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MELON IRRIGATION SCHEDULING 1985-1987

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1985 - 1987

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SUSTAINABLE AGRICULTURE

THE DEPARTMENT OF PRIMARY INDUSTRY AND FISHERIES IS COMMITTED TO THE PRINCIPLES AND PRACTICES OF SUSTAINABLE AGRICULTURE

Definition:

Sustainable agriculture is the use of practices and systems which maintain or enhance:

- the economic viability of agricultural production;
- the natural resource base; and
- other ecosystems which are influenced by agricultural activities.

Principles:

1. Agricultural productivity is sustained or enhanced over the long term.
2. Adverse impacts on the natural resource base of agricultural and associated ecosystems are ameliorated, minimised or avoided.
3. Harmful residues resulting from the use of chemicals for agriculture are minimised.
4. The nett social benefit (in both dollar and non-dollar terms) derived from agriculture is maximised.
5. Agricultural systems are sufficiently flexible to manage risks associated with the vagaries of climate and markets.

INTRODUCTION:

This report covers the initial investigations carried out by the Vegetables Research Group in the Horticulture Section of the Northern Territory Department of Primary Industry and Fisheries (formerly the Department of Primary Production and Department of Industries and Development), during the years 1985-87.

These projects were carried out on the Horticulture Research Area of the Coastal Plains Research Station and in one case on the rockmelon production areas of a co-operator/grower.

As well as the research projects a broad extension program was carried out by the Horticulture Extension Officer in association with the research group, on the use of tensiometers on farms during 1986 and 1987.

The projects were undertaken to answer questions emerging from industry practises and later to develop irrigation scheduling strategies based on the data collected. In 1985 the rockmelon industry was only four years old and was experiencing a rapid expansion of sown areas, with water being often the limiting resource.

These investigations are regarded as preliminary only and a more sophisticated research program to better define irrigation scheduling on a range of crops is planned for 1989/90. The ongoing research program will employ the use of a neutron probe, an infra-red gun and limited use of a porometer to refine the initial work described in this report.

The results of this work was presented to the industry in a Melon Growing Workshop held at Berrimah Farm in April 1987.

ROCKMELON IRRIGATION SCHEDULING

TITLE

Rockmelon irrigation scheduling studies using soil moisture tensiometer and wetting pattern observations with trickle irrigation and plastic mulch.

OBJECTIVES

The aim of this series of observations was to develop an irrigation scheduling procedure for rockmelons using simple tensiometers and to relate the consumptive water use of the crop to mean daily evaporation rates from a Class A open Pan evaporimeter. Before this could be achieved, expertise on the use of tensiometers had to be developed and certain parameters such as effective root zone and the relationship between the tensiometer reading and available soil moisture had to be determined. Also, the effect of plastic mulch on soil wetting patterns with currently available trickle irrigation systems and the physical characteristics of the sandy CPRS soils required definition.

BACKGROUND

The commercial production of rockmelons using trickle irrigation and plastic mulch has increased from 2.0 ha in 1981 to in excess of 150 ha in 1987 with a value of over $4 million and is the NT's largest horticultural crop. Up to 1985 no methods of irrigation scheduling has been used by growers and irrigation practise was generally based on local experience and grower expertise. For crops on sandy soils this could vary from 1-2 hours per day up to 8-10 hours per day depending on the grower. A local irrigation installation and consulting company have had very little basic information on the horticultural soils on which to base their irrigation designs, and usually design a system according to the growers perceived requirements. The sandy red earths of the CPRS Horticultural Research site have presented serious problems in developing suitable irrigation strategies for trials and in the use of soil moisture tensiometers. Observations on trials at CPRS during the 1984 season had indicated that premature ripening of fruit, poor fruit quality and 'suture greening' of melons could be associated with moisture stress during critical growth periods. The 'green sutures' or 'vein tracking' is a result of incomplete net development and is a varietal characteristic but is highly accentuated in stressed melons. After prolonged storage and transfer in low humidity cool storage the sutures turn brown through dehydration and the melons become unsaleable. Dehydration is also associated with flabbiness and poor quality fruit. The CPRS sandy red earths are similar to the soils in the newer horticultural areas and have relatively low water holding capacity which makes them difficult to efficiently irrigate.

TRIAL 1

IRRIGATION SCHEDULING OF ROCKMELONS, COOL SEASON 1985

INTRODUCTION

This trial was originally put down mid season in 1984 but constant breakdowns of the new irrigation system on CPRS severly stressed the melon crop so the trial was abandoned part way during growth. Having no local experience to draw upon, a literature search was made to gather information on irrigation practices in other melon production areas to use as a basis for initiating this work.

OBJECTIVE OF TRIAL

To assess three irrigation regimes during the final stage of fruit maturation and their effect on yield, quality and maturity of rockmelons.

MATERIALS AND METHODS

Melon cultivar:	Planters Jumbo
Sowing date:	14.05.85
Plot Size:	18.0m with 2.0m bed centres
Plant spacing:	0.6m single line (30 plants per plot)
Trial Design:	RCBD - 3 treatments x 4 replicates.
Harvest period:	07.07.85 to 17.08.85 (10 days).
Tensiometer placement:	2 tensiometers per plot set at 15cm and 30cm depths. Changed to 10cm and 20cm depths set mid way between plants and 15cm from trickle line.
Data collected:	Tensiometer readings taken at 0900 and 1500 hours daily. Irrigation frequency and duration recorded daily. Plot yields and percentage marketable fruit.
Time to first harvest:	85 days.
Trickle line:	Hardies 'Bi Wall' (R) used as industry standard. Discharge rate 3.6-4.0mm/m/hour.

Treatments:

Crop growth phase	Tensiometer Centibar (cb) readings		
	Treatment 1	Treatment 2	Treatment 3
1. Establishment phase	20	20	20
2. Crop growth (flowering fruit set and fruit filling).	30	30	30
3. Final stages of fruit maturity (early net stage onwards)	30-40	45-55	60-70

SOILS

The soils of the CPRS Horticultural Research area are classified as red earths of the Berrimah soil family. The topsoils are described as dark brown to reddish brown sandy loams with massive structure, earthy fabric and moderately weak consistency containing ironstone gravels. Soil physical analyses show a level of 10-15% clay, 45% coarse sand and 28% fine sand at 0-20cm soil depth. Approximately 80% of the clay in these soils is in the form of kaolinite which is a non-swelling clay type. The soils are relatively deep and are free draining, and are similar to the Tippera and Blain families of soils. All have low clay and organic matter contents and the pre-dominance of the clay mineral, kaolinite has resulted in low cation exchange capacities and very low moisture holding ability especially in the surface layers where the shallow roots of vegetables are located. Some limited work has been carried out on the moisture characteristics of the major soil types in the Top End but at a tension range from - 0.3 Bar to - 15.0 Bar, which is well beyond the range of vegetable irrigation management.

TENSIOMETERS

Irrigation scheduling determines how much water to give the crop and the timing and amount of each irrigation. The use of tensiometers is considered essential to improve and assist the accuracy of irrigation management to give optimum growth and maximum yields. They are simple, relatively inexpensive instruments which measure the tension in centibars (cb) that plants need to develop to extract moisture from the soil. They do not measure the total moisture content of the soil but they indicate when a plant is running out of water and requires irrigation. A high tension reading indicates a need for irrigation.

SUMMARY OF RESULTS

1. TENSIOMETER PLACEMENT

In the early stages of the trial it was found that the sets of tensiometers placed at 15 and 30cm depths allowed the soil immediately under the plastic to dry out and that they were too deep for effective wetting. At an early stage of growth, transverse trenches were dug across plots so that root distribution and the wetting pattern could be defined, and as a result, the tensiometers on all plots were re-set at a depth of 10cm and 20cm below the soil surface. This initial investigation, which was confirmed by observations on mature plants at a later date, showed that a high proportion of roots was confined to a 3-10cm deep band just underneath the plastic mulch and that 70-80% of all roots were contained in the first 20cm of topsoil. The wetting pattern had spread evenly across the soil profile underneath the plastic mulch but did not penetrate under the edges of the mulch. The shallow tensiometer was set into the zone of maximum root density, but also deep enough to ensure that it remained upright, while the deeper tensiometer was placed at the bottom of the design root zone to indicate the duration of the irrigation as well as to indicate if over-watering occurred.

2. MOISTURE CHARACTERISTICS

A review of the available literature on tensiometer practice suggested that water tensions of 30-35 centibars (cb) could be allowed on sandy soils before irrigation was necessary. However, in the second crop growth phase (flowering to fruit filling), tensiometer observations indicated that a much lower tension should be used. After an irrigation it would usually take 24 hours for a tension of 25 cb to develop but in the next 2-4 hours the tension could jump to 35 cb and beyond if water was not applied. This behaviour indicated that most of the easily available soil moisture was depleted at a relatively low soil moisture tension of 25 cb and that there was little reserve water held in the soil micro-pores for the plants to draw upon.

At this stage of the trial it was obvious that little was known about the moisture characteristics of the soil and the interpretation of the tensiometer readings. It was decided to conduct a series of investigations to determine the relationship between the amount of moisture actually in the soil and the water tension.

Initially, 8" plant pots with disturbed soil samples were used to calibrate the tensiometers but this was found to be inaccurate. An area of representative soil was therefore flooded and groups of tensiometers were installed at a depth of 10cm. A series of gravimetric moisture samples were taken at the level of the tensiometer's ceramic tip over a range of soil moisture tension readings. The relationship is illustrated in Figure 1. Field Capacity determinations were also made after 24 hours free drainage and the soil was found to have a moisture content of 19.5% gravimetric at a tension reading of 13 cb.

For practical purposes, the range of available soil moisture in the CPRS soil is from the Field Capacity (19.5%) and the 35 cb reading (14.5%) or 5% available gravimetric moisture. From Figure 1, it can be seen that a change in soil moisture tension from 25 to 35 cb units corresponds to a change in soil moisture content of 15.6% to 14.5% or a 1.1% difference for a relatively large increase in water tension. The moisture tension curve indicates that soil moisture is held very loosely in these soils, that they have a very stable pore size distribution and they tend to dry out very quickly.

3. CROP GROWTH PHASE 3

It was found that the imposition of the three treatments on the final phase of growth to evaluate the effect of moisture stress on quality, total soluble solids and yield could not be practically implemented. The nature of the sandy soil was such that to maintain the required moisture tension, several light irrigations were necessary every day to prevent the crop collapsing altogether from moisture stress. It has been a well tried traditional practice in melon growing areas to stress crops close to harvest by limiting irrigation water but this has been carried out on heavy soils. In the light sandy soils, this practice cannot be recommended due to the low level of available moisture that the plant has to rely on and which is very quickly

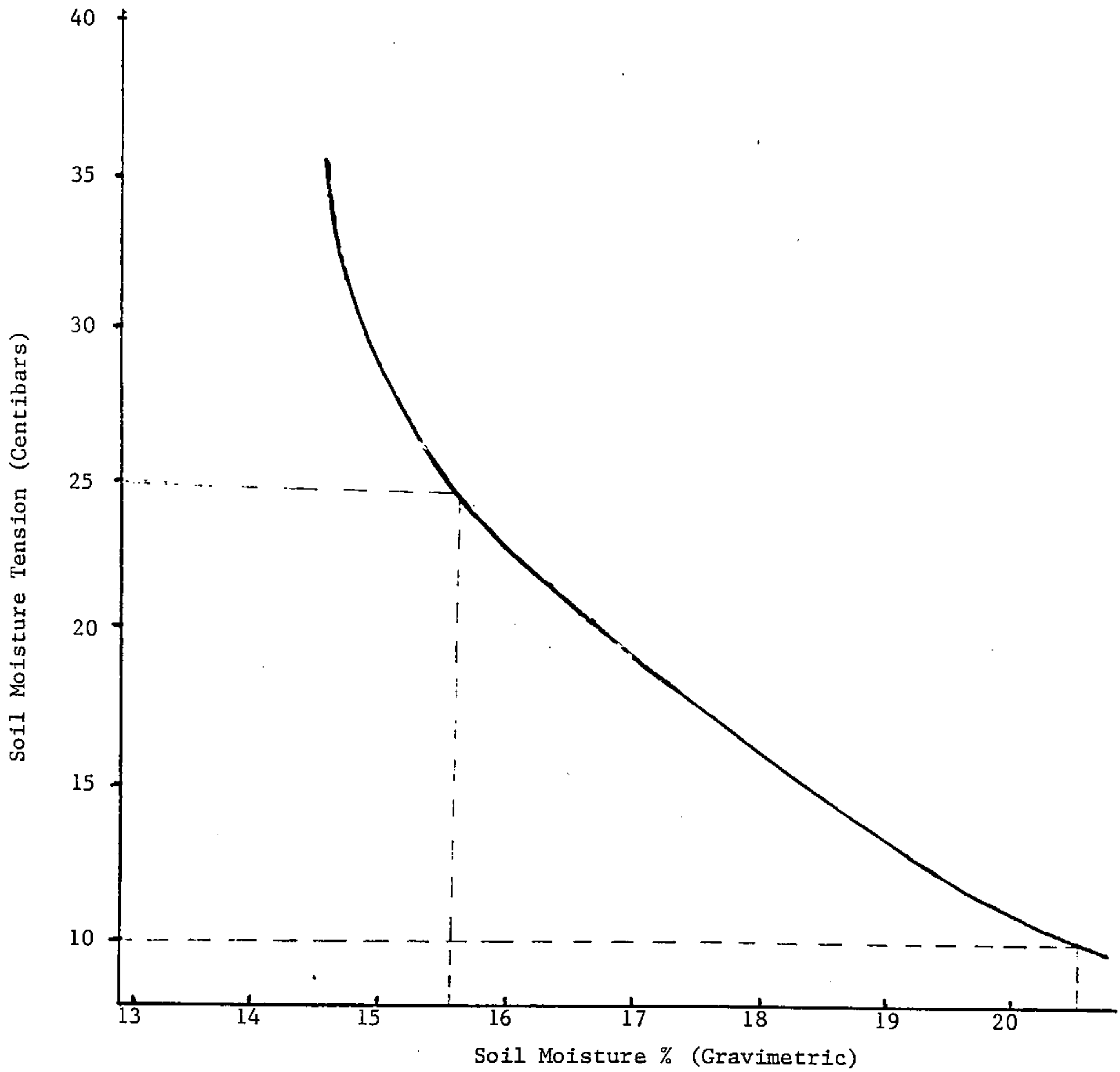


Figure 1. Soil Moisture Tension Curve

depleted on a hot windy day. There is no gradual reduction in available moisture with a corresponding slow increase in tensiometer moisture tension over 2 or 3 days to allow this gradual stressing to take place. The sandy soils are quickly depleted of available moisture which, if irrigation is irregular, leads to a cycle of checks or plant stresses that produce low quality fruit from premature ripening.

4. EFFECTIVE ROOT ZONE

During the latter stages of the trial a series of transverse trenches, 1.0m deep, were excavated through the melon beds in an attempt to plot the melon root distribution. The very fine root hairs made it difficult to use traditional point plotting techniques which are employed for tree roots. Visual estimates of root density were made down the profile after gently exposing the roots with low pressure water jets. Several organic and mineral dyes were injected through the trickle system in an attempt to highlight the soil wetting patterns but the very dark colour of the wetted soil made it difficult to observe where the dye actually was. Figure 2 diagrammatically illustrates the root system distribution of rockmelons under plastic mulch.

As previously stated, it was found that 70-80% of all roots were contained in the first 20cm of topsoil with a very high concentration of roots just underneath the plastic mulch and in a 3-10cm band. This area is known as the Design Root Zone (DRZ) and for the purposes of this work has been set at 20cm depth. The size of the root system and its distribution pattern are determined, to a great extent, by soil moisture content and distribution and their interaction with soil aeration and nutrient supply. The combination of trickle irrigation and plastic mulch encourages very shallow root development in rockmelons and confines the roots to a small volume of soil directly below the emitters. This limitation on root development to a specific soil volume has significant implications for crop management including fertiliser placement and injection and irrigation scheduling.

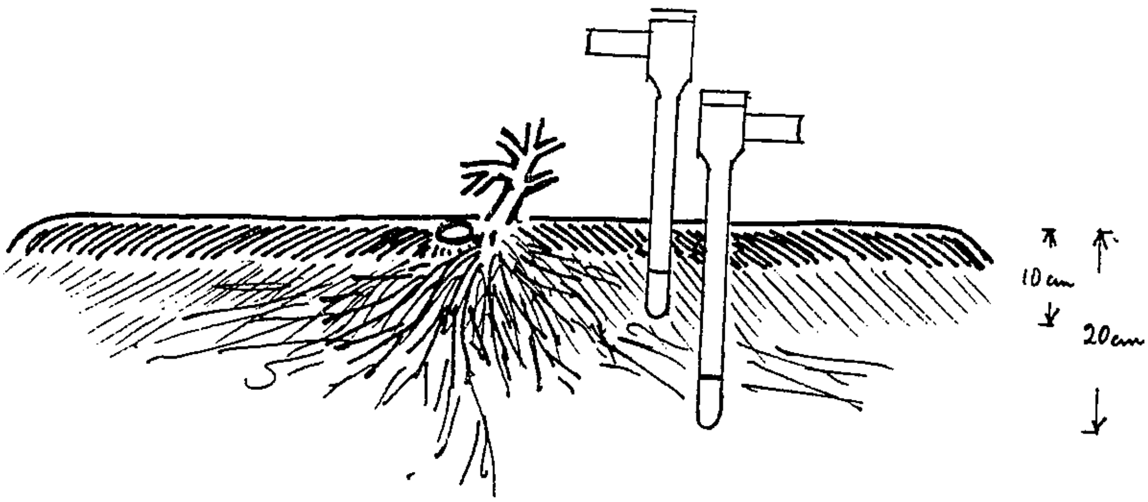
Assuming that there is only 5% gravimetric available moisture in the CPRS soils, then, by calculation and taking into account the design root zone (20cm), and the maximum allowable deficit, the nett water requirement in the root zone is 7.5mm. (See Appendix 1). The Bi-Wall (R) irrigation tube has a discharge rate of between 3.0 and 3.5mm/m^2/hr. which allows a maximum irrigation duration of 2 to 2.5 hours in any one irrigation. If this irrigation period is exceeded then the wetting pattern extends beyond the design root zone and wastage of water and leaching of nutrients occurs. The deeper tensiometer, set at 20cm soil depth, indicates when the root zone is saturated and helps to prevent over-watering taking place.

5. IRRIGATION SCHEDULING

In this trial an attempt was made to relate the total water use to the evaporation from a Class 'A' Pan evaporimeter to gain an approximate figure for crop correction factors at different stages of growth. The pan evaporimeter was not located on the trial site but was at the CPRS station some 4km away.

FIGURE 2

ROCKMELON ROOT DISTRIBUTION
UNDER PLASTIC MULCH



ROCKMELONS:- TABLE 1

COOL SEASON CROP: 14.5.85 to 17.8.85 (95 DAYS)

WATERING INTERVAL (DAYS)	30	38	8	19
WATERING DURATION PER DAY (HRS)	0.5	1.0	1.5	2.0
MEAN Eo PER DAY (mm)	5.44	5.19	5.04	5.33
CROP FACTOR	0.3	0.6	0.9	1.1

TOTAL WATERING TIME: 103 HOURS = 300mm

HOT SEASON CROP: 24.7.85 to 17.10.85 (86 DAYS)

WATERING INTERVAL (DAYS)	28	15	20	23
WATERING DURATION PER DAY (HRS)	0.5	1.0	2.0	3.0
MEAN Eo PER DAY (mm)	5.88	6.26	7.05	6.91
CROP FACTOR	0.4	0.5	0.8	1.3

TOTAL WATERING TIME = 144 HOURS = 430 mm

Corrections were made to allow for the re-setting of the pairs of tensiometers at a shallower depth in the first crop growth phase. The results are shown in Table 1 where the Crop Factor* reached a very high value of 1.1 during the final phase of crop development and a total of 103 hours of irrigation (approximately 300mm water) was required during cool mid-season conditions. The growing period was 95 days which included a 10 day harvesting period. It can be noted that in the crop maturation phase, a daily irrigation of 2 hours was required and this did not exceed the maximum allowable irrigation period so one irrigation per day would be adequate.

The total irrigation requirement for the crop and the corresponding crop factor appear high and this could be partly due to two main problems.

a. A high % of irrigation water could be lost to deep percolation in the coarse textured free draining soils. Excavation trenches have always shown the wetting pattern to extend deep into the subsoil and it was not confined to the 20cm zone.

b. The lag time usually associated with tensiometers results in over-irrigation. As a rule of thumb, the irrigation should cease when the deep tensiometer guage shows a reading of 15 cb. The wetting front will quickly percolate down and drop the reading to 8-10 cb which is full saturation. If the irrigation is continued until the reading is 10 cb then over irrigation will certainly occur. Depending on soil type the lag time for tensiometers is considered by some workers to be from 30-60 minutes.

The results of this trial indicate that irrigation should commence at a moisture tension reading of 20 to 25 cb and preferably at the lower level. The tensiometers should be set in pairs, one at 10cm and the other at 20cm depth, midway between plants and midway between the trickle tape and the edge of the plastic mulch on the plant side of the tape.

Experience gained with this trial has indicated that crops up to 5-6 weeks of age, or early fruit set, do not have a high moisture requirement and usually can be irrigated at any time of the day. Older crops, however, with a high moisture demand, must be irrigated during the period of maximum stress. This is usually between 12.00 and 3.00pm depending on wind conditions. The tensiometers will quickly indicate when soil moisture is being depleted by increased evapotranspiration and irrigation must be applied at this stage before plant stress occurs. Work in Israel on coarse sandy soils with low water holding capacity has shown that irrigation during the period of maximum plant requirement increased yield significantly,

* <u>CROP FACTOR</u> is a combined factor that relates plant water use and the evaporation of water with the different physiological stages of plant growth.

improved plant water potential as well as increased water use efficiency. The dominant component of water balance under the Israeli conditions was found to be deep percolation which could be offset to a certain extent by irrigating during hours of high net radiation flux when the transpiration rate could compete with the deep percolation rate.

Records of daily water evaporation from a Class 'A' evaporimeter (Eo) in July 1985 varied from 4.0mm/day to a maximum of 7.5mm/day depending on wind speed. It is recommended that a water balance irrigation scheduling system based on Eo would be too risky to use because of the highly variable day to day Eo as well as the very low water holding ability of the sandy soils. As a consequence, soil moisture tensiometers were recommended as the best practical method to introduce irrigation scheduling to the industry. Further discussions on irrigation scheduling will continue later in this Bulletin.

6. YIELDS

It was found that due to the nature of the CPRS soils, which was unknown at the time the trial was initiated, the three treatments in crop growth phase 3 could not be effectively maintained. Many short irrigations were necessary throughout the day to hold the tensiometers at the required tension otherwise the soil moisture would be rapidly depleted and plant stress would occur. The original assumptions on the treatment tension levels were obviously based on soils with a much higher water holding capacity than the CPRS sandy red earth. As a result, the treatments were not continued as they were considered to be impractical and no treatment yields and melon quality assessments were made. The total yield from the whole trial area was in the order of 30t/ha of marketable fruit with a high proportion of runner-set fruit.

TRIAL 2

TRICKLE IRRIGATION WETTING PATTERNS OBSERVATIONS - HOT SEASON 1985

AIM

To observe irrigation wetting profiles with two commercially available drip tapes (i) under plastic mulch, (ii) on bare ground and (iii) buried at 3 different levels. To determine irrigation scheduling requirements under hot weather conditions.

BACKGROUND

The melon industry commenced in 1981 employing drip irrigation and black plastic mulch technology as the industry standard. The black plastic mulch was originally considered essential for weed control as no effective herbicide is available for cucurbits with local weed species. Evidence is now suggesting that the mulch is essential in developing an effective wetting pattern in coarse sandy horticultural soils, while drip lines on bare ground produce a narrow confined pattern for root development. Growers have also questioned the expense of plastic mulch and whether it is necessary to achieve economic production of rockmelons.

MATERIALS AND METHODS

Rockmelon variety:	Planters Jumbo
Sowing date:	24.07.85
Plot size:	20.0m with 2.0m bed centres
Plant Spacing:	0.6m single line (33 plants per plot)
Trial Design:	Single plot observation areas only.
Harvest period:	7.10.85 to 17.10.85
Treatments:	Two commercial trickle tapes Bi-Wall (R) and T-Tape (R) of similar discharge rates, were compared with each having the same treatments.

1. Trickle line under black plastic mulch.
2. Trickle lines on top of bare soil.
3. Trickle lines 1/3 of plot at 5cm depth
   1/3 of plot at 10cm depth
   1/3 of plot at 15cm depth.

Management: As per Trial 1

The basal fertiliser on Treatment 3 (buried lines) was rotavated to a depth of 15cm in the plot. The trickle lines to each treatment had individual taps for irrigation control. Treatment 3 tended to be over-irrigated during the crop establishment phase to ensure that the seed had adequate moisture for germination. Foliar fertilisation program to all treatments. All plots were watered to tensiometer limits as required.

Time to first harvest: 76 days.

SUMMARY OF RESULTS

The most significant result to come out of this observation trial was the excellent wetting pattern that is developed under plastic mulch compared to unmulched treatments. There was an even distribution of moisture across the soil profile under the mulch with a very high concentration of feeder roots just under the soil surface.

The yield data presented in Table 2 should be treated with caution as the trial was not replicated and the figures are indicative of trends only. The trial was not instigated to compare the relative merits of the two trickle tapes then on the market but there is one obvious difference that warrants attention. In Treatment 2, with tapes on bare soil the Bi-Wall® has significantly outperformed the T-Tape® due to the fact that it is a squirting emitter and not a drip type. The tapes were placed on the windward side and the spray from the Bi-Wall® carried water over a wide area of soil surface and so promoted a more extensive surface root system. This is shown diagrammatically in Figure 3.

The yield data presented in Table 2 is marketable yield based on size gradings only and there was no culling of melons based on sutures and poor netting. This was an oversight at the time and is misleading so the results should be treated with some suspicion. In Treatment 3, Bi-Wall buried at 5cm achieved a high yield with reasonable fruit quality whereas Figure 3 shows that the wetting pattern was severely restricted and the root distribution was sparse but deep. This result could be erroneous as Bi-Wall (R) buried at 10cm achieved a very poor plant performance.

Table 2 exhibits some general trends.

i) Only the plastic mulch treatments produced consistently good quality fruit.

ii) Burying the tape too deeply gave poor fruit quality indicating that plant stress was becoming more severe. This stress is obviously related to the difficulty of tensiometer placement with buried tapes and plant vigour could be associated with fertiliser placement.

iii) Weed growth was less vigorous with tapes buried at 10 and 15cm due to the restricted wetted surface area.

Figure 3 diagrammatically shows wetting patterns and root distributions of the treatments. The plots were allowed to substantially dry out so that the delineation of the wetting patterns would be more distinct. Generally,

i) Without plastic mulch, the melon roots penetrate deeper into the soil, spread wider and are generally less concentrated than the dense, fine roots under mulch.

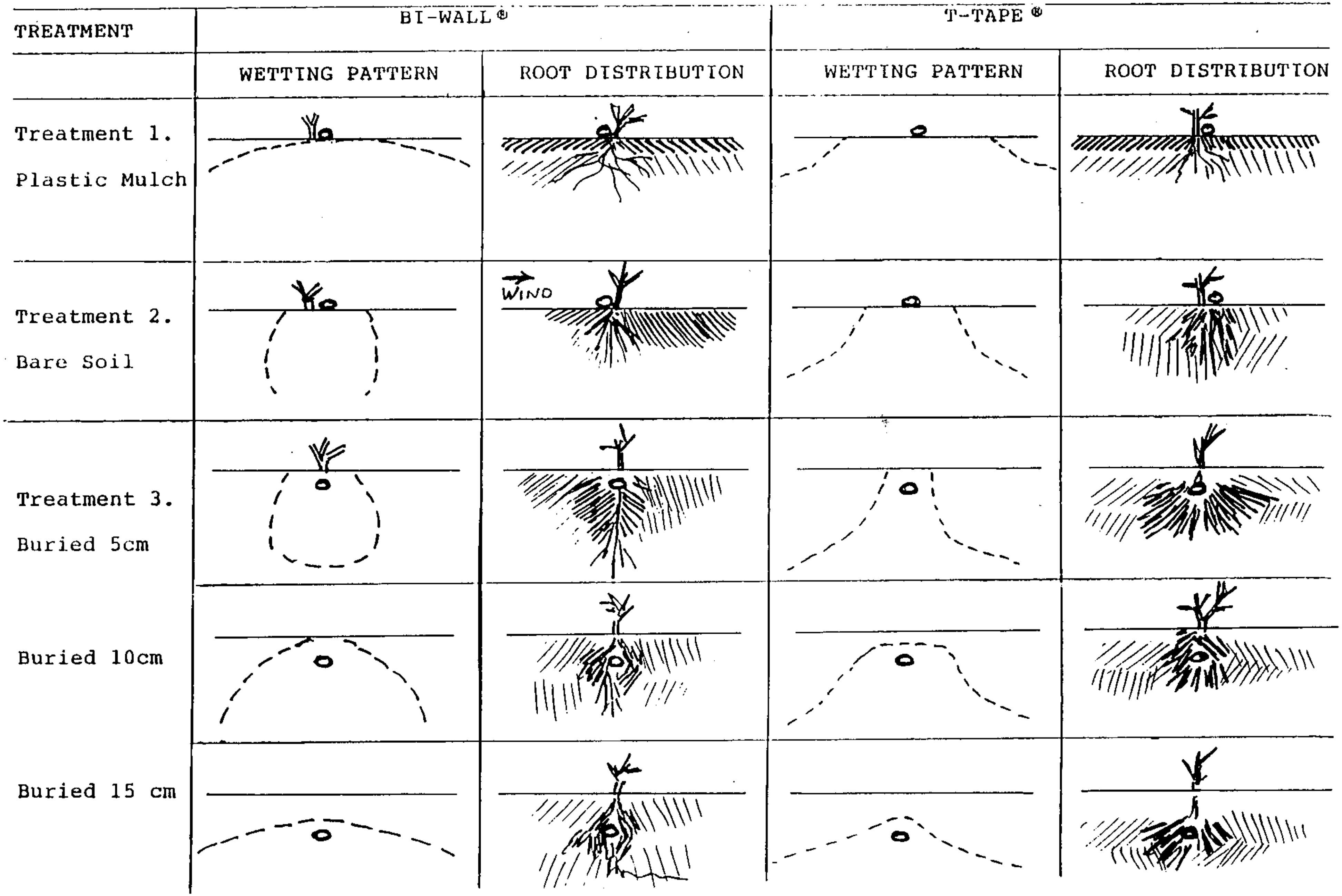
TABLE 2

WETTING PATTERNS OBSERVATION TRIAL: 1985 PLANTERS JUMBO ROCKMELON, SOWN 24.07.85 - MARKETABLE FRUIT ON SIZE GRADING ONLY

TREATMENT	Total Mark. Yield (kg)	% Mark. Yield	% Mark. Fruit Size (kg)	% Large Fruit	% Med. Fruit	% Small Fruit	Av No. Mark. Fruit/ Plants	Plant Vigour Scale (1-5) 5=V.Good	Weed Growth Scale (1-5) 5=Severe	Comments
Treatment 1										
Tube under plastic mulch									)	Good quality
Bi-wall	94.60	62.1	1.48	11.6	50.5	37.9	1.9	4.5	0)	Good fruit
T-Tape	121.00	76.5	1.55	25.5	51.0	23.5	2.4	5	0)	Good nets
									)	Some sutures
Treatment 2										
Tube on Top of bare soil									)	Poor net
Bi-Wall	78.00	65.8	1.56	22.4	43.4	31.6	1.5	4	3)	Distinct sutures
T-Tape	27.60	38.3	1.53	10.6	27.7	61.7	0.5	1.2	5)	on most fruit
									)	bad stem end cracking
Treatment 3										
Tube buried - bare soil										
Bi-Wall at 5cm	119.70	80.8	73.1	7.7	15.4	1.9	5	5		Good fruit some sutures
Bi-Wall at 10cm	37.20	47.4	1.38	-	47.4	52.6	0.8	3	3	Small fruits poor nets
Bi-Wall at 15cm	60.60	54.2	1.55	20.8	33.3	41.7	1.2	3	1.2	Bad sutures
T-Tape at 5cm	46.20	47.6	1.54	23.8	23.8	52.4	0.9	2	4-5	Fair fruit some sutures
T-Tape at 10cm	76.50	64.3	1.42	14.3	50.0	32.1	1.6	3-4	4	More sutures poorer nets
T-Tape at 15cm	45.30	44.0	1.37	-	44.0	52.0	1.0	4	2-3	Poor fruit big sutures Poor nets

FIGURE 3:

WETTING PATTERNS OBSERVATIONS TRIAL: 1985 WETTING PATTERN AND ROOT DISTRIBUTION



ii) Additional water was applied to buried tapes to wet up the surface especially in the early stages of plant establishment. Losses due to deep percolation would be high.

iii) The wetting pattern in unmulched soil tends to fluctuate at the surface leading to periodic wetting and drying out which resulted in sparser feeder root development (see diagram p.14).

iv) The deeper the tape is buried the wider the wetting pattern becomes although it does not necessarily reach the surface. This is a reflection of the saturated hydraulic conductivity of these sandy soils.

v) Feeder roots were found in dry soil well out of the wetting pattern zone although it was often difficult to distinguish these from weed roots in unmulched plots.

Irrigation records were kept on the plastic mulch treatments to assess irrigation scheduling under hot weather conditions during September and October. As in the 1985 cool season crop, an attempt was made to relate the total water use on the trial to the evaporation from a Class A pan evaporimeter. The results are shown in Table 1 with the cool season results. The Crop Factor reached a very high value of 1.3 with a total watering time of 144 hours or 430mm of water used for the crop. The hotter conditions of this growing period substantially increased crop transpiration rates. It was found that a three hour irrigation period was required in the final growth phase when using tensiometers to schedule waterings and that it was absolutely critical that the major portion of the water was available during the maximum stress period (12-3.00pm). Given that the maximum irrigation duration is approx. 2 hours (Appendix 1), then a 1 hour irrigation must be applied in the mornings. In practice it was found that after a one hour irrigation, starting at 9.30am, the tensiometers would not reach 20 cb again until about 2.00pm when the second irrigation would start.

Two irrigations per day in hotter weather raise practical problems for growers as most would admit that it is difficult to monitor manual valves more than once per day. Automatic irrigation systems using solid state controllers is obviously the way the industry will have to go. In fact, 3 or 4 short duration irrigations per day using a pulsing technique may be the most practical way of overcoming the peak demand period requirements.

Records of daily water evaporation (Eo) from the Class 'A' evaporimeter during October 1985 varied from a minimum of 5.0mm/day up to a maximum of 9.8mm/day with a monthly average of 7.4mm/day. Again the high value of the Crop Factor could be due to the water lost in deep percolation in these soils and the tensiometer lag time. Even so, with a trickle tape discharging 3.5mm/m^2/hr, an average 3 hour irrigation would apply 10.5mm of water to the crop which is well above the average daily water requirement. On a hot windy day , well in excess of the 3 hour irrigation would be required. The Crop Factors were calculated on total daily water use based on daily irrigation time, known operating pressure and an average tape discharge rate and the actual daily evaporation from the evaporation pan (Eo). Evidence now suggests that the original calculations have underestimated the actual consumptive use of water by the crop and the tapes may have been discharging at 4.0mm/m²/hr due to the shorter run lengths. The original calculations were based on a discharge rate of only 2.92mm/m²/hr. If this was the case then the Crop Factor would be about 25% higher than calculated and this very high value cannot be accepted. The only logical explanation is large water losses due to deep percolation in these free-draining sandy soils.

The trial has substantially added to our knowledge of water and root distribution in the CPRS soils but has also raised the issues of water infiltration and deep percolation in these soils on which we have no data whatsoever.

TRIAL 3

ROCKMELON TIME OF IRRIGATION

INTRODUCTION

During 1986 and 1987 the DID Horticulture Section actively promoted the use of soil moisture tensiometers in the horticulture industry as a means of effective irrigation management or scheduling. This extension effort was a result of research on the irrigation requirements of rockmelons carried out during 1985. It was recognised that the most critical issue facing the melon industry in terms of yield and fruit quality was the efficient management of irrigation. Growers tended to over-extend their water resources and were not able to put on the amount of water the plants required as well as putting it on at the critical stress period. The result was a long series of plant stresses which resulted in premature maturity of fruit with its inherent problems of poor nets, distinct green sutures and low sugar content. Quite often the grower does not have enough water to irrigate all the more mature crops at the one time so must start earlier and finish later than recommended. It is not known what the effect of this would be on the yield and quality of melons provided that sufficient water is applied when irrigation is carried out.

OBJECTIVE OF TRIAL

To determine the effect on melon yield and quality when irrigating melons both before and after the critical stress period. To attempt to establish the time of the stress period by using a porometer to determine stomatal conductance of the plants.

METHOD

Melon Cultivar:	Planters Jumbo
Sowing date:	27.05.87
Plot size:	40m with 2.0m bed centres
Plant Spacing:	0.6m single line (64 plants per plot)
Trial design:	Single bed observation areas.
Harvest period:	07.08.87 to 14.08.87
Time to First Harvest:	72 days.
Fertilisation:	Foliar application.
Treatments:	1. Irrigate daily at 1000 hours 2. Irrigate daily at 1200 hours 3. Irrigate at optimal time (20 centibars) 4. Irrigate daily at 1600 hours. Treatments commenced immediately after fruit set. All treatments were irrigated until tensiometers dropped to 10-12 cb.
Data Collected:	Daily records kept of tensiometer readings just prior to irrigation; the duration of irrigation; incidence of suture greening; porometer readings at hourly intervals from dawn until dark on 06.08.87; recording 5 plants x 2 leaves.

SUMMARY OF RESULTS

i) Irrigation timing

The yield and quality data are presented in Table 3. There was no significant difference in plant performance between the four treatments although there is a tendency for plants irrigated at or near the optimum time to have more suture problems. Melon crops may require a slight stress during the maturation phase to improve netting even in local sandy soils but this would be difficult to achieve commercially. Treatments 1 and 4 nearly always had a higher soil moisture tension value than treatments 2 and 3, indicating that they would have been under a slight stress during the last 4 weeks of growth. Therefore, watering either before and after the stress period did not produce significant differences in yield or quality in the trial.

It should be noted that at no time was the trial under any visible moisture stress and the area was surrounded by Bana grass windbreaks and was thus well protected. Because of this protection the results achieved might not be duplicated in a grower's crop which is usually exposed and subject to higher plant transpiration rates. That is, the management of the trial was able to keep the tensiometer readings to an acceptable level by watering at 10.00am without plant stress occuring but this would have to be verified commercially.

ii) Consumptive Water Use

From the sowing date, 27.05.87, until melon fruit set, 13.07.87, the four treatments received the same amount of irrigation water. From the 14.07.87 the treatments were imposed using irrigation controllers that were adjusted constantly to tensiometer readings so that under-watering or over-watering did not occur. The results can be seen below in Table 4.

TABLE 3

WATER USE 14.07.87 TO 13.08.87 (IRRIGATION HOURS)

Treatment	Water use 14-7 to 13-8-87 (hours)	% increase over optimum time	Total irrign hours over trial period
1. Irrigate 1000 hrs	77.5	54.5	120.5
2. Irrigate 1200 hrs	56.5	11.9	99.5
3. Irrigate at 20 cb	50.5	0	93.5
4. Irrigate 1600 hrs	65.5	29.7	108.5

TABLE 4

ROCKMELON TIME OF IRRIGATION TRIAL 1987 - SEED SOWN 27.05.87

	Total Yield (kg)	Large Fruit		Medium Fruit		Small Fruit		% Fruit no suture	% Fruit medium suture	% Fruit heavy suture	% Fruit pointed stem end
		wt(kg)	% fruit	wt(kg)	% fruit	wt(kg)	% fruit				
Treatment 1											
Irrigate 1000 hours	348.20	44.10	8.3	241.10	65.7	63.0	26.0	39.3	36.0	24.3	23.7
Treatment 2											
Irrigate 1200 hours	387.60	71.10	12.7	249.90	63.7	66.60	23.6	24.8	39.0	39.4	29.2
Treatment 3											
Irrigate tensiometer 20cb	373.00	74.40	13.5	241.20	62.7	57.40	23.8	28.9	33.4	35.4	29.6
Treatment 4											
Irrigate 1600 hours	407.70	75.50	12.4	265.60	62.2	66.60	25.4	33.8	37.7	27.9	28.2

These results can only be considered to indicate a trend as constant power failures at the research site made irrigation controller maintenance difficult and lead to experimental errors. Also, the irrigation of treatment 4 was difficult in that the tensiometer could not always be monitored before the water was cut off as that would have been 7.00 or 8.00pm. As a result it was difficult to estimate the irrigation requirement for the following day and the hours of irrigation may be on the low side.

The results indicate that it is possible to irrigate outside the optimal period but with a significant loss in irrigation efficiency. Much more water has to be applied to a crop to maintain a soil moisture tension within reasonable limits. The time of irrigation of treatment 3 (optimal time) did vary from 1200 to 1700 hours but was generally from 1300 to 1400 hours. The tensiometers on treatments 1 and 4 did fluctuate widely and on occasion, quite long irrigation times were necessary to bring them back to a satisfactory soil moisture tension. In fact a periodic over-irrigation has been found necessary with T-Tape (R) to re-establish the wetting pattern under the plastic which seems to contract over time. This is probably a function of tensiometer placement and should be further investigated. It should be emphasised that this experiment was carried out in cool weather with a well protected crop where transpiration rates would not be excessive. It may not be possible to irrigate a commercial crop some 4 or 5 hours before or after its optimal irrigation time with one water application per day without stressing the plants.

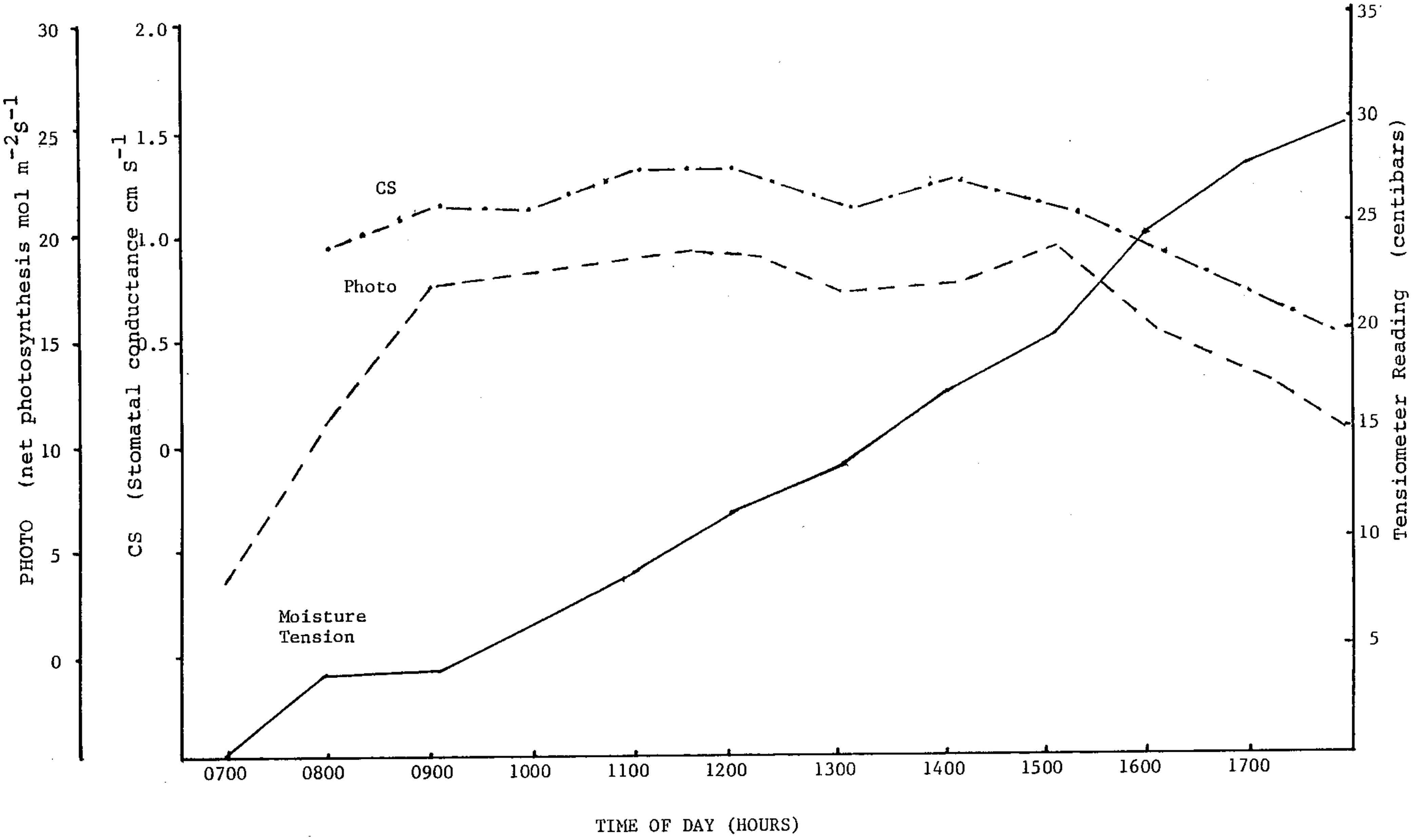
It is suggested, and further work needs to be carried out, that the problem with irrigating a crop at a time well removed from its optimal irrigation time, is due to deep percolation of water away from the design root zone of the plants. As previously mentioned in Trial 1, the Israeli experience has demonstrated that crops are more efficiently irrigated during the maximum stress period where the transpiration rate can compete with the deep percolation rate and less water is lost into the soil below the plant roots. With treatment 1, some 55% additional water had to be applied to wet up the soil volume well below the root zone to ensure that there was sufficient water held in the root zone for plant use.

iii) <u>Porometer Readings</u>

With co-operation from Mr Steve Cole of the CSIRO, a portable Li-Cor Li-6200 Photosynthesis system or Porometer was used on the trial in an attempt to relate measurements of plant stress to the soil moisture tension based on tensiometer readings. Hourly readings were taken off 2 leaves on 5 plants in Treatment 3 (optimal irrigation time) from 6.00am to 6.00pm. The readings were taken the day before first harvest on the trial and the trial was not irrigated until the recordings had been completed.

The results can be seen in Figure 4. Both CS, the stomatal conductance and PHOTO, net photosynthesis, follow a similar pattern and both significantly depress in value between 20 and

Figure 4: The relationship of stomatal conductance and photosynthetic rate with soil moisture tension on rockmelon plants.



25 cb moisture tension. This suggests that the recommendation of commencing irrigation at a 20 cb reading on a tensiometer is reasonably accurate under the conditions of the trial. The reduced rate of net photosynthesis and the closing up of leaf stomates indicates that the plant is under some stress although solar radiation at that time was not a limiting factor.

At 1600 hours a series of readings were taken on Treatment 4 where plants were exhibiting severe moisture stress and tensiometer readings had climbed to 70 cb. It was found that the stomatal conductance value was about half that of plants on Treatment 3 under a soil moisture tension of 25 cb. Also the net photosynthesis rate was low and about the same as recorded for Treatment 3 at 1800 hours. This behaviour suggests that the rockmelon plants do not have an efficient shut down mechanism in times of severe stress and could be permanently damaged or have reduced yield potential if moisture is limiting during critical growth phases.

TRIAL 4

BUTTERNUT IRRIGATION TRIAL: 1987

AIM

To compare the performance of butternut pumpkins with and without plastic mulch and with buried trickle tapes.

BACKGROUND

Butternut pumpkins are considered to be a low value crop and are mainly grown on trickle tape but without plastic mulch in an effort to reduce costs of production. Some growers have buried the trickle tape and have claimed that they have had better results. The best results are usually obtained with overhead irrigation where fruit splitting is not so much a problem. Requests have been made to the Section about the best method of growing butternuts using trickle irrigation. This small observation trial was planted in an effort to answer some of these queries.

MATERIALS AND METHODS

Butternut variety:	Large butternut.
Sowing date:	30.07.87
Plot size:	22m with 2.0m bed centres
Plant spacing:	1.0m single line (21 plants per plot)
Trial Design:	Observation plots only.
Date of Harvest:	03.11.87.
Treatments:	

Treatment 1. Trickle tape under plastic mulch.

Treatment 2. No mulch - trickle tape buried 100mm.

Treatment 3. No mulch - trickle tape on top of bare soil.

Fertilisation: Nutrients through trickle tape.

Irrigation: To 20 cb moisture tension.

SUMMARY OF RESULTS

The results are summarised in the following table.

TABLE 5

BUTTERNUT YIELDS - IRRIGATION TRIAL 1987

Treatment	MARKETABLE FRUIT Tot.Wt. (kg)	Av. Fruit Wt. (kg)	% Mark. Fruit	SPLIT FRUIT Tot.Wt. (kg)	% Split Fruit
1. Plastic mulch	82.1	1.5	67	42.3	33
2. No mulch - tape buried.	33.4	1.2	84	7.1	16
3. No mulch tape on soil surface	29.9	1.3	92	2.4	8

The plastic mulch treatment gave high yields although there was a very high percentage of split fruit. This was probably the result of allowing the bed to dry out too much before heavy rain fall late in October. There was no significant difference between buried tape and that on the soil surface. Butternuts are a deep-rooted plant but perform very well with plastic mulch which provides a larger rooting area for the plant. Plant roots did not grow into and block the tape which can occur if moisture is limiting. This small trial indicates that a doubling of yields is possible using plastic mulch but the economics would have to be closely looked at before recommendations could be made.

OTHER TRIALS

i) A large irrigation scheduling trial with rockmelons in 1984 was terminated after constant breakdowns of the irrigation system on the station. The crop was so badly stressed that little worthwhile data could be obtained from it.

ii) In 1986 a rockmelon wetting patterns trial was laid down to compare the performance of four trickle tapes that were commercially available at the time. A rockmelon variety trial was superimposed on this trial to evaluate their performance under late season conditions. Consistent rain late in the trial made the wetting pattern data difficult to interpret and little worthwhile information could be gathered.

iii) In 1987 a large irrigation management trial was conducted with open-pollinated hami melons to;

a. determine the duration of moisture stress required after fruit set to raise fruit sugar content to acceptable levels, and to

b. observe the effect of vine pruning on fruit size.

Treatments were designed to maintain a high level of moisture stress at 4 different periods before maturity was reached. The trial failed, basically as a result of planting the crop too late in the season. The fruit were maturing during the latter half of August which was too hot for sugar development. The majority of fruit was affected by sunburn and rotted before maturity was reached. Some fruit were harvested on 3.9.87 and sugar levels tested. The best readings were 11-12° Brix while most fruit were in the 8-10° Brix range. It is necessary to reach 15-16° Brix for top quality O.P. Hami melons. It is generally agreed now that these melons can only be grown from hot into cooler weather conditions to produce good quality fruit and the Top End may not be cool enough for their successful production.

iv) During the 1987 growing season an extension exercise was carried out on a commercial melon farm to determine the soil moisture characteristics of the two pre-dominant soil types present. Physical analyses of these soils was carried out by the Soil and Land Resource Unit of the NT Conservation Commission who co-operated in the project. The moisture characterstics of the two soil types were determined by calibrating soil moisture tensiometers against gravimetric soil samples over a range of moisture tensions as was used in trial 1, 1985.

The results of this work confirmed that these soils had an excellent capacity to retain soil moisture and that the frequency of irrigation could be significantly reduced by allowing soil moisture tensions to reach 35-40 centibars. One of the more important factors would be the capacity of these soils to be dried out during fruit maturation without reaching a situation, which occurs in sandy soils, where stressing could occur.

CONCLUSION

These experiments have provided basic data that was required to develop irrigation scheduling procedures for rockmelons. Because of the total lack of information on the physical and hydrological characteristics of Top End soils a number of assumptions were made. These seem to be bearing up under practice. Basic data are not available on infiltration rates, saturated hydraulic conductivity, soil bulk density and moisture characteristic curves on major horticultural soils. The only group who deal with soils work in the NT is the Land Resources Survey and Evaluation Project unit of the NT Conservation Commission and their expertise is not in this area. This basic research program has also highlighted the special problems in irrigating the sandy horticultural soils found in the more recent horticultural developments in the NT.

The primary objective of irrigation is to provide plants with sufficient water to prevent stress that may cause reduced plant yields. Irrigation scheduling determines how much water to give a crop and the timing and duration of each irrigation. The optimum irrigation frequency depends on the soil infiltration rate, the soil water holding capacity and the root zone volume. The research program, briefly, has identified the following criteria for use in irrigation scheduling:-

1) The use of tensiometers as simple, relatively inexpensive instruments which are sufficiently accurate to provide reasonable irrigation management. It is considered that a water balance system based on evapotranspiration measurement would be too risky given the nature of Top End soils. The placement of the tensiometers is important. They should be in pairs, and at the correct depth and distance from the trickle line to produce the desired wetting pattern and root zone volume.

2) The calibration of the tensiometers with soil moisture content and the estimation of available soil moisture content was conducted on the CPRS sandy red earths. This exercise should be carried out for all major soil types used for horticulture. A moisture tension of 20 cb was recommended for initiating irrigation.

3) The design root zone was defined at 20 cm depth and the maximum irrigation duration for a given trickle tape (approx. 2 hours) in one irrigation was calculated. Tensiometer placement is critical in establishing the wetted soil volume around the design root zone.

4) From many observations, knowledge of crop behaviour and climatic factors, and the performance of the tensiometers, irrigation is best carried out during the time of maximum plant stress (usually 1.00-3.00pm). It was also observed that crops up to 5 or 6 weeks of age can be successfully irrigated at any time of the day without suffering stress but more mature crops must be watered during this stress period.

5) Plastic mulch must be used on sandy soils to create an effective wetting pattern for root distribution and development.

6) It is recommended that 2 or more light irrigations be applied to maturing crops per day to maintain available water around the roots at a low soil moisture tension and to reduce wastage through deep percolation. Automatic irrigation controllers are considered essential to achieve this objective.

7) During hot weather late in the season a grower must be prepared to irrigate at least twice a day for a total of at least 3 hours per day to prevent plant stress.

8) Effective windbreaks will lower the consumptive water use by a crop by reducing transpiration from the leaf surface. Windbreaks will also reduce the damage to leaves which has a direct effect on fruit sugar levels and fruit quality.

9) The use of green manure crops to increase soil organic matter will gradually improve the water holding capacity of the soil. Their use is essential in light sandy soils and they should form an important component of the overall farm management system.

Appendix 2 contains some examples of irrigation scheduling exercises which are largely self explanatory. The example given is a grower who grows 40ha of melons over a 20 week growing period but would have 20ha in the ground at any one time. By irrigating twice a day the grower can reduce his peak water requirement to half the amount needed for one watering. They are designed to show the scheduling possibilities and to emphasize the very large quantities of water that is required to schedule water to the demands of the crop in a peak stress period. The grower in example 2 would have a very tight program which further reduces his peak water requirement but would be in difficulties when hot weather forces him to water three hours per day.

The irrigation research program, given the present resources and expertise, cannot go any further apart from refining current techniques. There are many grey areas that require additional work and the soil definition problems mentioned in the beginning of this section require specialist attention. Also considered important are the relationship of trickle discharge rate to wetting patterns, deep percolation and saturated hydraulic conductivity. This type of information is absolutely fundamental to the design and operation of irrigation scheduling systems. The research program has achieved what it set out to do and that is to establish the basic foundations for an irrigation scheduling system. However, further work is essential to further refine and develop these systems on the various horticultural soils of the NT.

The industry has, generally, accepted that there is a problem in melon irrigation in terms of quantity of water and frequency of application to crops. For some growers with limited water resources it would be in their interests to drastically reduce their acreages to fit their water availability and so improve their yields and fruit quality. The district average of 12-14 t/ha of marketable fruit could be easily doubled and possibly trebled without further inputs of technology or resources, simply by efficient water management. The industry trend must be towards vastly improved yields or returns per unit area by more intensive management, the use of automatic irrigation controllers and the capacity to irrigate at least two or three times per day on sandy soils.

Conventional irrigation theory and the use of evapotranspiration estimation systems, special formulas and some sophisticated instruments for measuring soil water potential are not effective under our climatic and soil conditions. The NT is going away from these conventional irrigation practices and developing systems that will suit our special conditions and problems. By doing this we must be aware of developments in other areas where similar soils exist. The Israeli experience on soils of low water holding capacity suggests that it is more appropriate to measure soil water movement in order to schedule irrigation rather than to use soil water potential when irrigating more than once per day.

APPENDICES

Appendix I contains some of the basic calculation used in estimating irrigation scheduling on the CPRS soils.

Appendix 2 is an attempt to simplify irrigation scheduling by making a number of broad assumptions and applying them to three examples. Perhaps the most significant aspect raised is the very large quantities of irrigation water that is required on mature crops over a short period of time. If more than one irrigation can be applied per day then the pumping requirement can be halved. The examples refer to an average melon farm that has 40 ha (100ac) of crop in over a 20 week period which is 20 ha (50ac) of crop in during a 10 week period, sown in 2.0 ha plantings.

APPENDIX I

CPRS red earth soil

Field capacity (FC) = 19.5%
Wilting point (WP) = 14.5%
Bulk density (BD) = 1.5 approximately
Total available water capacity (TAWC) = FC - WP
% volume basis = % weight basis x B.D.
1% of water content in soil = 10mm of water per meter depth of soil.

TAWC/1m depth = [FC (weight) - WP (weight)] x B.D. x 10mm
= (19.5 - 14.5) x 1.5 x 10
= 75mm water/ 1.0m depth.

Deisgn Root Zone (DRZ) = 20cm for rockmelons.

Design TAWC = 75mm x 0.2
= 15mm in first 20cm of soil.

Design Net Water Requirement (NWR) = Design TAWC X MAD (%)mm
where MAD = Management Allowable Deficit (assume 50%)

= 15 x 0.5
= 7.5 mm

(i) Using Bi-wall (R), discharge rate is 3.5 l/m/hr
= 3.5mm/m²/hr using 1.0m plastic mulch
ie $\frac{7.5}{3.5}$ = 2.1 hours maximum irrigation duration

(ii) Using T-Tape (R)

a. discharge 4.0 l/m/hr at 8 psi = 4.0mm/m²/hr
= $\frac{7.5}{4.0}$ = 1.9 hours maximum irrigation duration

b. discharge 5.0 l/m/hr at 15 psi = 5.0mm/m²/hr
= $\frac{7.5}{5.0}$ = 1.5 hours maximum irrigation duration

APPENDIX 2

MELON IRRIGATION (SANDY SOILS)

ASSUME

- Melons over 6 weeks old must be watered at critical stress time (1.00 - 3.00 pm)
- Melon blocks are 2.0 ha (5 ac) areas
- Irrigation requirement is 5000 gal/ha/hr
- Minimum of 2 hrs irrigation generally required

1. PLANTINGS ONE WEEK APART

Total Area = 20 ha (50 ac)

4 areas to be watered at once (8 ha)

pump capacity = 40,000 GPH

AGE	10	9	8	7	6	5	4	3	2	1	0 Wks
Block No.	1	2	3	4	5	6	7	8	9	10	
Irrign	2.0	2.0	2.0	2.0	1.5	1.5	1.0	1.0	0.5	0.5	Hrs

2. PLANTINGS TWO WEEKS APART

Total Area = 10 ha (25 ac)

2 areas to be watered at once (4 ha)

pump capacity = 20,000 GPH

AGE	10	8	6	4	2	0	WEEKS

1. IRRIGATION SCHEDULING

Plantings 1 week apart

Total Area = 10 x 2.0 ha blocks = 20 ha (50 ac)

Watering TWICE daily

Watering TWO plantings at once

Maximum irrigation time = 2 hours/day

TIME	PLANTINGS	IRRIGN PERIOD (HRS)	IRRIGN REQUIR (HRS)	DEFICIT
8.00am	10,9	0.5	0.5	-
8.30am	8,7	1.0	1.0	-
9.30am	6,5	1.0	1.5	0.5
10.30am	4,3	1.0	2.0	1.0
11.30am	2,1	1.0	2.0	1.0
12.30pm	6,5	0.5	0.5	-
1.00pm	4,3	1.0	1.0	-
2.00pm	2,1	1.0	1.0	-
3.00pm				

TOTAL IRRIGATION TIME = 7 HOURS

IRRIGATION REQUIREMENT = 2 x 2.0 ha = 4 ha

4 ha x 5000 GPH = 20,000 GPH

PLANTING 1,2,3,4,5 and 6 IRRIGATED
TWICE DAILY

2. IRRIGATION SCHEDULING

Plantings 1 week apart
Total area = 10 x 2.0 ha blocks = 20 ha (50 ac)
Watering TWICE daily
Watering ONE planting at once
Maximum irrigation time = 2 hours/day

TIME	PLANTING	IRRIGN PERIOD HRS	IRRIGN REQUIR HRS	DEFICIT
4.00am	10	0.5	0.5	-
4.30am	9	0.5	0.5	-
5.00am	8	1.0	1.0	
6.00am	7	1.0	1.0	
7.00am	6	1.0	1.5	0.5
8.00am	5	1.0	1.5	0.5
9.00am	4	1.0	2.0	1.0
10.00am	3	1.0	2.0	1.0
11.00am	2	1.0	2.0	1.0
12.00pm	1	1.0	2.0	1.0
1.00pm	6	0.5		
1.30pm	5	0.5		
2.00pm	4	1.0		
3.00pm	3	1.0		
4.00pm	2	1.0		
5.00pm	1	1.0		
6.00pm				

Total irrigation time = 14 hours

Irrigation requirement = 1 x 2.0 ha = 2.0 ha
2.0 ha x 5000 GPH = 10,000 GPH

Plantings 1,2,3,4,5,6 irrigated twice daily

3. IRRIGATION SCHEDULING

Plantings 1 week apart

Total area = 10 x 2.0 ha = 20 ha (50 ac)

Watering THREE times daily

Watering TWO plantings at once

Max irrigation time = 3 hours/day

TIME	PLANTINGS	IRRIGN PERIOD HRS	IRRIGN REQUIR HRS	DEFICIT
5.00am	10,9	0.5	0.5	-
5.30am	8,7	1.0	1.5	0.5
6.30am	6,5	1.0	2.0	1.0
7.30am	4,3	1.0	3.0	2.0
8.30am	2,1	1.0	3.0	2.0
9.30am	6,5	1.0		-
10.30am	4,3	1.0		1.0
11.30am	2,1	1.0		1.0
12.30pm	8,7	0.5		-
1.00pm	4,3	1.0		-
2.00pm	2,1	1.0		-
3.00pm				

TOTAL IRRIGATION TIME = 10 HOURS

IRRIGATION REQUIREMENT = 2 x 2.0 ha = 4 ha

4 ha x 5000 GPH/ha = 20,000 GPH

PLANTINGS 1,2,3,4, IRRIGATED 3 x DAILY

5,6,7,8 " 2 x DAILY