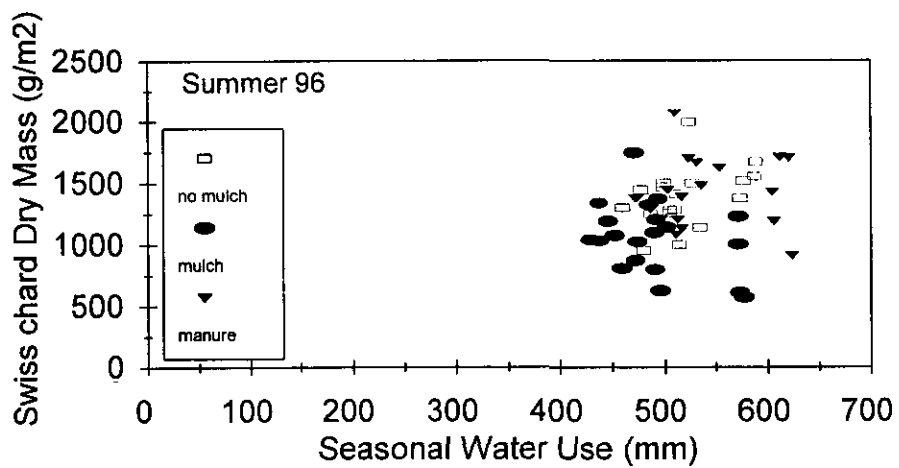


Fig. 5.14(b) The water – dry matter production functions for the summer 1996/97 season for swiss chard.

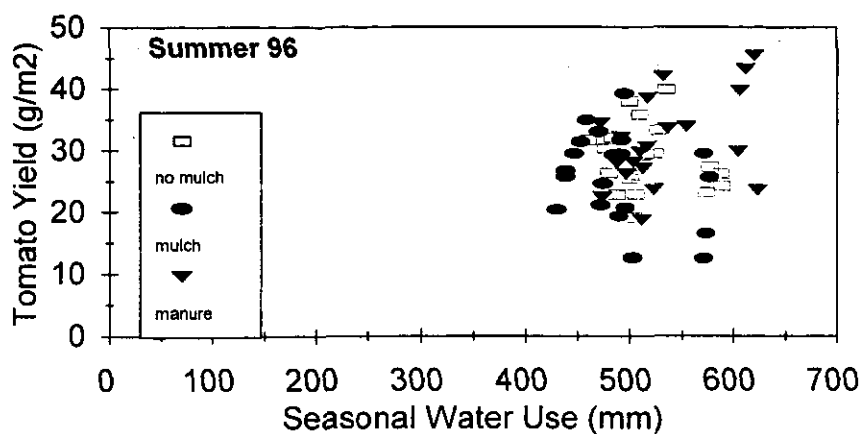


Fig. 5.14(c) The water – dry matter production functions for the summer 1996/97 season for the tomato crop.

When the mean total mass across treatments is considered (Fig. 5.15(a)) again there are no significant differences, however the mulch treatments are on the low yield side.

The kraal manure treatments are also not significantly different from the bare soil treatment either. Despite the non-significance of this result, it in effect shows little or no benefit from applying either kraal manure or a mulch for the summer grown vegetables.

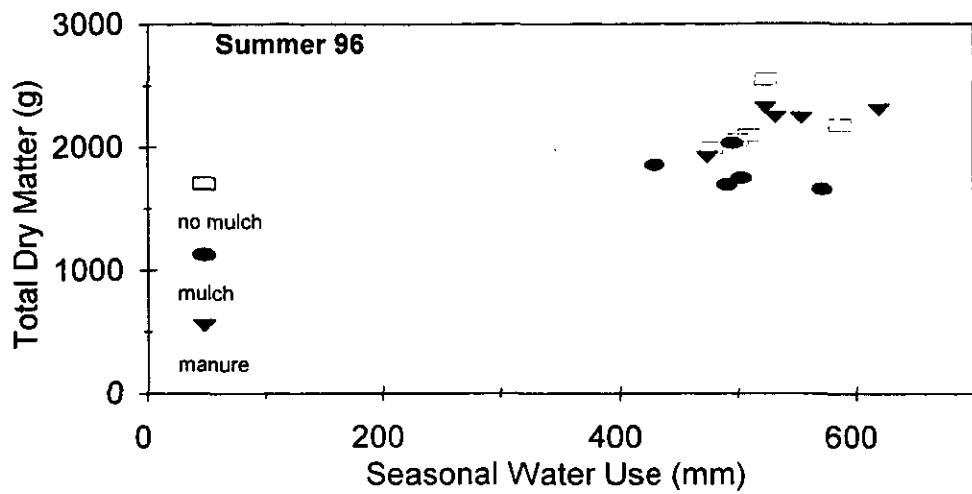


Fig. 5.15(a) The total mass for all crops versus the water use per plot for 1996/97.

The water use efficiencies (WUE) (Fig. 5.15(b)) calculated for the summer 96/97 show a trend to a lower value under the mulch situation.

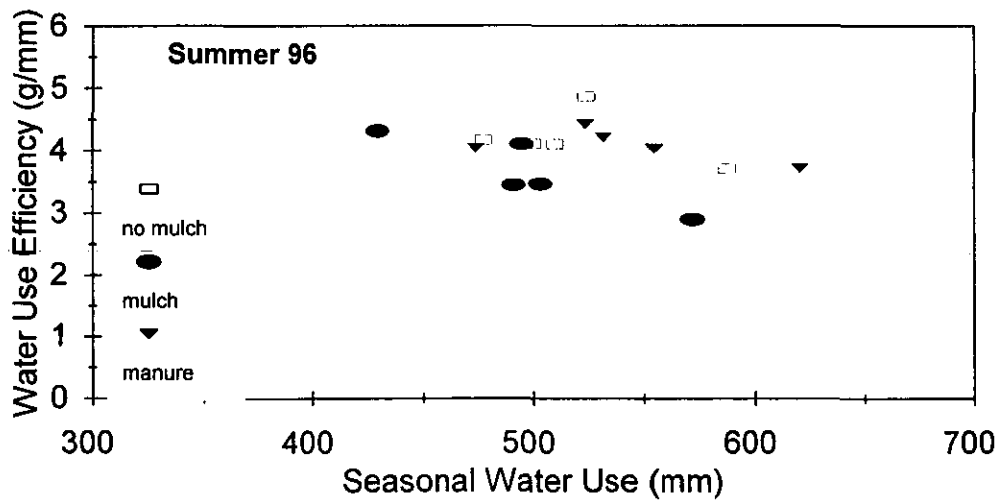


Fig. 5.15(b) The water use efficiency for the no mulch, mulch and manure treatments for summer 1996/97.

The bare soil and kraal manure cover the same range of water use and water use efficiencies. The fact that the 1201 treatments have a higher water use value, tends to draw them to lower WUE values.

During winter 96, there are no significant trends in the water use yield production functions (Fig. 5.16(a,b,c)). The mulch and bare soil treatments are intermingled in all three crops. The total dry matter produced only tends to emphasize the clumping of the seasonal water use values. The seldom irrigated treatments (S210 and D210) received slightly less water than the others. The frequently irrigated treatments (weekly or twice weekly) (1102 and 120) received slightly more water during the season.

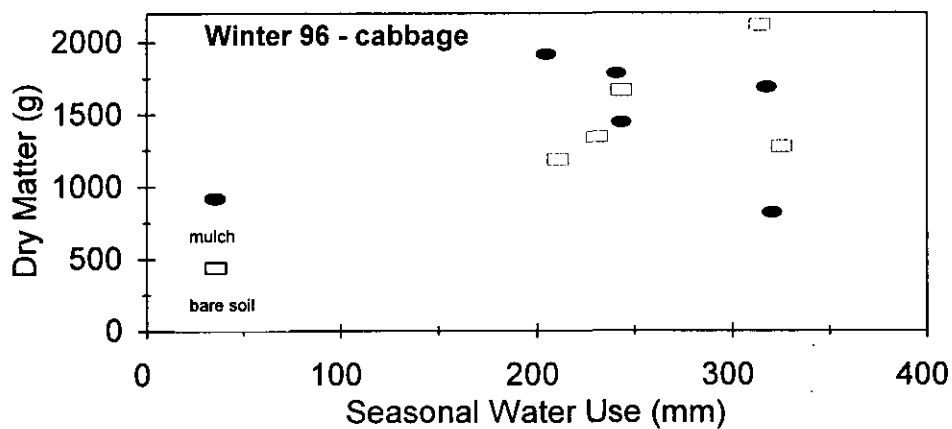


Fig. 5.16(a) Dry matter production versus seasonal water use for cabbage during winter 1996 under bare soil and mulch treatments.

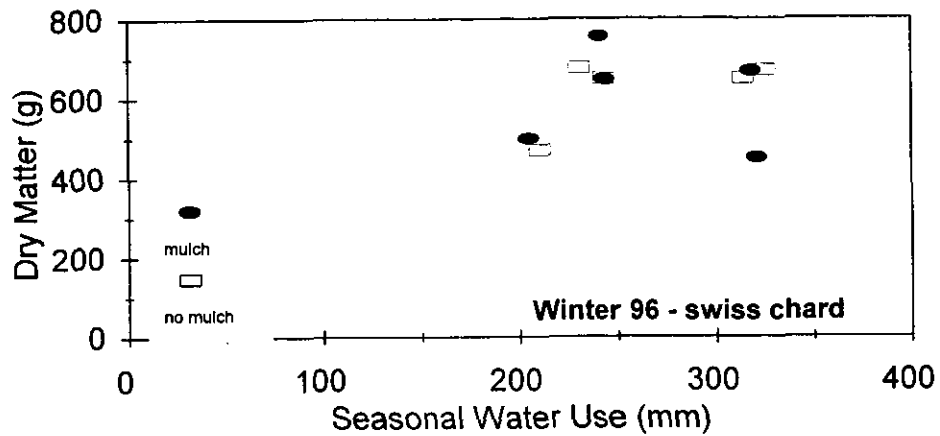


Fig. 5.16(b) Dry matter production versus seasonal water use for Swiss chard during winter 1996 under bare soil and mulch treatments.

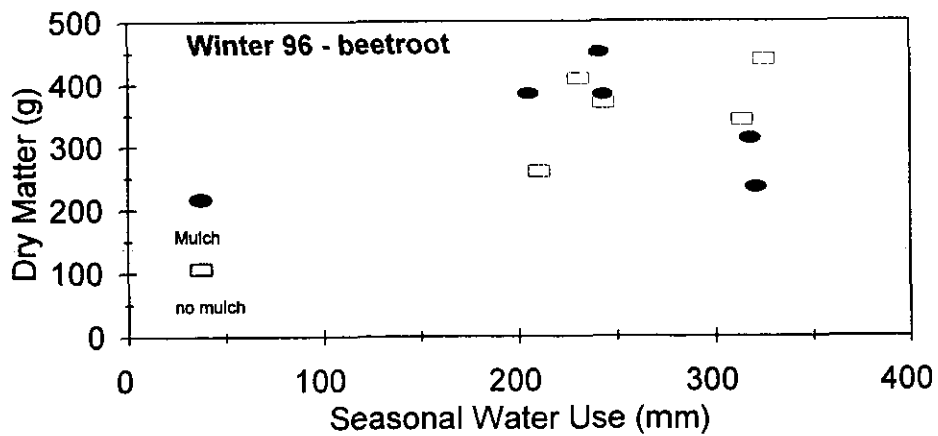


Fig. 5.16(c) Dry matter production versus seasonal water use for beetroot during winter 1996 under bare soil and mulch treatments.

For the winter 1996, there is a trend showing through the bare soil and mulch treatments. Generally speaking the treatments receiving 20 mm per week (1102,120)

be it in one or 2 applications, have a lower WUE value (Fig. 5.17 (a)). At the other extreme, the treatment receiving the least irrigation produced the highest WUE value.

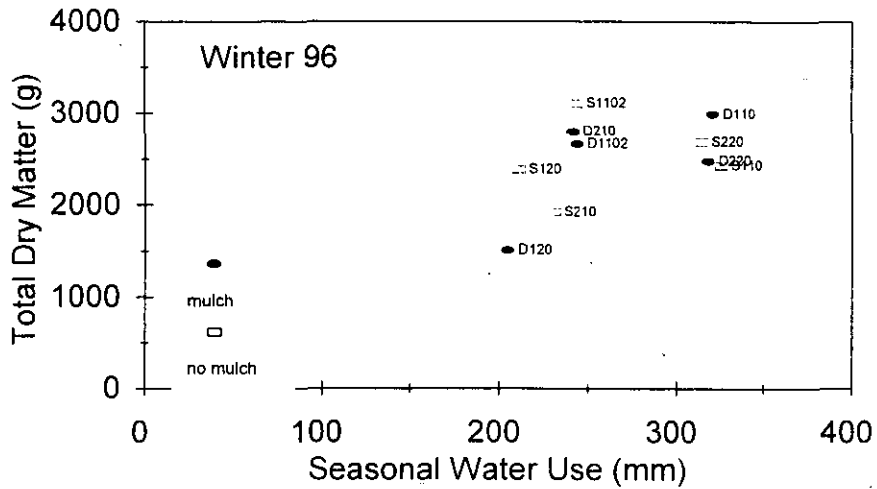


Fig. 5.17 (a) The water – dry matter production functions for winter 1996 showing mulch and bare soil treatments.

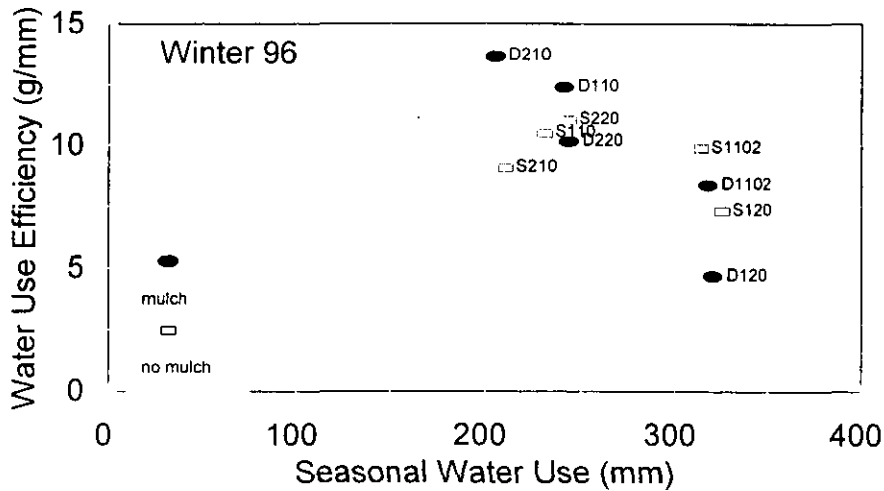


Fig. 5.17 (b) The water use efficiency for winter 1996 showing mulch and bare soil treatments

During winter 1997, there are no significant trends of differences between the yield production functions from the mulch or kraal manure treatments (Fig. 5.18 (a & b)). The only trends are in the amount of water used, whereby the 20 mm weekly treatment

used an average of 450 mm and the 10 mm fortnightly treatment used on average of 350 mm, but the range of yields produced from the various replications and cultivation treatments mean that there is no significant differences in final total above ground dry matter yield. Although there are no significant differences, it is a significant result in the sense that it implies that the effect of the cultivation treatments is not worth the effort.

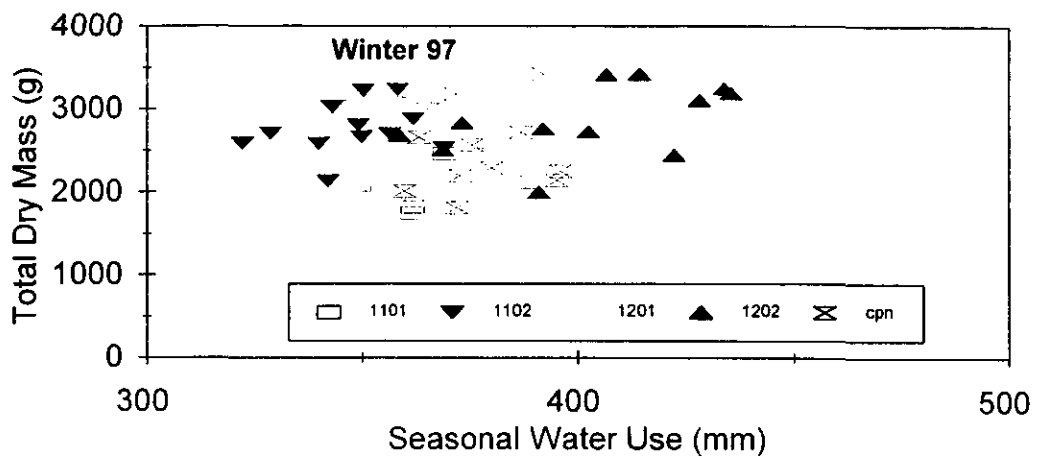


Fig. 5.18(a) The water ~ dry matter production functions for winter 1997 showing the various irrigation treatments.

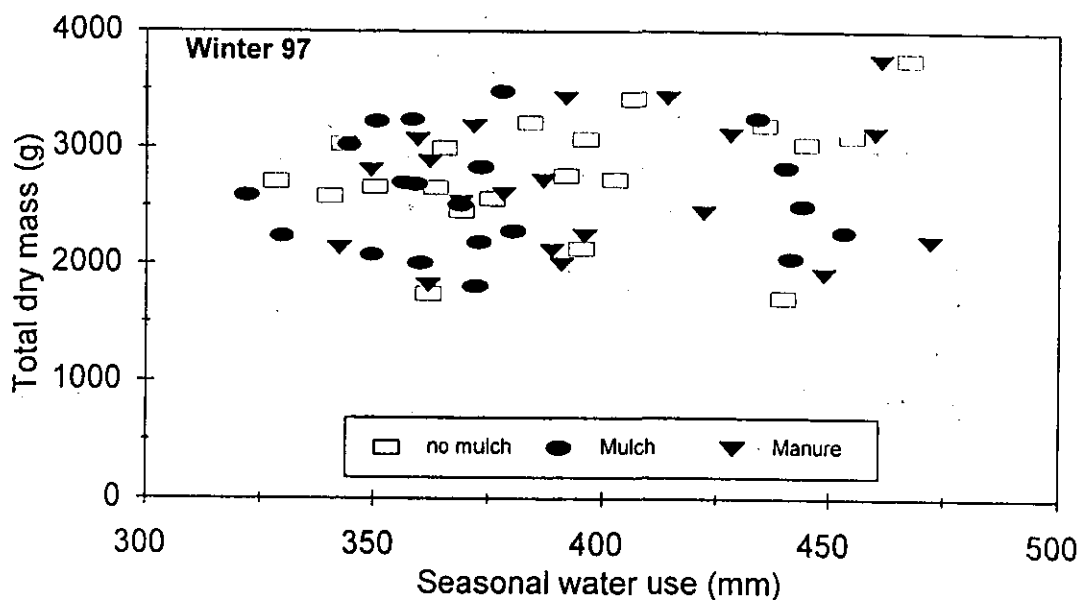


Fig. 5.18(b) The water – dry matter production functions for winter 1997 for mulch, bare soil and manure treatments.

From the irrigation application point of view it is also a significant result, as it means that the same vegetable production can be obtained with less frequent irrigation and less water. The yields produced from 350 mm water use are not significantly different from these produced from 450 mm water use. The labor and pump costs for weekly irrigation would also not be worth it as the fortnightly irrigation of 10 mm gives the same yields as the weekly 20 mm irrigation.

The water use efficiencies are again clumped according to the irrigation treatments (Fig. 5.19). The frequent irrigation gave water use efficiency (WUE) values in the range 3.8 to 8 g mm<sup>-1</sup> compared to the WUE range for the fortnightly irrigation is 6.2 to 9.2 g mm<sup>-1</sup>. These values are not significantly different, but it appears that there is a trend towards higher WUE for the fortnightly irrigation treatments.

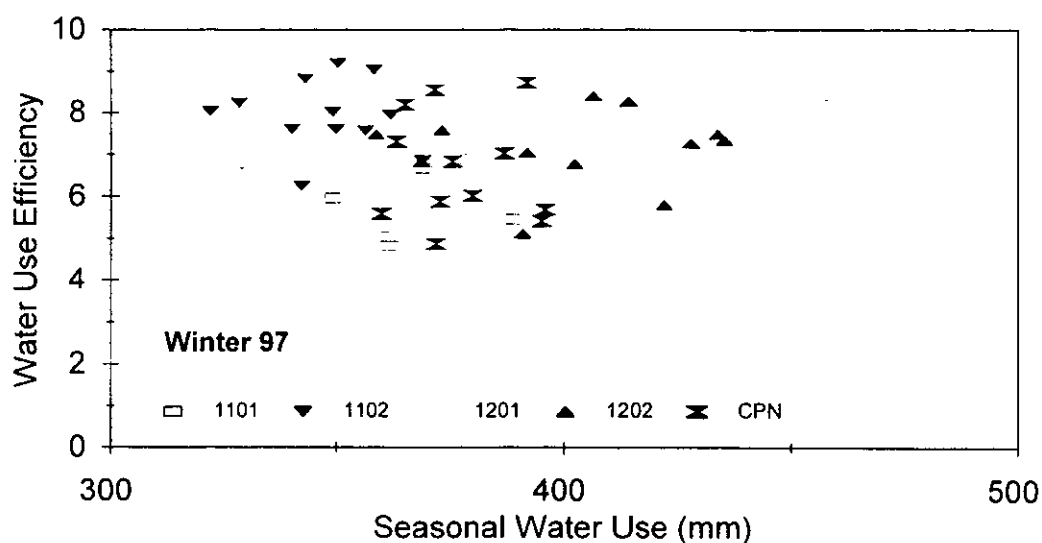


Fig. 5.19 The water use efficiency versus water use for the no mulch, mulch and kraal manure treatments for all the irrigation treatments in winter 1997.

### 5.3.6 Statistical Analysis

The cultivation practices (mulch and cattle manure) and irrigation had a small effect on the dry matter yield, of each crop individually and the total dry matter production. In general there was no difference between any of the treatments over the various year. This result however is significant in itself and the consequences need to be discussed further with irrigation planners. Consider the winter 1995 where there were five irrigation treatments and two initial profile water contents. The Swiss Chard yield was significantly different at the different starting profile water capacities (Table 5.3.6.1). The water use was also significantly different at the different irrigation applications and frequencies (Table 5.3.6.2).

Table 5.3.6.1 Analysis of Variance Table for winter 1995: Swiss Chard yield (SPINY) - dependent variable

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Model	7	326.21875	46.6026786	5.60	0.0006
Error	24	199.75000	8.3229167		
Corrected Total	31	525.96875			
	R Square	C.V.	Root MSE	Wuse Mean	

	0.62022	25.01851	2.884947	11.531250	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	3	39.34375	13.1145833	1.58	0.2212
PROFILE	1	270.28125	270.28125	32.47	0.0001
IRIGXPROFIL	3	16.59375	5.53125	0.66	0.5820

Table 5.3.6.2 Analysis of Variance Procedure for winter 1995: Water use (WUSE) - dependent variable

Source	DF	Sum of Squares	Mean Square	F value	Pr > F
Model	7	68126.875	9732.41071	22.19	0.0001
Error	24	10528.000	438.66667		
Corrected Total	31	78654.875			
	R Square	C.V.	Root MSE	Wuse Mean	
	0.86614	14.66564	20.94437	142.8125	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	3	67126.625	22375.54167	51.01	0.0001
PROFILE	1	288.000	288.00000	0.66	0.4257
IRIGXPROFIL	3	712.250	237.41667	0.54	0.6587

Considering the winter 1996 season the Swiss Chard yield and total mass were significantly different between treatments. The beetroot and cabbage yields were not significantly different (Table 5.3.6.3). The total mass harvest from a single treatment was significantly different for the irrigation level and also the cultivation practices irrigation level. This indicates that the effect of the mulch is influenced by the irrigation treatments, amount and/or frequency.

Table 5.3.6.3a Analysis of Variance Procedure for winter 1996: SPINY - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	9	3.76376E+11	4.18196E+10		0.0037
Error	30	3.46402E+11	1.15467E+10	3.62	
Corrected Total	39	7.22778E+11			
	R Sqr	C.V.	Root MSE	SPINY Mean	
	0.5207	17.52263	107455.7	613239.42	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	2.65560E+11	6.63900E+10	5.75	0.0015
BERWERK	1	3.76506E+09	3.76506E+09	0.33	0.5722
IRIGXBEWERK	4	1.07051E+11	2.67628E+10	2.32	0.0800

Table 5.3.6.3b Analysis of Variance Procedure for winter 1996: BEETY beetroot yield - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	9	1.85194E+11	2.05771E+10	1.89	0.0926
Error	30	3.2614E+11	1.08905E+10		
Corrected Total	39	5.11908E+11			
	R Square	C.V.	Root MSE	SPINY Mean	
	0.361772	29.11121	104357.4	358478.37	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	6.51770E+10	1.62943E+10	1.50	0.2283
BERWERK	1	1.18898E+09	1.18898E+09	0.11	0.7434
IRIGXBEWERK	4	1.18828E+11	2.97070E+10	2.73	0.0477

Table 5.3.6.3c Analysis of Variance Procedure for winter 1996: KOOLY cabbage yield - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	9	5303583.025	589287.003	2.40	0.0349
Error	30	7371081.750	245702.725		
Corrected Total	39	12674664.775			
	R Sq	C.V.	Root MSE	KOOLY Mean	
	0.4184	32.41195	495.6841	1529.3250	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	3007670.650	751917.662	3.06	0.0315
BERWERK	1	5593.225	5593.225	0.02	0.8811
IRIGXBEWERK	4	2290319.150	572579.788	2.33	0.0787

Table 5.3.6.3d Analysis of Variance Procedure for winter 1996 total mass: TOTMASS - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	9	9.64687E+11	1.07187E+11	4.83	0.0005
Error	30	6.65498E+11	2.21833E+10		
Corrected Total	39	1.63019E+12			
	R Sqr	C.V.	Root MSE	TOTMASS Mean	
	0.59176	15.30346	148940.5	973247. 150	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	5.27499E+11	1.31875E+11	5.94	0.0012
BERWERK	1	9.17133E+09	9.17133E+09	0.41	0.5251
IRIGXBEWERK	4	4.28017E+11	1.07004E+11	4.82	0.0040

For the winter 1997, season again only the Swiss Chard yield was significantly different across treatments (Table 5.3.6.4). However, this was across the cultivation treatments namely mulch, manure and bare soil. The Swiss Chard yield on the mulch treatment was significantly different from that obtained by the bare soil or kraal manure treatments.

Table 5.3.6.4a Analysis of Variance Procedure for winter 1997: SPINY - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	14	83903.43333	5993.10238	2.50	0.0101
Error	45	107829.50000	2396.21111		
Corrected Total	59	191732.93333			
	R Sq	C.V.	Root MSE	SPINY Mean	
	0.43760	23.43653	48.95111	208.86667	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	22459.1000	5614.7750	2.34	0.0691
BERWERK	2	32544.1333	16272.0667	6.79	0.0026
IRIGXBEWERK	8	28900.2000	3612.5250	1.51	0.1815

Table 5.3.6.4b Analysis of Variance Procedure for winter 1997: BEETY beetroot yield - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	14	599788.9333	42842.0667	0.67	0.7861
Error	45	2858049.0000	63512.2000		
Corrected Total	59	3457837.9333			
	R Sqr	C.V.	Root MSE	SPINY Mean	
	0.17345	31.81890	252.0163	792.03333	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	241670.7667	60417.6917	0.95	0.4434
BERWERK	2	105367.0333	52683.5167	0.83	0.4428
IRIGXBEWERK	8	252751.1333	31593.8917	0.50	0.8515

Table 5.3.6.4c Analysis of Variance Procedure for winter 1997: KOOLY cabbage yield - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	14	1955429.733	139673.559	0.65	0.8066
Error	45	9642280.000	214272.889		
Corrected Total	59	11597709.733			
	R Sqr	C.V.	Root MSE	KOOLY Mean	
	0.16860	42.50914	462.8962	1088.93333	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	777347.233	194336.808	0.91	0.4680
BERWERK	2	36313.233	18156.617	0.08	0.9189
IRIGXBERWERK	8	1141769.267	142721.158	0.67	0.7182

Table 5.3.6.4d Analysis of Variance Procedure for winter 1997 total mass: TOTMASS - dependent variable

Source	DF	Sum Squares	Mean Square	F value	Pr > F
Model	14	3393807.333	242414.810	0.89	0.5741
Error	45	12251827.000	272262.822		
Corrected Total	59	15645634.333			
	R Sqr	C.V	Root MSE	TOTMASSMean	
	0.21691	19.46123	521.7881	2681.16667	
Source	DF	AnovaSS	Mean Square	F value	Pr > F
IRIG	4	920277.167	230069.292	0.85	0.5041
BERWERK	2	348460.233	174230.117	0.64	0.5321
IRIGXBERWERK	8	2125069.933	265633.742	0.98	0.4671

An attempt was made to test the sensitivity in the top layers of soil so similar statistical analysis was performed for the water-balance in the 0 - 45 cm layers of soil. However, no additional value was obtained from this analysis. One of the difficulties is that the water balance uses total amounts of rainfall and irrigation and so it is not possible to proportion that to the different layers of the soil. This makes it appear that there were not many changes in the water balance performed for the rooting depth and for the whole soil profile.

These statistical analysis emphasize the fact that the only vegetable that has a significant yield differential across the irrigation treatments is the Swiss Chard. This may be due to the type of serial harvesting that takes place for Swiss Chard over the season. So that the crop can rest or decrease its evapotranspiration every 2 weeks when the older outer leaves are harvested. Perhaps this allows the crop to recover somewhat and continue leaf growth.

## 5.4 Conclusions

As already stated there are no significant differences between the vegetable yields on different irrigation treatments. This is in part due to the design of the experiment which focused on the high yield level and adequate water supply. The cultivation treatments (mulch and kraal manure versus no mulch) also made no significant difference to yield values. The kraal manure often requires a longer time to be absorbed so often the crops improve during the second year. This was however not investigated in this study.

Despite the fact that there are no significant differences in yield a positive conclusion can be drawn, in that the lower water applications gave the same range of yields. So it can be recommended that the irrigators can use the longer time interval between irrigations (fortnight). This will save on labour and pump costs. The application of less water over the whole season can often substantiate savings. This could allow for further land to be brought under irrigation cultivation with the same water quota. This would then also spread the overhead costs of the irrigation equipment over a larger production area and higher gross income.

This information can be used for the further planning and development of new irrigation schemes. The management strategies of longer irrigation intervals for vegetables grown on good irrigable soils can be included into the training programmes and design criteria. The use of short frequent irrigations would only be necessary early in the season with the seedlings and small transplants during the establishment period.

Despite the fact that the top soil layers (to 30 cm) showed a zig-zag pattern of water depletion, there was little effect on the yield. This indicates that the roots had been established in the deeper layers, probably promoted by the two week spacing of irrigations.

The difference of 25 mm soil water between mulch and no mulch cultivation treatments in winter appears not to be significant. However, over a large land surface area, this could prove to be a large savings as the mulch also increases the soil temperature and allows better root growth.

The difference of between 65 and 80 mm on the total water use for the treatments irrigated on a weekly or fortnightly basis provides a water saving of 16 – 26 %. This creates a type of deficit irrigation management practise that can be used for vegetables.

So despite the negative appearance of the results, there are several useful pieces of information available from the vegetable irrigation trials. This water use data will be further manipulated in the following chapter where the crop factors will be calculated.

## Chapter 6

### WATER REQUIREMENTS OF VEGETABLES IN MULTICROPPING CULTIVATION IN SMALL PLOTS

#### 6.1 Introduction

In general results from the on-station field experiment will be discussed in the light of the literature and in comparison with the Soil Water Balance (SWB) model (Annandale, Benade, Van der Westhuizen and Campbell, 1996). Mulch and cattle manure applications to crops have been used for many years and in a variety of countries. The water use under this type of system is, however, only one of the aspects that needs to be considered. A multi-disciplinary team is really needed to study all aspects including the pests and diseases, pathogens and microbes as well as the allelopathy between the roots and the agrometeorological aspects of temperature and radiation balance. This was not attempted in this project.

The water use data has been used to calculate crop evaporation factors that could be used for irrigation planning. This data set however is insufficient to come to firm conclusions and recommendations. The Soil Water Balance Model (SWB) was run to try to simulate yield and soil water depletion for a vegetable multi-cropping situation.

#### 6.2 Mulch and Cattle Manure Applications

Cattle manure has been used in crop production for many, many years (Nel, Barnard, Steynberg, De Beer, Groeneveld, 1996), however, the effects are usually measured from the perspective of soil fertility and organic matter in the soil. It is well-known that the effects are long lasting and are often not apparent during the year of application. In this project the focus is on water, so fertility aspects have not been addressed. From the long-term trials carried out at the University of Pretoria, it was shown that manure applications can provide sufficient nutrients for crop requirements during most seasons (Nel *et al*, 1996). It has also been shown that application of manure significantly increased plant available water capacity of sandy loam soils

(Salter and Haworth, 1961). However, increased fertility status usually promotes better crop growth and so water use would also increase (Affholder, 1995, Vos and Sumarni, 1997). This would then form a feedback loop so that effectively soil water depletion may be greater with the application of manure.

The use of mulches is not as common as the use of manure, however mulch can affect a number of processes in a cropping system. A mulch is any shallow layer at the interface of soil and atmosphere with properties that are different from the original soil surface layer (Stigter, 1984). Tilander and Bonzi (1997) list the effects of a mulch on crop production in the semi-arid tropics. Mulching results in the conservation of soil water (Bristow & Horton, 1996; Gajri, Arora and Chaudhary, 1994). Mulch limits the radiant energy available and so decreases evaporation from the soil surface. Furthermore, mulch also presents a physical barrier to water vapour movement from the soil surface into the atmosphere. Mulch decreases soil surface temperature (Varadau and Rao, 1983), as a result of changes in the energy balance at the soil surface, including changes in the radiation balance, and transfer of heat to and from the boundary layer. These effects of mulch on conservation of soil water may be confounded by increased interception of rain and increased infiltration or decrease runoff due to the presence of the mulch (Tilander and Bonzi, 1997; Abrecht and Bristow, 1996). All these factors benefit the crop via the increased root growth and higher plant available water content. The effects of mulches relating to the soil fertility include the ability to trap nutrients in the form of dust and increased microbial activity due to more favorable environmental conditions. This promotes increased recycling of nutrients from mulch or crop residues by decomposition. These beneficial effects should be considered in any long-term scheme of the use of mulching in a crop production system.

The reported response of crop yield to mulches varies widely reflecting the combination of effects of various factors (Tilander and Bonzi, 1997). In many of the studies with mulches all factors mentioned above are not measured or discussed (Shock, Hobson, Seddigh, Shock, Stieber and Saunders, 1997). Therefore many times

the effect of the mulch on crop yield or water use cannot be conclusively attributed to any one mechanism. Tilander and Bonzi (1997) report a range of sorghum yields for various different mulch treatments. These variations could not be correlated with soil water content or soil temperature or a combination of both. Cogle, Rao, Yule, George, Srinivasan, Smith and Jangawad (1997) suggested that increased maize and sorghum yields on mulch treatment plots were due to changes in soil water availability, although they did not measure soil water contents. Gajri, Gill, Chaudhary and Singh (1997) showed that sunflower yields were significantly increased under mulch treatments and depleted the soil water following the development of extensive root systems. Gill, Gajri, Chaudhary and Singh (1996) showed that mulch improved rooting and resulted in increased maize yields. As crop growth and the water balance are a dynamic system it is difficult to attribute the yield increases to a single factor. It appears that mulch provides for decreased soil surface evaporation which can be perceived as water conservation. However, this water is then used by the crop which develops a larger canopy and better root system. The result may be similar to what was observed for sorghum grown in the Sahel. The final soil water content of mulch treated soil was lower and cumulative seasonal crop water use was greater than the control plots, as the 'conserved' water has been transpired by the crop (Zaongo, Wendt, Lascano and Juo, 1997).

Lascano, Baumhardt, Hicks and Heilman (1994) postulated that mulching changes the partitioning of water between transpiration and soil surface evaporation without a change in total seasonal water use of the crop. They compared evaporation from the crop and soil for a conventional tillage and one mulched with wheat stubble. Under conventional tillage, crop and soil evaporation are almost equal, but with wheat stubble crop evaporation increases and soil evaporation decreases. The total measured seasonal evapotranspiration was, however, not effected by mulch, since this is limited by the amount of radiant energy available for evaporation (Lascano *et al*, 1994). The consequence of this shift in water use to be transpired rather than evaporated, is that the seasonal evapotranspiration water use efficiency was 37 % higher under the wheat-stubble treatments.

The data from the field experiment show similar trends, that total evapotranspiration of crops with manure or mulch is similar to that of a no mulch crop. However, as no attempt was made to separate the evapotranspiration components during this experiment, it is not possible to comment further on this aspect. The water use efficiency graph does indicate a slight trend to a higher value and this could be for the reason described above.

### **6.3 Calculation of Water Use to $ET_0$ Ratio**

The weather data was used to calculate the Penman-Monteith potential evapotranspiration  $ET_0$  (Fig. 6.1a & b) (Allen, Pereira, Raes and Smith, FAO, 1996). The  $ET_0$  is summed for the daily periods between the neutron probe readings. These potential evapotranspiration values were then used together with neutron moisture meter readings of water use to calculate the field measured crop factors (Green, 1985; Doorenbos & Pruitt, 1992).

There are no statistically significant differences in calculated crop factors for the different cultivation or irrigation treatments. In some cases intervals used are too long to be useful. As the neutron probe readings were not made both before and after irrigation, measured water use is not as accurate as it could have been, therefore it is difficult to calculate crop factors accurately.

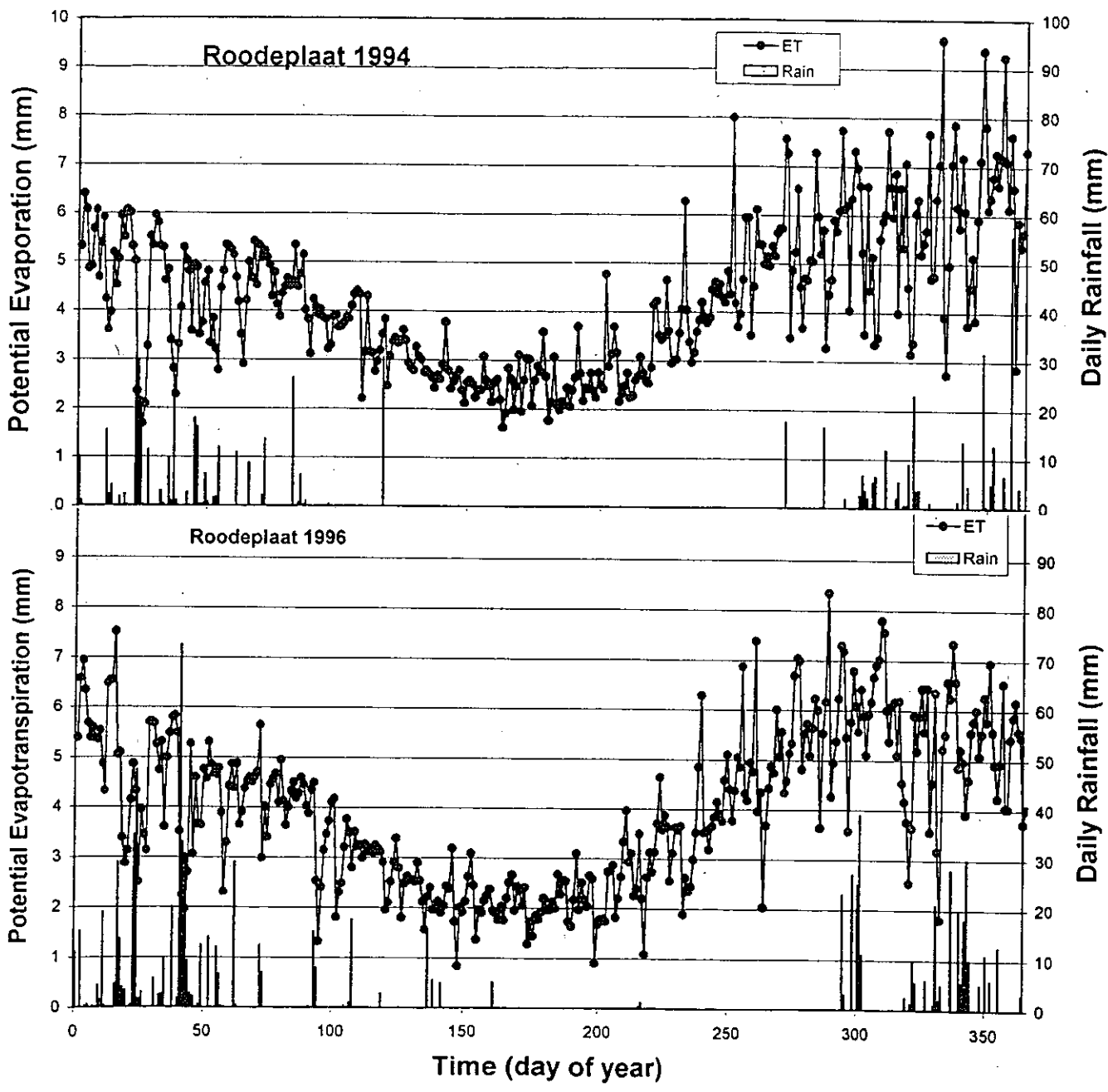


Fig. 6.1(a) Penman-Monteith potential evaporation for Roodeplaai for 1994 & 1996.

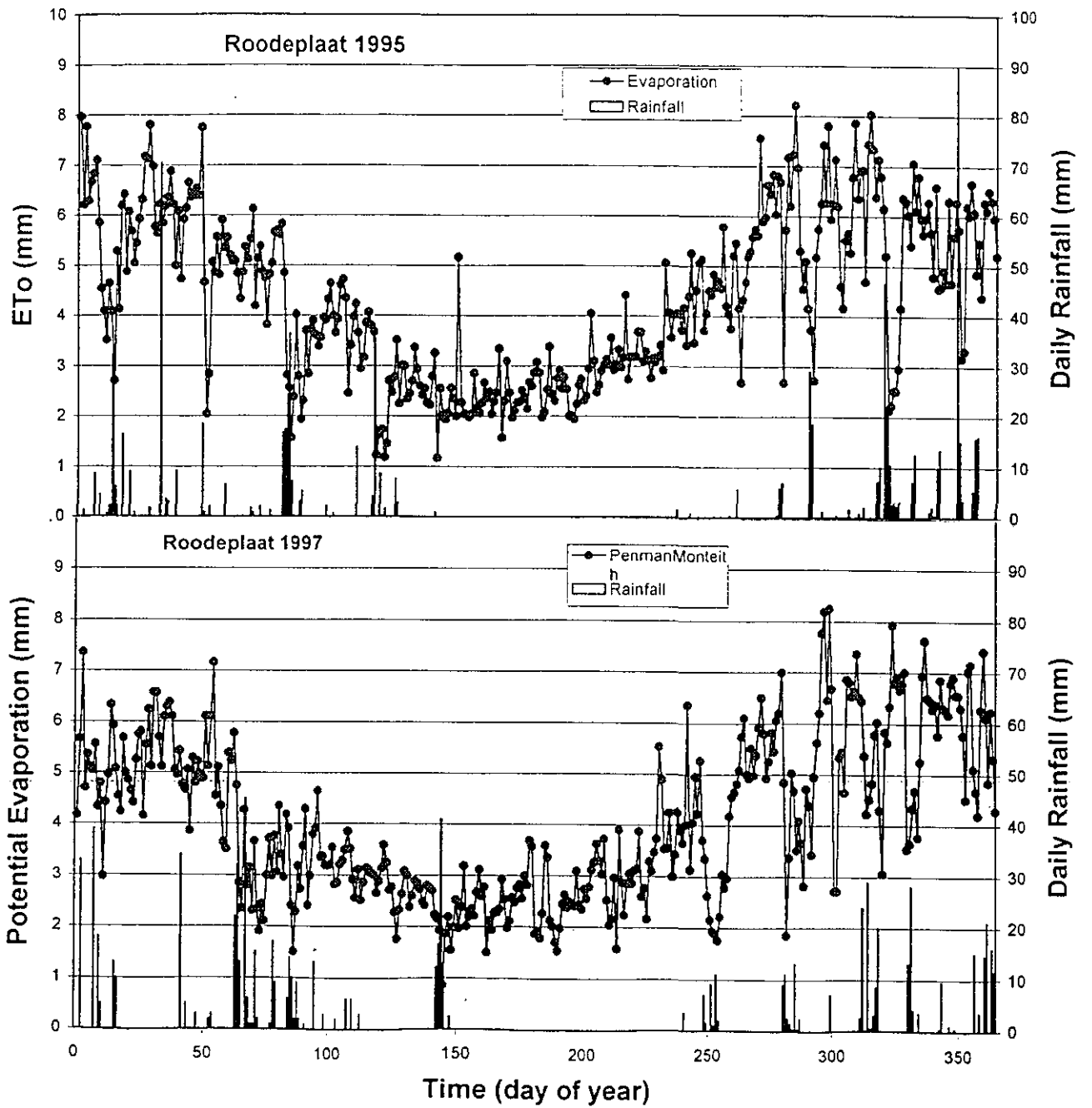


Fig. 6.1(b) Penman-Monteith potential evaporation for Roodeplaat for 1995 & 1997.

During the summer of 1996/97, the increase in crop factor during the development phase is clearly seen from zero to above one (Fig. 6.2). However, these values show little differences between the irrigation treatments or the cultivation treatments. The crop factor remains low (near zero) till 20 days after transplanting. The increase is then rapid to a maximum after 45 days. All treatments have achieved a value greater than 1.0 by 40 days after planting. For the no mulch treatments the 1.0 level is reached slightly earlier by 35 days after planting. Manure treatments and mulch treatments are similar and the 1.0 level is reached a week later. The curves are rather confounded due to the frequent irrigation and rainstorms and only weekly soil water content measurements, particularly in the later part of the season.

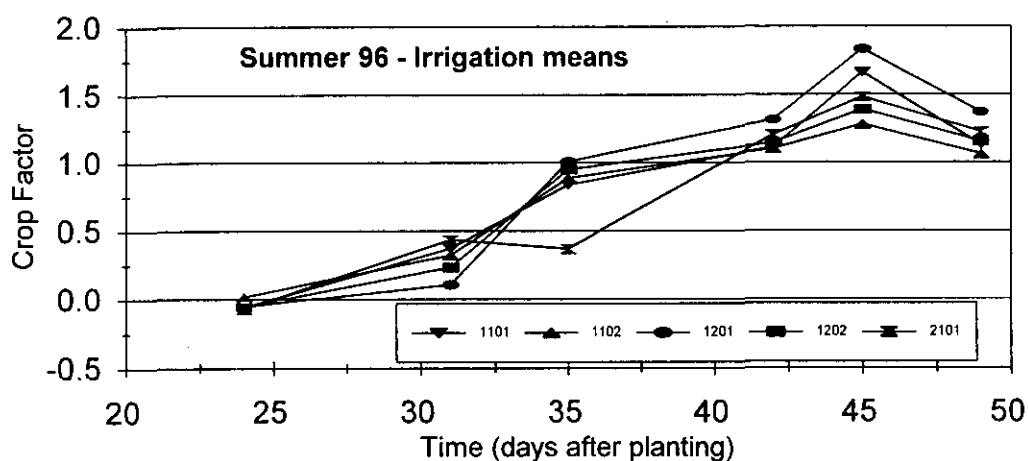


Fig. 6.2 (a) Calculated mean crop factors for the irrigation treatments for the early part of the summer 1996/97 season.

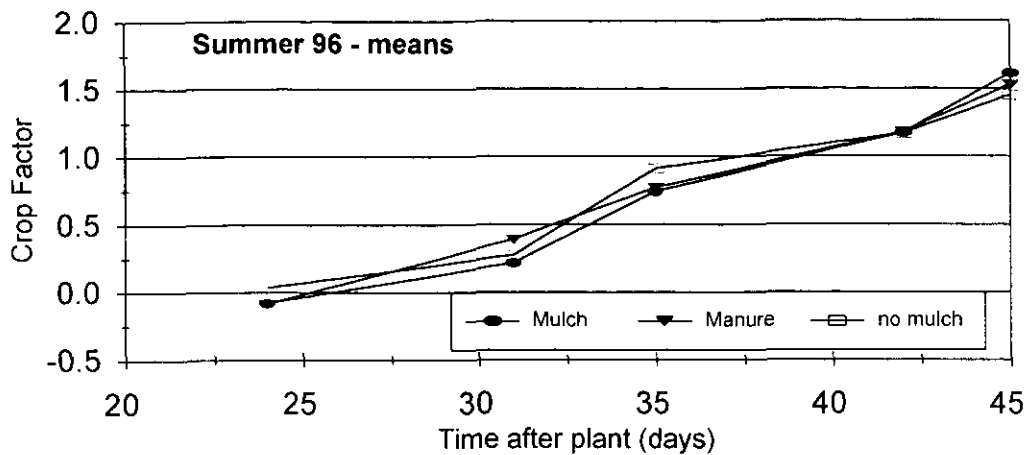


Fig. 6.2 (b) Calculated mean crop factors for the cultivation treatments for the early part of the summer 1996/97 season.

From the winter 96 data it appears that the no mulch crop factor is also slightly higher than the mulch during the earlier part of the season (Fig. 6.3). However, there were no trends visible for the rest of the growing season, as the crop factor remains lower than 0.8 except after irrigation events. When irrigation treatments were combined according to the frequency of water application, fortnightly irrigation treatments consistently show a lower crop factor (0.3) on alternative weeks when not receiving water. Throughout the winter season crop factors remained less than one. This indicates that there could be large savings of water during these winter vegetable crops.

Neither the summer growing season, nor the winter growing season, gave crop factors or periods similar to SWB recommendations (Table 6.1). During the mid-season winter the crop factors were consistently lower than 1.0. During the summer growing season the development period when the crop factor changed from 0 to 1.0 was relatively short, namely less than 20 days. If one is to use the FAO system to obtain a crop factor then one would have to adapt them accordingly. For most vegetable crops used, the development period is normally 60 - 70 days. This data set shows that for summer 1996 the crop factor was at 1.0 after 20 days, giving a much shorter

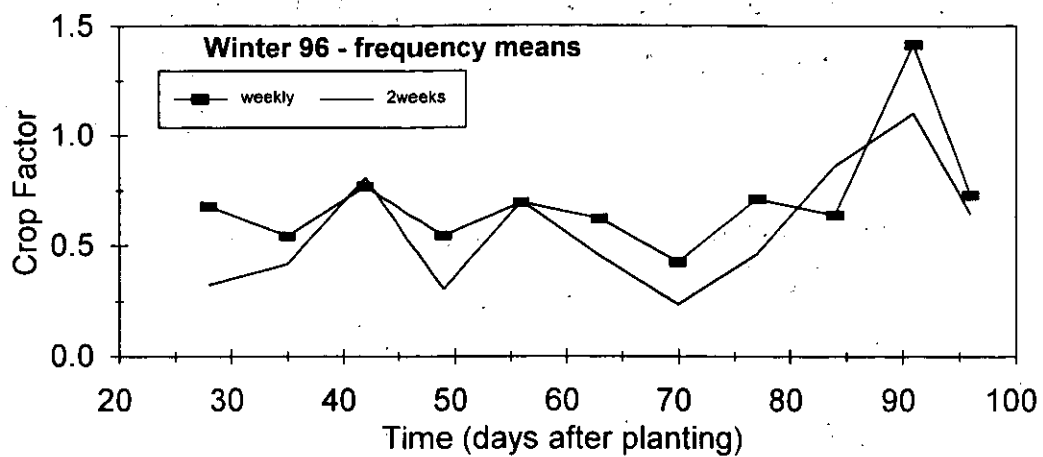


Fig. 6.3 (a) Calculated crop factors for winter 1996 showing the means for the weekly and two weekly irrigation treatments.

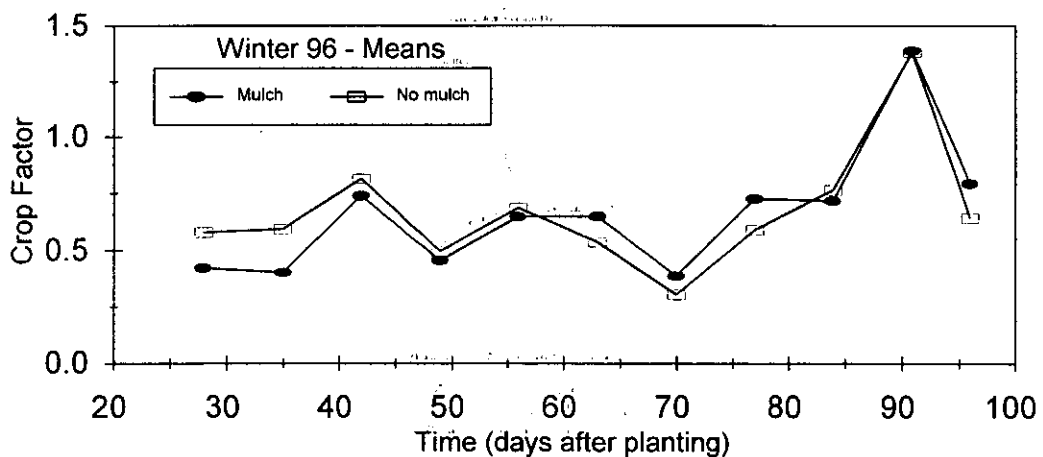


Fig. 6.3 (b) Calculated crop factors for winter 1996 showing the means for the mulch and bear soil treatments

development period Therefore use of the FAO crop factors would have resulted in an underestimation of crop water use. A further difficulty lies in the fact that in subtropical Africa the same crops are grown in both summer and winter seasons.

However, the length of the development phase is different in the two seasons and this project shows that the maximum crop factor attained was also different. Therefore the use of thermal time as control of the development would be more useful and successful.

**Table 6.1 “FAO crop parameters” for each crop calculated by SWB model**

Parameter	Crop	Initial	Development	Mid-season	Late season	Total length
Period (days)	Beetroot	26	79	50	5	160
	Cabbage	5	62	97	1	165
	Cowpeas	20	30	60	25	135
	Swiss Chard	36	73	50	1	160
	Tomato	30	40	45	30	145
	BCSinter	14	45	56	3	118
Crop factor	Beetroot	0.13		1.18	1.04	
	Cabbage	0.13		1.22	1.22	
	Cowpeas	0.15		1.1	0.3	
	Swiss Chard	0.13		1.21	1.21	
	Tomato	0.15		1.15	0.55	
	BCSinter	0.13		1.2	1.2	

#### 6.4 Application of SWB Model

The Soil Water Balance SWB model (Benadé, Annandale & Van Zyl, 1995) was used to simulate the soil water balance of experimental plots. Prior to running the model, certain decisions must be made about which mode or modules to use for this particular application.

##### 6.4.1 Methods section

An attempt was made to adjust the FAO crop parameters according to the actual measured season length for each crop (Table 6.1). However, as the one crop Swiss Chard is grown during both summer and winter seasons, it really would be preferable to have a thermal time in degree days to control the switches between the different crop growth stages. Despite having this limitation it was decided to use the FAO #24 approach to crop parameters (Doorenbos & Pruitt, 1992), because the task of creating a crop factor file for the growth model to simulate the inter-cropping combination of crops would be very difficult, as all the necessary detailed data was not collected from the field experiment.

Therefore, the SWB-FAO model was used throughout the results presented below. The existing crop parameter files in SWB-FAO for the different crops were used. (The cabbage variety, Grand Slam was selected despite actually using Drum Head in the field experiment). A crop factor file (BCSinter) was built for the inter-cropping combination of crops for the winter season. This was done in consultation with the developers of the model at the University of Pretoria. The main factor that was taken into consideration was the actual length of the growing season. The values for the various stages were adjusted in the same proportions as the existing values for a particular crop, so actual measured length of the season was used to adjust the various periods. The highest crop factor from the three crops growing at any one time was used for each phase to represent the combined value. Effectively, winter 1996 data was used to create the BCSinter crop parameter file. The extreme irrigation treatments were used in the simulation runs, namely the largest amount of irrigation applied being 20 mm every week (1201) and the smallest amount of irrigation water applied being 10 mm every second week (1102). The profile available water capacity was set to 396 mm as the upper limit or field capacity. This was also equivalent to 0.22 volumetric water content at the upper limit and 0.10 as the permanent wilting point. The actual measured value of the initial soil water content from the field experiment was used as an input for each specific treatment to adjust the simulated water content on the date the measurement was taken in the field.

The standard statistics and graphs as generated from SWB were used for the analysis. The water use data was loaded into the SWB model following the necessary calibration, and the model was run for 3 seasons, namely winter 1996, summer 1996/97 and winter 1997.

#### **6.4.2 Crop parameter files**

One of the difficulties encountered in using SWB was to correctly adjust the FAO crop parameter file for each specific cultivar. In the case of Swiss Chard, the actual cultivar that was used in these experiments had been calibrated in detail by the model

developers. It will be shown that this is probably the reason that the Swiss Chard gave the best simulation results. The crop parameter file that was constructed as a combination of the various individual crops for use with the multi-cropping plots, did not perform well in the simulations. It appears that the lack of the correct cultivar crop parameter files is a stumbling block to the wider application of SWB. Although this aspect has already received attention (Annandale *et al.*, 1996), it appears that the 1998 version was still not sufficiently versatile for a general user.

#### **6.4.3 Simulation of mulch treatments**

An attempt was made to simulate water use by the treatments with a mulch layer placed on top of the soil between the crop rows. The model uses the top soil layer between 0 and 15 cm to simulate the soil surface evaporation component of evapotranspiration, as there are no roots extracting water from this layer. In an attempt to simulate the effect of the mulch, the model was run with a shallower first soil layer, namely 0 - 5 cm to limit the soil surface evaporation. However, it appears that this does not give a significant difference in water use from other layers. This needs to be seen in the light of the discussion of the actual field soil water depletion data – discussed in the next section of this chapter.

#### **6.4.4 Soil water deficit simulation**

In general, across all crops and all three seasons, the fortnightly irrigation of 10 mm (1102) was simulated better by SWB than the weekly irrigation of 20 mm (1201). It appears therefore that the drier situation is simulated better by SWB than the treatments receiving a large amount of applied water. There is not sufficient data or detailed analysis done to be able to speculate about the reasons for these discrepancies. During winter 1997, additional plots with only a single crop were also monitored for Swiss Chard and cabbage. The single crop plot of Swiss Chard gave the best simulation of water use during winter 1997 (Fig. 6.4). The fortnightly irrigation (S1102) obtained a Wilmot D-value of 0.93 compared to 0.72 for the weekly irrigation treatment (S1201) for measured versus simulated water deficit in the soil

profile (Table 6.2). As already indicated the Swiss Chard genetic file was formulated at Roodeplaat with the same cultivar as used in this experiment.

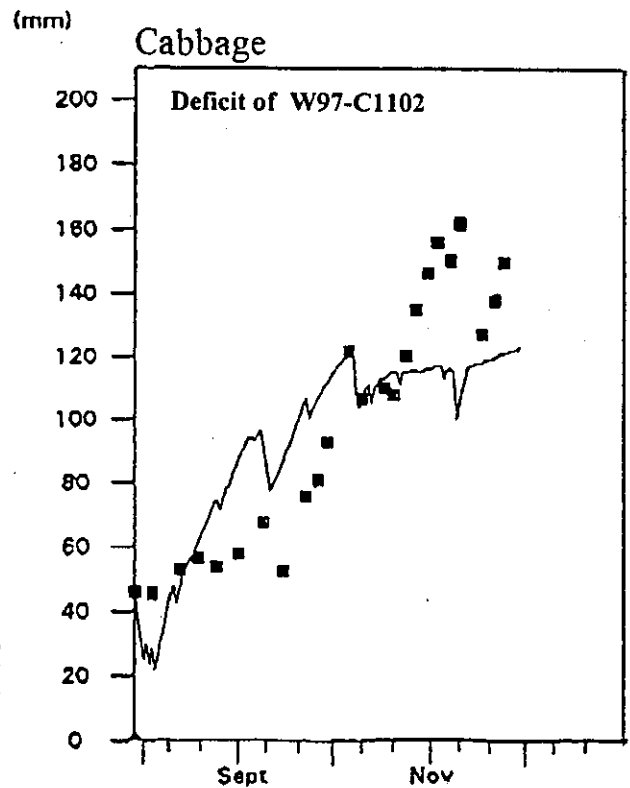
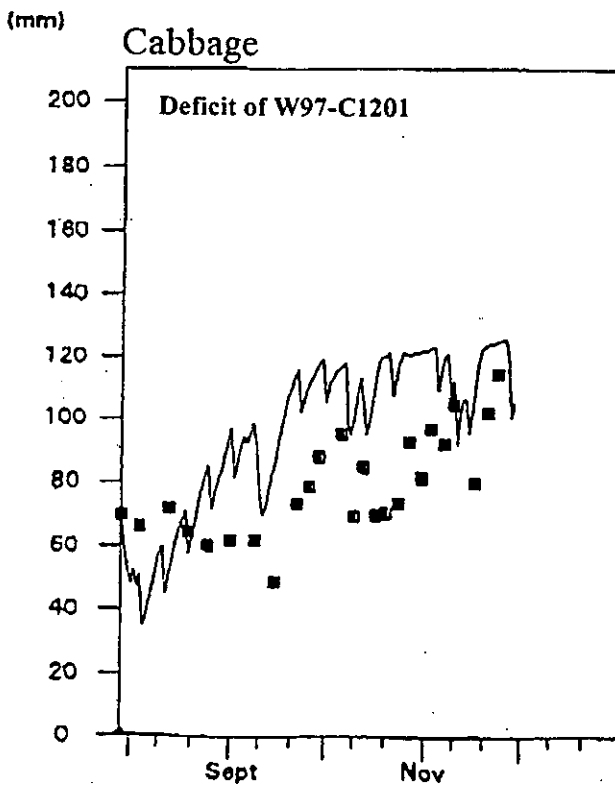
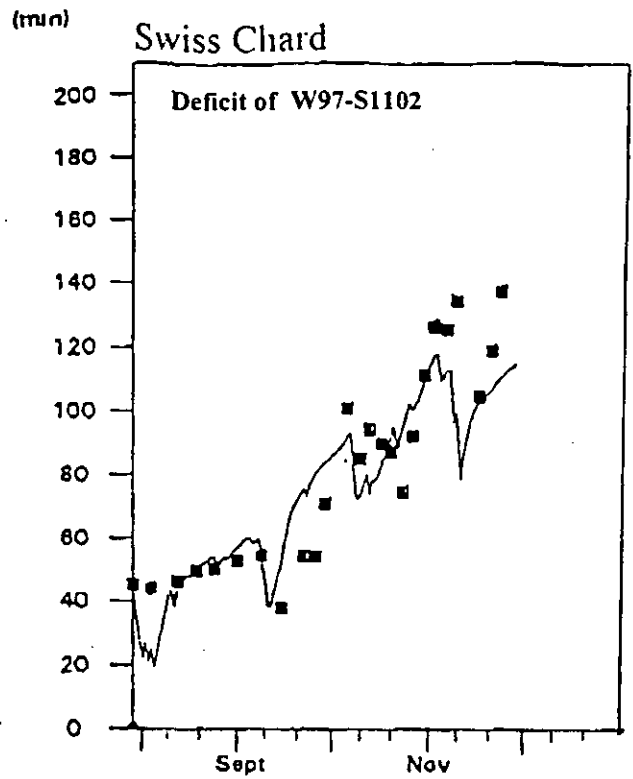
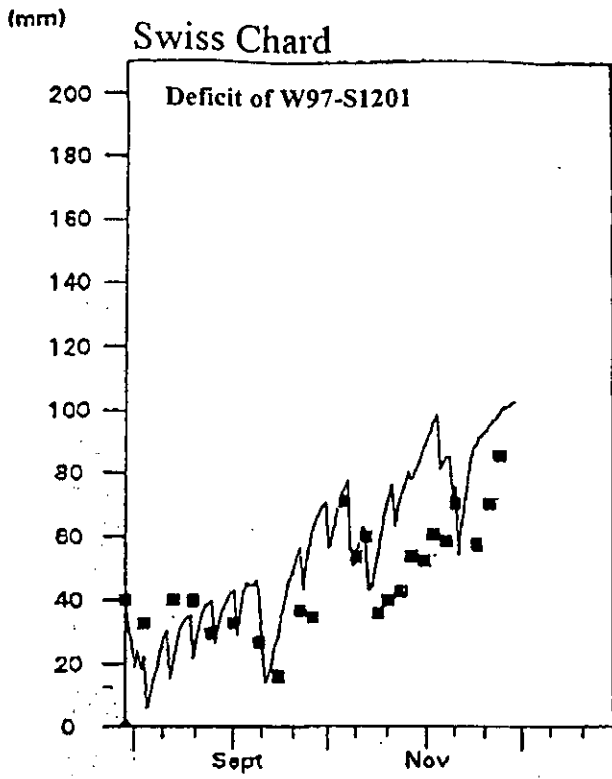


Fig. 6.4 The comparison of the simulated versus measured soil water deficit for the whole profile for winter 1997 for the single crop plots of cabbage and Swiss chard.

It would therefore be expected to perform excellently under those circumstances. The mono-crop of cabbage also showed good results for the fortnightly irrigation with a D-value of 0.81 (C1102) for measured versus simulated water deficit in the soil profile during the season (Table 6.2).

**Table 6.2. Statistical results from SWB simulations for the end of season soil water deficit.**

Winter96	Swiss Chard		Intercropping		Beetroot		Cabbage	
	1102	1201	1102	1201	1102	1201	1102	1201
D	0.9	0.49	0.73	0.42	0.86	0.44	0.67	0.33
RMSE	15.2	34.8	27.9	41.4	18.6	39	35.4	52.5
MAE %	15	59	28	69	20	66	37	90
% Yield Reduction	16	14	37	28	18	16	27	22
Summer 96/97	Swiss Chard		Intercropping		Tomato		Cowpeas	
	1102	1201	1102	1201	1102	1201	1102	1201
D	.85	.52	*		.88	.47	.79	.37
RMSE	17.7	26.3	*		21.7	38.6	32.4	45.4
MAE %	17	50			22	69	36	87
% Yield Reduction	29	17			65	32	17	4
Winter97	Swiss Chard		Intercropping		Beetroot		Cabbage	
	1102	1201	1102	1201	1102	1201	1102	1201
D	.93	.52	.8	.29	.92	.48	.78	.35
RMSE	13.4	27.6	25.2	43.9	15	31.1	26.8	43.4
MAE %	14	39	25	68	15	45	27	65
% Yield Reduction	24	16	60	28	25	17	29	23
Winter 97	S1102	S1201					C1102	C1201
D	.93	.72					.8	.57
RMSE	15	23.8					28.7	31.1
MAE %	14	40					23	36
% Yield Reduction	24	16					29	30

\*the inter-cropping crop parameter file was not created, because there was not another summer season with which to test it

For the multi-cropping plots for fortnightly irrigation the use of the Swiss Chard crop parameter file gave the best result ( $D = 0.93$ ), compared to the BCSinter giving 0.83 and beetroot 0.92 and cabbage 0.78 (Table 6.2) for soil water deficits. Again it is evident that the model performed well on these treatments receiving fortnightly irrigation (Fig. 6.6).

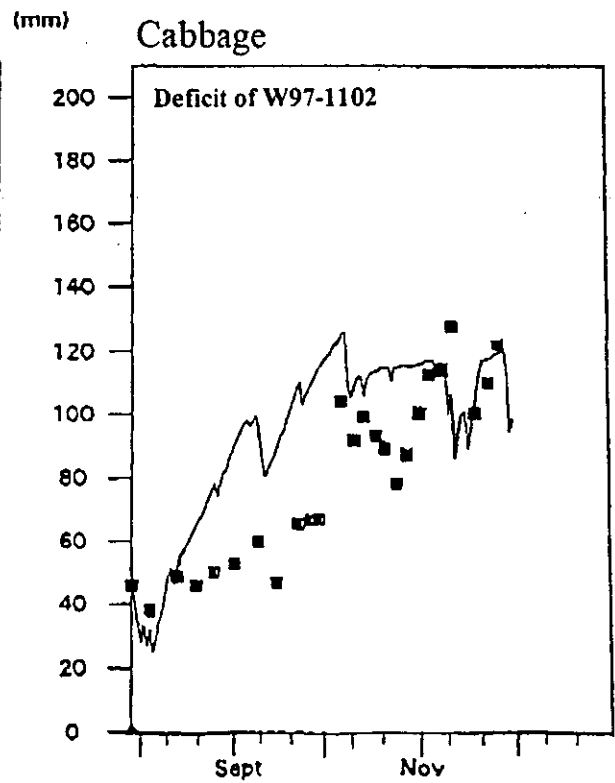
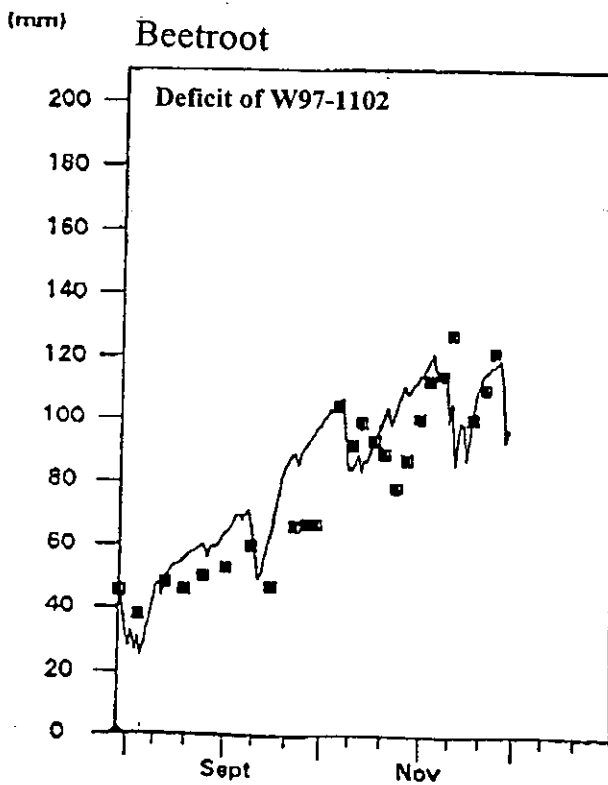
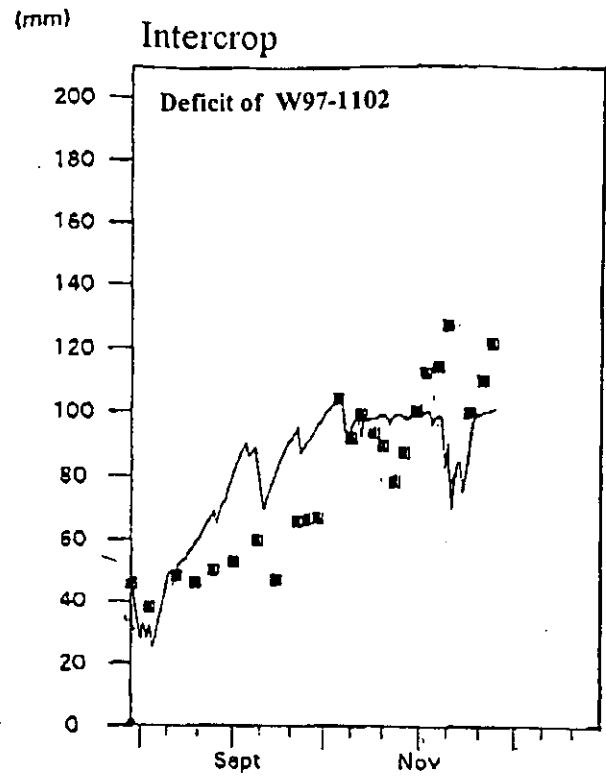
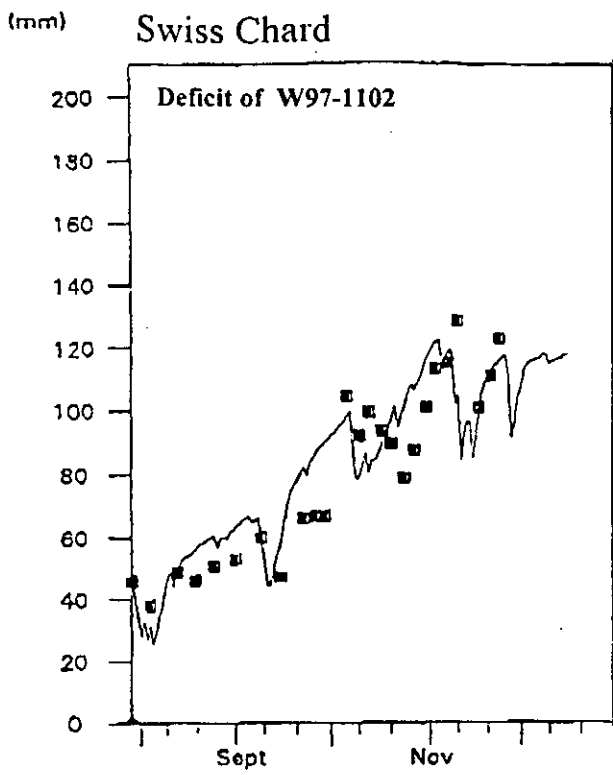


Fig. 6.5 The comparison of the simulated versus measured soil water deficit for the whole profile for winter 1997 for 10 mm fortnightly for each of the crops.

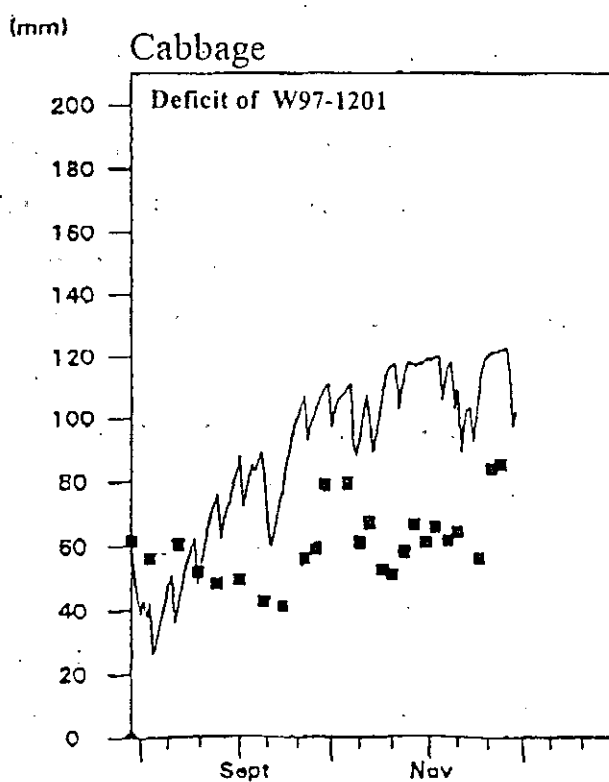
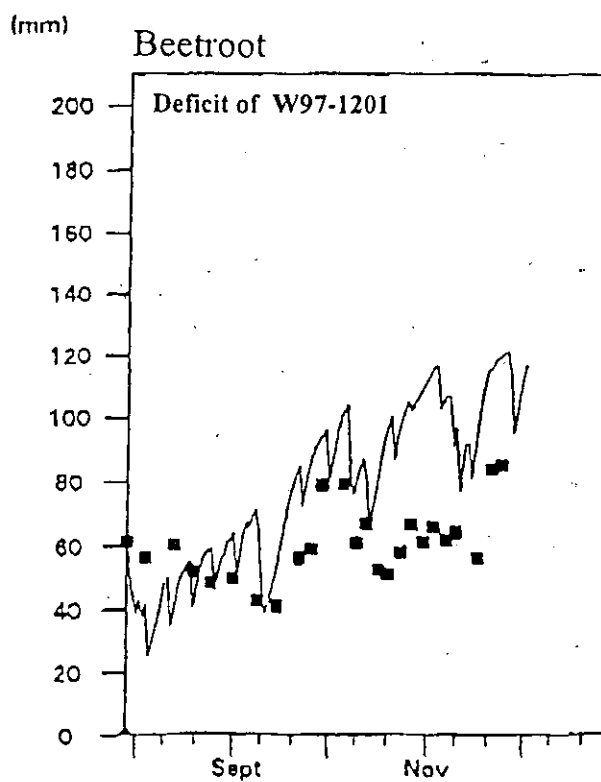
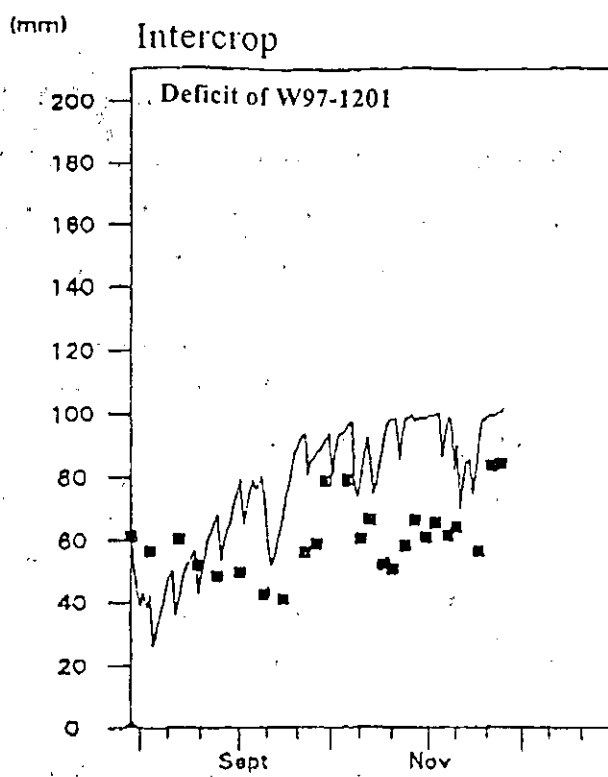
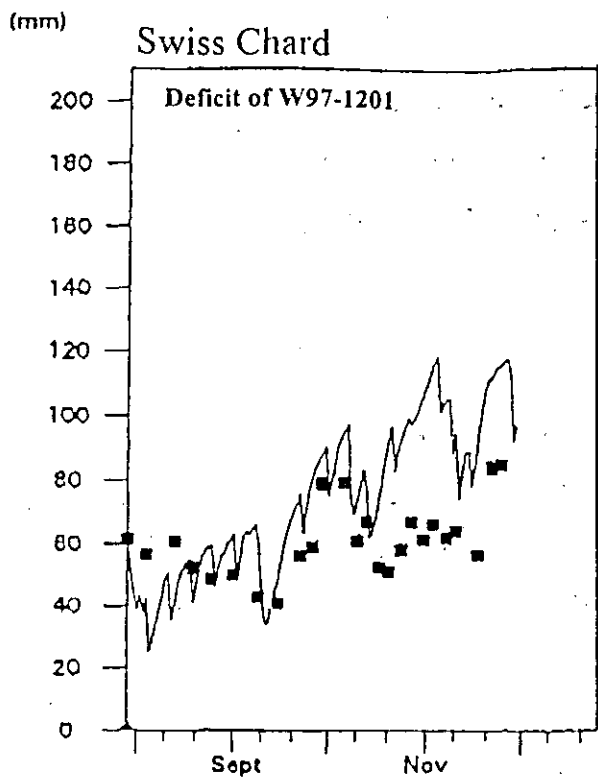


Fig. 6.6 The comparison of the simulated versus measured soil water deficit for the whole profile for winter 1997 for the 20 mm weekly treatment for each of the crops.

However, on the weekly irrigation (1201) the D-values range from 0.35 - 0.52 (Table 6.2) showed much poorer simulation of water use for multi-cropping under adequate water conditions. The Swiss Chard crop parameter file however performed the best under these conditions  $D = 0.52$  (Table 6.2).

The above discussion was mainly based on the results from the winter 1997 season. However, similar results (Table 6.2) were obtained during the two other seasons, (winter 1996 and summer 1996/97). The fortnightly irrigation gave a good result with D-values range from 0.78 to 0.93 over all seasons for the simulation of the soil water deficit. However, the D-values for the weekly irrigation range from 0.35 to 0.52 for the multi-cropping vegetable plots.

#### ***6.4.5 Simulation of water content in the various soil layers***

The water content as measured with the neutron probe in the field was compared with the simulated values from SWB for winter 1996 and winter 1997. As the results are similar in both seasons, only one season will be discussed in detail, although the D-values for both are presented at Table 6.3. In general the measured values are higher than simulated values, which is particularly noticeable during the winter 1996 data set.

The simulations are poor in the upper soil layers and D-values range from 0.20 to 0.61 for the 15 to 30 cm layer and 0.29 to 0.82 for the 0 to 15 cm layer. It is again noticeable that the Swiss Chard crop gives the best correlation between measured and simulated values. Between 30 and 60 cm soil depth, the simulation shows a rapid decline in soil water all the way to the lower limit or permanent wilting point. Measured soil water content values however decline much more slowly and do not dry out so much. So the simulation extracts too much water, too quickly or too soon in the season. The trend is not at all similar and this is shown by the low D-values of 0.1 to 0.71. The exceptions were again the Swiss Chard plots that gave higher D-values 0.74 to 0.86 (Table 6.3). At depths below 75 cm, there is little change in measured soil water content as this appears to be below the root zone. The soil water contents

remain fairly constant during the growing season, and in most cases so does the simulation.

**Table 6.3. D values for soil water content from SWB simulations over various seasons for the various crops at each soil depth (S96/7 = summer 1996/97; W96 = winter 1996; W97 = winter1997).**

Season	Crop	Treatment	0-15 cm	15-30 cm	30-45 cm	45-60 cm	60-75 cm	75-90 cm	90-1.05	1.05-1.2	1.2-1.35	
W96	SwissChard	1102	0.77	0.53	0.86	0.74	0.52	0.39	0.39	0.39	0.46	
	Inter-crop	1102	0.8	0.46	0.7	0.71	0.65	0.46	0.39	0.39	0.46	
	SwissChard	1201	0.29	0.24	0.56	0.69	0.35	0.34	0.44	0.44	0.29	
	Inter-crop	1201	0.38	0.21	0.44	0.52	0.63	0.34	0.44	0.44	0.29	
	Beetroot	1102	0.78	0.52	0.84	0.81	0.66	0.53	0.39	0.39	0.46	
	Beetroot	1201	0.31	0.23	0.53	0.68	0.53	0.33	0.44	0.44	0.42	
	Cabbage	1102	0.82	0.46	0.7	0.66	0.56	0.6	0.68	0.39	0.46	
	Cabbage	1201	0.45	0.21	0.45	0.48	0.53	0.53	0.63	0.45	0.17	
S96/7	Cowpeas	1102	0.6	0.32	0.48	0.57	0.71	0.65	0.55	0.88	0.47	
	Cowpeas	1201	0.44	0.25	0.08	0.29	0.29	0.29	0.26	0.67	0.21	
	Tomato	1102	0.51	0.32	0.51	0.69	0.77	0.67	0.58	0.73	0.32	
	Tomato	1201	0.57	0.25	0.1	0.35	0.31	0.28	0.27	0.65	0.32	
	SwissChard	1102	0.5	0.3	0.55	0.71	0.65	0.57	0.29	0.26	0.22	
	SwissChard	1201	0.66	0.22	0.13	0.32	0.22	0.28	0.32	0.3	0.32	
	W97	SwissChard	S1102	0.53	0.61	0.74	0.85	0.75	0.6	0.42	0.45	0.37
		SwissChard	S1201	0.54	0.31	0.31	0.26	0.4	0.52	0.39	0.38	0.4
Cabbage		C1102	0.44	0.47	0.52	0.7	0.79	0.85	0.55	0.45	0.45	
Cabbage		C1201	0.47	0.27	0.25	0.26	0.26	0.5	0.81	0.45	0.45	
SwissChard		1102	0.51	0.45	0.58	0.77	0.69	0.68	0.45	0.36	0.36	
SwissChard		1201	0.54	0.18	0.18	0.17	0.24	0.44	0.41	0.44	0.44	
Beetroot		1102	0.55	0.44	0.55	0.76	0.73	0.75	0.46	0.36	0.36	
Beetroot		1201	0.57	0.17	0.16	0.2	0.23	0.41	0.48	0.44	0.44	
Cabbage		1102	0.39	0.37	0.46	0.58	0.65	0.73	0.69	0.36	0.36	
Cabbage		1201	0.42	0.18	0.14	0.15	0.24	0.22	0.88	0.44	0.44	
	Inter-crop	1102	0.33	0.38	0.49	0.61	0.63	0.69	0.78	0.36	0.36	
	Inter-crop	1201	0.38	0.2	0.16	0.17	0.25	0.19	0.85	0.42	0.42	

The simulations are poor in the upper soil layers and D-values range from 0.20 to 0.61 for the 15 to 30 cm layer and 0.29 to 0.82 for the 0 to 15 cm layer. It is again noticeable that the Swiss Chard crop gives the best correlation between measured and simulated values. Between 30 and 60 cm soil depth, the simulation shows a rapid decline in soil water all the way to the lower limit or permanent wilting point. Measured soil water content values however decline much more slowly and do not dry out so much. So the simulation extracts too much water, too quickly or too soon in the season. The trend is not at all similar and this is shown by the low D-values of 0.1 to 0.71. The exceptions were again the Swiss Chard plots that gave higher D-values

0.74 to 0.86 (Table 6.3). At depths below 75 cm, there is little change in measured soil water content as this appears to be below the root zone. The soil water contents remain fairly constant during the growing season, and in most cases so does the simulation.

This was the first attempt at simulating a multi-cropping situation using SWB. In general the soil water content simulations were poor even though the same soil parameter file was used as used by regular users of the model at Roodeplaat. Further calibration and testing would be necessary before the model could be used with any confidence for multi-cropping systems. If a SWB crop parameter file was developed for an intercrop for the model then an improved simulation could be expected.

## **6.5 Conclusion**

The crop factors calculated from the ratio of water use to potential evapotranspiration show little differences between experimental treatments in the summer. In the winter there were slight differences during the first 35 days after transplanting, with the no mulch being higher than the mulch treatment and the weekly irrigation being higher than the two weekly irrigation applications. Therefore, if the irrigation interval is lengthened to 2 weeks, the crop factors can be slightly reduced during the initial growth stages.

As the Swiss Chard was grown during both winter and summer seasons, there needs to be an adjustment in the length of the initial and development growth stages. It would appear to be better to use a thermal time method to accumulate heat units during the season than a fixed time period. When the calculated crop factors were considered, it appears that during winter at Roodeplaat a value of between 0.5 and 0.7 would be adequate for the whole season. This could result in a substantial saving of irrigation water and other associated expenses.

As the summers are warm, the initial growth rate is steep and the calculated crop factor reached a value of 1.0 within 40 days after transplanting. This is only 55 % of

the length of the development phase recommended by FAO. This would have to be taken into serious consideration when planning the irrigation as the crop was at a full canopy situation earlier than predicted.

The calculated crop factors show us differences between the conventional and mulch or cattle manure treatments. From the literature it appears that more detailed measurements are needed to divide the evapotranspiration between the soil surface evaporation and crop transpiration components. This entails difficult methodology and could not have been part of a general experiment such as this. Further detailed experiments are necessary to monitor the detailed radiation and water balance, crop growth and development together with the microbial activity under mulch conditions.

The SWB model provided good simulations for the Swiss Chard crop which had already been calibrated in detail at Roodeplaat. However, the simulation of other crops was not as good. The fortnightly irrigation gave better simulation results than the weekly irrigation intervals. When the Swiss Chard crop parameter file was used for the intercropping plots, a reasonable simulation resulted, probably due to the fact that the Swiss Chard dominated the three crops with a large leaf area. It appears that further cultivar specific field measurements were needed to ensure the correct crop parameter file as an input into the SWB model.

In general it can be concluded that the crop factor for the dominant crop can be used for the calculation of water use of an intercropping field. Care must be taken to ensure the correct time periods for the different growth stages of the various crops before applying the FAO crop factors. These time periods will vary according to the planting dates and seasons in which the crop is planted.

## Chapter 7

### CONCLUSIONS AND RECOMMENDATIONS

This project has further contributed towards the application of Farming Systems Research and Extension (FSRE) methodology in the previously disadvantaged farm communities in South Africa. The application of FSRE methodology must follow a process and largely be driven by the farm community themselves. If this project is assessed from a traditional research viewpoint it may appear not to have achieved the goals, but if assessed from the viewpoint of FSRE, progress has been made in applied research, on-farm trials with community involvement as well as much capacity building for both researchers and extension personnel.

The first phase of FSRE is the diagnostic phase. The "felt needs" were identified using the Participatory Rural Appraisal (PRA) methods at two irrigation schemes namely Hoxane and Olifants-Arabie. This form of investigation enabled the local farmers to participate and make a contribution, despite being illiterate. During the transition phase in South Africa, it is most important to maintain transparency and this was achieved. The PRA techniques worked well in small groups and many of the farmers were able to make a contribution to the task at hand. This form of capacity building promoted ownership of the ideas generated and of subsequent projects that were implemented.

The PRA training that was provided during these exercises benefited the NPDA extension staff in the particular area. The recommendation is that these participatory techniques be used during project development for identification and characterization of the natural resources. These methods can also be used in the context of project or trial evaluation. Some carefully planned tasks can be carried out to identify the needs and highlight the possible options to address them.

In the on-farm trials various technologies were investigated. The range of treatments was limited due to time and financial constraints. However, potential solutions were

identified from the local knowledge base where aspects other than applied agricultural science are of importance. The use of qualitative research methods by pure agricultural scientists was a broadening of the project team's outlook and experiences. The aspects that are vital include the methods used for farmer selection. Care must be taken to consult all role-players and to include them in pre-trial planning.

It is difficult to assess the benefit of the on-farm trials to the farming community at New Forest Irrigation Scheme. The current circumstances of the participating farmers can be seen. Despite the results not being conclusive, the capacity building given to the extension workers and to leaders of the farmer community was noteworthy. Many of the extension staff were enthusiastic to be a part of the on-farm trials and they have had good hands-on experience in managing on-farm trials. The impact it has had on the farming community at New Forest should be investigated. The presence of the WRC project at the grassroots level is good for the overall local image of the Department of Water Affairs and Forestry. It is recommended that these farm communities and the Department of Agriculture must continue to be involved with the ARC researchers and WRC funded projects. The commitment to the project by all involved was good to see and contributed to its success.

The on-station experiments have made a valuable contribution to the yield production functions for vegetables grown under a multi-cropping system. As organic methods become more commonly used, this information will be needed by the farmers and the irrigation planners. Although, the statistical analysis showed that there were little or no significant differences (because of the small range of yield production values), the result is still valid. The non-significant result actually shows that these treatments are not making any major contribution to the crop yield, under adequate irrigation. These trials would need to be conducted over an extended time period, so that the long-term effect of the cattle manure can be monitored.

The crop irrigated with 20 mm on a weekly interval used more water than the other irrigation schedules, but still produced the same biomass yield. So under the Roodeplaat winter conditions of a deep irrigation soil, it proved unnecessary to apply

so much water as 10 mm applied at a weekly interval was sufficient. When the fortnightly interval is considered, the 10 mm treatment produced equivalent yields to the 20 mm treatment when the soil profile was full at the beginning of the season. Although the water use efficiencies are similar across treatments, the trend appears to be that the application rate of 10 mm gives high WUE for lower seasonal water use values.

The experiment showed that similar vegetable yields were obtained with lower water application rates (10 mm versus 20 mm) and longer irrigation intervals, (2 weeks versus 1 week). This information can be applied during irrigation design and planning. The irrigation scheduling management strategy can be altered so as to increase the area of land irrigated with a certain amount of water and possibly reduce the capital outlay for irrigation equipment. This would be of particular interest to farmers irrigating from boreholes and those with high pumping costs.

The water requirements of small plot multi-cropping of vegetables for winter and summer seasons were compared. The water production functions for these various vegetable crops will contribute to a more balanced planning of water requirements in community gardens or small irrigation schemes supplied by borehole water. These values can be used to calculate the size of land that can be irrigated from a borehole which would be drilled for a community garden development project.

Recommendations flowing out of the on-farm trials include the following:

- A pilot project of at least one year should initially be funded to establish the community needs using participatory techniques and the viability of on-farm trials at a specific location.
- The farmer selection needs much care and attention to ensure good successful cooperation and technology transfer.
- Partnerships between researchers and extension personnel need to be supported at all levels in the structures of both organisations.
- Sufficient funds need to be available to provide for adequate communication and transportation between the on-farm site and the homebase.

- The objectives of the on-farm trials, as agreed upon by all roleplayers need to be used as a basis for the on-station trials where the scientific basis of the mechanisms can be studied.
- The combination of qualitative and quantitative research in a single project needs to be carefully balanced and assessed according to the standards of each type of research.

Recommendations from the on-station multi-cropping vegetable trials include the following:

- Different crop factors are recommended for a specific crop if grown in winter and summer seasons at the same location.
- Within the range of good yields, further addition of irrigation water may provide little or no effect on the vegetable yield.
- Longer time intervals between irrigation applications will not necessarily reduce the yield, particularly with winter or spring plantings.
- The use of a mulch ground covering or incorporation of cattle manure does not change the total seasonal water use of vegetable crops.
- The crop factor of the dominant crop (highest leaf area) can be used to represent the vegetable inter-cropping situation.
- Further detailed studies of the radiation and water balance of mulches and inter-cropping are needed together with a multidisciplinary team to investigate the microbial activity.

In general the benefits of this project were far reaching as they not only effected the researchers but also NPDA extension personnel and small-scale farmers at Hoxane, Olifants-Arabie and New Forest Irrigation Schemes.

The project enabled researchers from several ARC research institutes, namely, Institute for Soil, Climate and Water; Institute for Grain Crops; Plant Protection Research Institute; Roodeplaat Vegetable and Ornamental Institute; the Institute for Tropical and Sub-tropical Crops and the Institute for Tobacco and Cotton to work together as a team. It provided an opportunity for exposure of researchers to work on

cooperative projects with each other and small-scale farmers at the irrigation schemes. There was much capacity building taking place during this project and the transformation of the ARC from being focused on commercial farmers to working with the previously disadvantaged small-scale farmers. As can be seen from the list of team members, the project provided an opportunity for four black researchers and two black technicians to receive training and experience in FSRE methods. Nine extension personnel were also involved in the operation of the on-farm field experiments. For many of these it was the first exposure to cooperative projects with agricultural researchers. The on-farm trials also exposed at least ten small-scale farmers to the experience of a cooperative FSRE research project. Many more farmers on all three irrigation schemes received training on a continuous basis over the period of the project at the monthly training sessions. The farmers days held each cropping season were also attended by the local government officials and farmers (up to 300) from the surrounding area. Therefore, the effect of this project was to provide a technology transfer opportunity for many, many people, on both the providing and receiving sides.

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## Appendices

Appendix 1 Soil analysis for on-farm trials at New Forest Irrigation Scheme 1997 and for each treatment in each of the farmers fields.

### Mr Harry Mdluli

Treat	Lab No	Dept h	P mg/kg	K mg/kg	Ca Mg/kg	Mg mg/kg	pH Water	T/acidity cmol(+)/kg	% SV	R ohms
Kraal	2991	Top	58.9	661	456	167	7.08	0.00	0.0	600
Kraal	2992	Sub	23.9	368	228	30	5.38	0.20	7.9	900
Mulch	2993	Top	46.7	51	259	33	5.52	0.05	2.9	2300
Mulch	2994	Sub	21.3	356	230	53	6.44	0.00	0.0	2300
Chemical	2995	Top	34.5	95	273	41	5.96	0.00	0.0	2400
Chemical	2996	Sub	31.4	57	227	33	5.81	0.00	0.0	3800
Farmer	2997	Top	41.1	62	225	38	6.07	0.00	0.0	2000
Farmer	2998	Sub	33.0	41	117	29	5.45	0.13	12.3	5700

### Mr W. Phoku

Treat	Lab No	Dept h	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	pH Water	T/Acidity cmol(+)/kg	% SV	R ohms
Kraal	2983	Top	6.8	1049	151	52	7.09	0.00	0.0	450
Kraal	2984	Sub	1.9	691	77	15	5.31	0.26	10.3	4000
Farmer	2985	Top	4.0	56	252	41	6.54	0.00	0.0	3200
Farmer	2986	Sub	1.2	38	188	36	6.32	0.00	0.0	3000
Mulch	2987	Top	5.0	102	456	62	6.67	0.00	0.0	7300
Mulch	2988	Sub	1.7	32	128	20	6.36	0.00	0.0	9800
Chemical	2989	Top	2.2	44	301	37	6.68	0.00	0.0	5500
Chemical	2990	Sub	1.6	42	213	39	6.26	0.00	0.0	7200

Mr T. Mashele

Treat	Lab NoV	Dept h	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	pH Water	T/Acidity cmol(+)/kg	% SV	R ohms
Kraal	2975	Top	95.6	523	1766	510	7.47	0.00	0.0	1400
Kraal	2976	Sub	27.3	386	336	75	7.32	0.00	0.0	3600
Farmer	2977	Top	27.0	91	684	72	6.54	0.00	0.0	5400
Farmer	2978	Sub	18.2	78	435	49	6.97	0.00	0.0	5500
Mulch	2979	Top	23.5	122	626	64	6.44	0.00	0.0	5400
Mulch	2980	Sub	3.6	94	792	74	7.22	0.00	0.0	3800
Chemical	2981	Top	20.0	75	404	60	6.21	0.00	0.0	7000
Chemical	2982	Sub	6.0	90	370	58	6.73	0.00	0.0	5200

Mr E.P. Manzini

Treat	Lab NoV	Dept h	P mg/kg	K Mg/kg	Ca mg/kg	Mg mg/kg	pH Water	T/Acidity cmol(+)/kg	% SV	R ohms
Kraal	2959	Top	55.1	497	1096	347	7.06	0.00	0.0	820
Kraal	2960	Sub	2.4	578	306	62	5.82	0.00	0.0	4400
Mulch	2961	Top	25.2	58	260	49	5.33	0.23	11.1	8100
Mulch	2962	Sub	1.5	51	457	62	5.99	0.00	0.0	6400
Farmer	2963	Top	32.2	74	233	43	5.16	0.42	19.8	6600
Farmer	2964	Sub	1.4	54	456	72	5.18	0.39	11.5	3400
Chemical	2965	Top	32.6	56	362	53	5.53	0.07	2.9	5900
Chemical	2966	Sub	1.4	52	494	67	5.98	0.00	0.0	1200

Mr H. Mxumalo

Treatment	Lab NoV	Sender no	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	pH Water	T/Acidity cmol(+)/kg	% SV	R ohms
Kraal	2952	Top	57.2	904	2556	460	7.60	0.00	0.0	500
Kraal	2953	Sub	2.4	105	2226	110	7.80	0.00	0.0	580
Mulch	2954	Sub	1.5	51	353	84	6.40	0.00	0.0	730
Fertilizer	2955	Top	13.3	80	400	71	6.00	0.00	0.0	6400
Fertilizer	2956	Sub	1.1	25	273	79	6.12	0.00	0.0	9100
Farmer	2957	Top	6.0	93	456	81	6.26	0.00	0.0	5400
Farmer	2958	Sub	2.3	47	426	99	6.16	0.00	0.0	7200

Mr A Nukeri

Treatment	Lab No	Sender no	P mg/kg	K mg/kg	Ca mg/kg	Mg Mg/kg	pH Water	T/Acidity cmol(+)/kg	% SV	R ohms
Kraal	2944	Top	71.0	1784	843	324	8.19	0.00	0.0	360
Kraal	2945	Sub	2.1	431	391	84	5.48	0.12	3.1	630
Farmer	2946	Top	27.0	151	464	104	6.282	0.00	0.0	3300
Farmer	2947	Sub	2.5	52	431	77	6.06	0.00	0.0	5500
Mulch	2948	Top	5.3	89	276	58	5.53	0.09	4.1	6600
Mulch	2949	Sub	1.2	34	458	60	6.02	0.00	0.0	6100
Chemical	2950	Top	6.7	34	635	74	6.47	0.00	0.0	5900
Chemical	2951	Sub	1.1	44	503	82	6.01	0.00	0.0	7100

Mr E Mathebula

Treatment	Lab No	Sender no	P mg/kg	K mg/kg	Ca mg/kg	Mg Mg/kg	PH Water	T/Acidity cmol(+)/kg	% SV	R ohms
Kraal	2967	Top	28.6	1177	422	159	7.64	0.00	0.0	520
Kraal	2968	Sub	1.5	843	409	68	5.60	0.00	0.0	4400
Farmer	2969	Top	16.4	159	403	72	6.26	0.00	0.0	4100
Farmer	2970	Sub	2.3	84	407	71	6.28	0.00	0.0	5100
Mulch	2971	Top	3.9	106	280	48	5.93	0.00	0.0	6600
Mulch	2972	Sub	1.2	58	418	71	6.23	0.00	0.0	5200
Chemical	2973	Top	3.3	59	318	54	6.06	0.00	0.0	7000
Chemical	2974	Sub	1.1	44	377	118	6.56	0.00	0.0	5000

Appendix 2 On-station trials plot layout at Roodeplaat. (see chapter 5)

**Table 5.2.2 Details of treatments labels over all the seasons.**

Year	Season		Crops					Irrigation					Cultivation			Initial profile		
	Summer	Winter	Beetroot	Cabbage	Cowpea	Swiss Chard	Tomato	According to soil water depletion	2 x week	Weekly		Fort-nightly		No mulch	Mulch	Kraal Manure	Fully wet	Partially wet
										10 mm	20 mm	10 mm	20 mm					
94/95	X		X			X								X			P1	P2
95		X	X			X				W1B1	W1B2	W2B1	W2B2	X			P1	P2
95/96	X					X	X	Heavy Rainfall – no irrigation					X					X
96		X	X	X		X		1102	110	120	210	220	S	D				X
96/97	X				X	X	X	CPN		1101	1201	1102	1202	X	D	K		X
97		X	X	X		X		CPN		1101	1201	1102	1202	X	D	K		X

Appendix 3 On-station trials plot layout at Roodeplaat.

WRC vegetable project layout 1995  
Buckets 10 litre

B1	-	10mm irrigation	B2	-	20mm irrigation
W1	-	Weekly	W2	-	Every second week
T1	-	One access tube	T3	-	Three access tubes
P1	-	Start low profile	P2	-	Start full profile

Empty Profile  
Full Profile

B1W1T3P1 56 55 54	B2W2T1P1 53	B2W1T3P1 52 51 50	B1W1T1P1 49
B2W1T1P1 57	B1W1T3P1 58 59 60	B2W2T3P1 61 62 63	B1W2T3P1 64 65 66
B2W2T1P1 70	B1W2T1P1 69	B1W2T1P1 68	B2W1T1P1 67
B1W2T3P1 71 72 73	B2W1T3P1 74 75 76	B1W1T1P1 77	B2W2T3P1 78 79 80

B2W1T1P2 86	B1W1T1P2 85	B2W2T3P2 84 83 82	B1W2T1P2 81
B1W2T3P2 87 88 89	B2W1T3P2 90 91	B1W2T1P2 92	B2W1T1P2 93
B1W1T3P2 103 102 101	B1W2T3P2 100 99 98	B2W1T3P2 97 96 95	B2W2T1P2 94
B2W2T1P2 104	B2W2T1P2 105	B1W1T1P2 106	B1W1T3P2 107 108 109

SOUTH

WRC Vegetable Experiment Field layout 1995

Drippers typhoon 30cm 1.65 l/u

W1D1B - Weekly irrigation 10mm dripper in beetroot

W1D2B - Weekly irrigation 20mm

W2D1B - Two weeklikse irrigation 10mm

W2D2K - Two weekly irrigation 20mm dripper in cabbage

Empty profiel

Full profiel

N  
o  
r  
t  
h

W1D1K 37 II	4m	W1D2B 36 I	4m	W1D1B 13 II	4m	W1D2K 12 I
38		35		14		11
39		34		15		10
W1D1B 40 II	4m	W1D2B 33 I	4m	W1D1K 16 II	4m	W1D2B 9 I
41		32		17		8
42		31		18		7
W2D1K 43 IV	4m	W2D2K 30 III	4m	W2D1B 19 IV	4m	W2D2B 6 III
44		29		20		5
45		28		21		4
W2D1B 46 IV	4m	W2D2K 27 III	4m	W2D1K 22 IV	4m	W2D2K 3 III
47		26		23		2
48		25		24		1

## PROJECT LAYOUT WRC 1996 WINTER SEASON

Declaration: D 1 10 2 - D=With mulch layer, 1=irrigate weekly, 10=10mm  
 2=twice per week

S 1 10 2 - S=Without mulch layer

D 2 10 - D=mulch layer, 2=twice per week, 10=10mm

D 2 20 - D=mulch layer, 2=twice per week, 20=20mm

### IRRIGATION FREQUENCY

10mm 2X Week	10mm 1X Week	10mm 1X 2 <sup>nd</sup> Week	20mm 1X 2 <sup>nd</sup> Week	20mm 1X Week
No crop - no mulch 41 42 43 44		No crop - mulch layer 45 46 47 48		

D1102 33	D110 32	D210 17	D220 16	D120 1
D1102 34	D110 31	D210 18	D220 15	D120 2
D1102 35	D110 30	D210 19	D220 14	D120 3
D1102 36	D110 29	D210 20	D220 13	D120 4

WITH  
MULCH

S1102 37	S110 28	S210 21	S220 12	S120 5
S1102 38	S110 27	S210 22	S220 11	S120 6
S1102 39	S110 26	S210 23	S220 10	S120 7
S1102 40	S110 25	S210 24	S220 9	S120 8
Irrigate every Tuesday & Friday 1x10mm	Irrigate every Tuesday 1x10mm	Irrigate every second Tuesday 1x10mm	Irrigate every second Tuesday 2x10mm	Irrigate every Tuesday 2x10mm

NO  
MULCH

PROEFUITLEG WNK 1996 SOMER SEISOEN

Irrigation

2101 - 2x10mm weekly  
 1101 - 10mm weekly  
 1102 - 10mm 2nd week  
 1201 - 20mm weekly  
 1202 - 20mm 2nd week

Treatment

D - Mulch  
 K - Kraal manure

D2101 49	D1101 48	D1102 25	D1201 24	D1202 1
D1201 50	D2101 47	D1101 26	D1202 23	D1102 2
D1101 51	D1201 46	D2101 27	D1102 22	D1202 3
D1201 52	D1102 45	D1202 28	D2101 21	D1101 4

M  
U  
L  
C  
H

1101 53	2101 44	1102 29	1202 20	1201 5
1201 54	1102 43	1202 30	1101 19	2101 6
1202 55	1101 42	2101 31	1102 18	1201 7
1102 56	1201 41	1101 32	1202 17	2101 8

K1202 57	K1101 40	K1201 33	K1102 16	K2101 9
K2101 58	K1102 39	K1202 34	K1101 15	K1201 10
K1201 59	K2101 38	K1101 35	K1202 14	K1102 11
K1101 60	K1202 37	K2101 36	K1102 13	K1201 12

K  
R  
A  
A  
L  
  
M  
A  
N  
U  
R  
E

## PROJECT LAYOUT WRC 1997 WINTER SEASON

Declaration:

- Irrigation:- CPN - Weekly according to CPN  
                   1101 - 10mm weekly  
                   1102 - 10mm every second week  
                   1201 - 20mm weekly  
                   1202 - 20mm every second week
- Treatments:- K - Kraal fertilizer  
                   D - Mulch layer (mixed residue)  
                   C - Only cabbage  
                   S - Only spinach

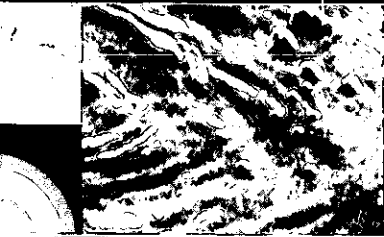
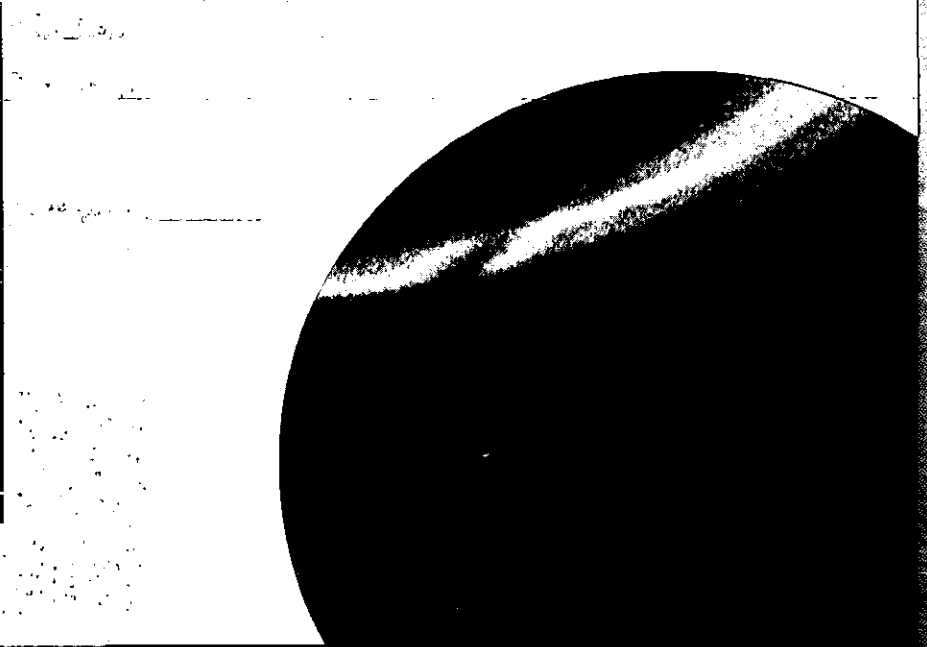
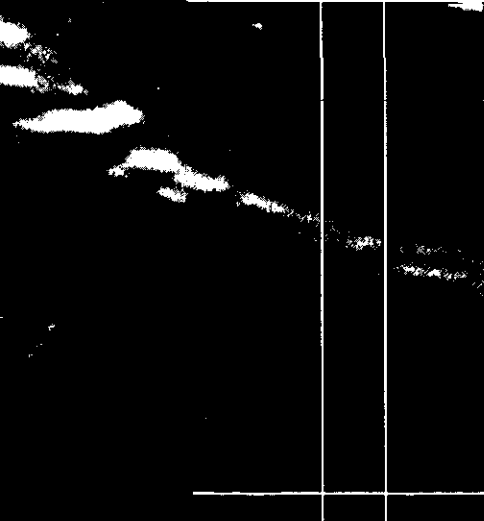
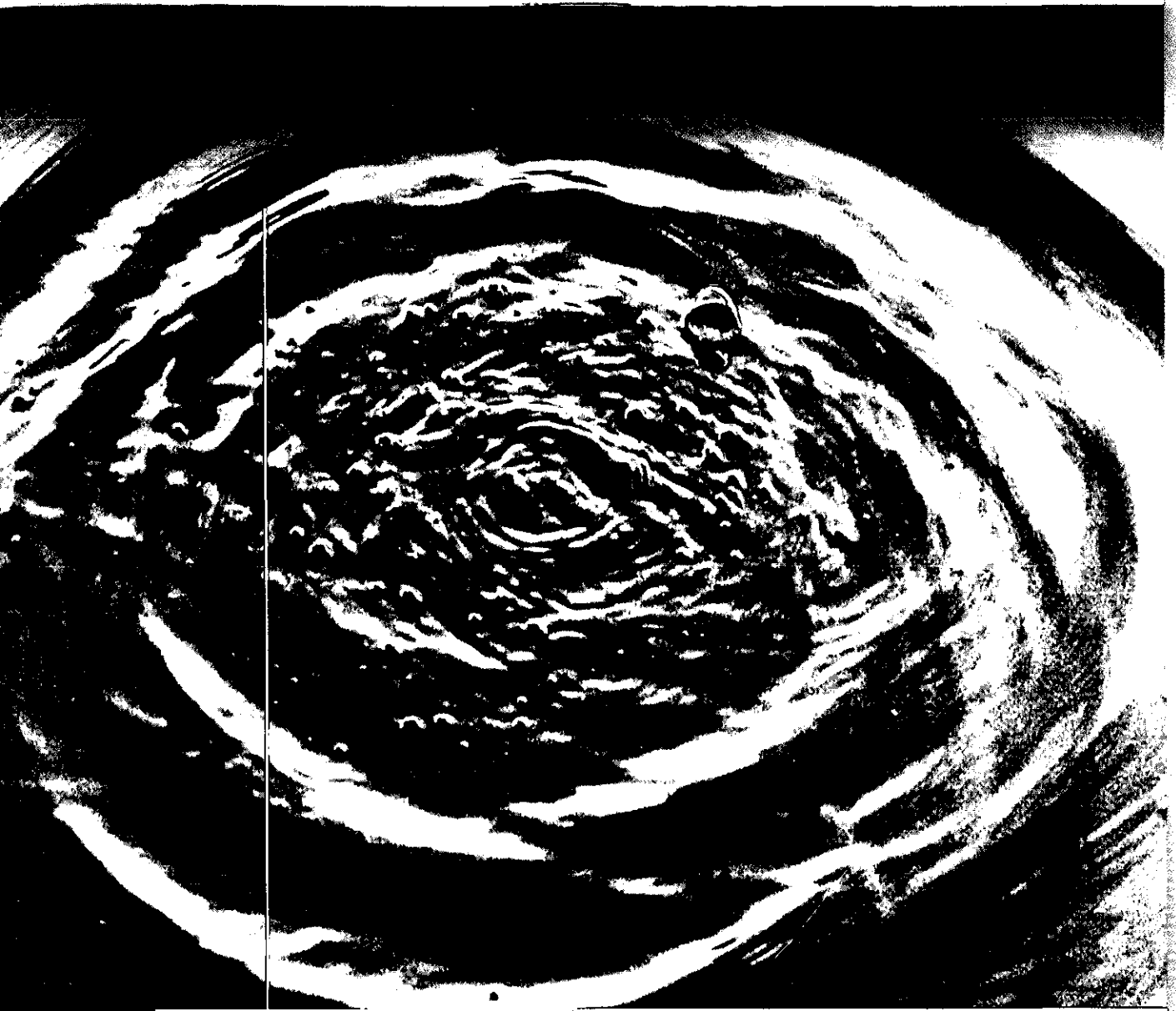
S1202 10	S1102 11	S1201 30	S-CPN 31	S1202 50
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1101 9	1101 12	1102 29	1202 32	1201 49
1201 8	1101 13	1102 28	CPN 33	1101 48
CPN 7	1202 14	1102 27	1202 34	1102 47
1201 6	CPN 15	1201 26	CPN 35	1202 46

C-CPN 5	C1101 16	C1102 25	C1201 36	C1202 45
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D1201 4	D1101 17	D1201 24	D-CPN 37	D1101 44
D-CPN 3	D1202 18	D1102 23	D1201 38	D-CPN 43
D1101 2	D1102 19	D1201 22	D1202 39	D1102 42
D1202 1	D1102 20	D1202 21	D1101 40	D-CPN 41

K1201 51	K1102 58	K-CPN 59	K1202 66	K1101 67
K1102 52	K1202 57	K1101 60	K-CPN 65	K1201 68
K1201 53	K1101 56	K1202 61	K1102 64	K-CPN 69
K-CPN 54	K1102 55	K1201 62	K1101 63	K1202 70



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