Mauritius Research Council

Late Production of Onion in the Region of La Marie/Glen Park

Final Report

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AGRICULTURAL RESEARCH AND EXTENSION UNIT
(Food and Agricultural Research Council)

Late production of onion in the region of La Marie/Glen Park

End of Project Report

by

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Executive summary

Onion is an important vegetable cash crop in Mauritius. It is grown mainly for the fresh market consumption and for storage. The local production of onion is highly seasonal with the bulk of the crop harvested around October to November. This results in a seasonal surplus production of 1600 to 1800 tonnes annually.

The aim of this project is to study the prospects of producing high quality onions in the late season in the region of La Marie. If onions could be produced during that period, these can be cured and stored by the farmers for sale as from February a period when the country depends on imported onions to satisfy the local requirement.

This project was implemented in order: (a) to study the performance of the onion crop at 3 planting dates namely the 28th of May, the 16th of June, and the 17th of July 1999 raised under 3 different water regimes namely, 0.5 ET_{crop} (I_1), 1.0 ET_{crop} (I_2) and 1.5 ET_{crop} (I_3) compared to the rainfed crop (I_0), and (b) to study the storage potential of the onion crop harvested at the 3 different planting dates and 4 water regimes. The project was implemented in an on-site field trial in a planter's field at La Marie.

Results show that a significant increase in the marketable onion bulb yield was obtained with increasing water regimes from the rainfed situation to 1.5 ET crop. With a delay in planting date from the 23rd of May to the 17th July, a significant drop in yield was obtained irrespective of water regimes. The most suitable water regimes for optimum crop yield was 263, 385 and 328 mm for the 3 respective planting dates. The highest crop water supply was required at the bulbing phase which starts at 2 to 2½ months after transplantation. When bulbification is delayed to the summer months, a high water supply of 40 to 60 mm was required weekly. If the bulbing phase occurs in late winter/early summer, a lower water supply of 20 to 25 mm was required.

As regards keeping quality the best storage performance was obtained with onions harvested from the second planting date with 82.6% of marketable onion, recovered after a storage period of 3 months.

Acknowledgement

We wish to express our gratitude to the following:

1. The Mauritius Research Council for having kindly provided part funding for the running of the project,

2. The management of Agricultural Research and Extension Unit for their support

3. The Sept Cascade Cooperative Society for their support for on-farm trial in the implementation of the project.

4. The Biometrician of AREU for guidance and statistical analysis.

1. Introduction

Onion is an important vegetable cash crop in Mauritius. It is grown mainly for the fresh market consumption and for storage. The local demand has been increasing over the last few years and is presently of the order of 10,000t annually. This is met partly by the local production which is around 6,000t annually and partly by imports. The gross annual market value of our production amounts to Rs60mm approximately.

The bulk of onion production is produced in three main localities, namely the South East costal belt (Belle Mare/Palmar/Trou d'Eau Douce and Grand Sable/Petit Sable), the Central West region (La Chaumière/La Ferme Bambous) and the South (La Marie/Glen Park/Closel and Mare Longue). The latter region accounts for about 35 to 40 per cent of the local production. There are about 400 onion growers in that region with plot sizes ranging from 0.10 to 1 hectare.

Onion production in Mauritius is highly seasonal with the bulk of the crop harvested around October to November. This results in a seasonal surplus production. About 1,600 to 1,800t of onions are purchased by the Agricultural Marketing Board from the local producers for storage under refrigerated conditions. This onion is released for sale by the AMB in period of shortages and furthermore, each year onion is imported by the AMB as from February till July in order to meet the local requirement.

In the region of La Marie/Glen Park, a period of rainfall deficit normally occurs during the months of October to December. This is perceived as a serious constraint to the production of onion bulbs in late December/ early January. If adequate irrigation facilities are provided, late production of high quality onion could be made possible. The onions could be cured and stored by the farmers for sale as from February, a period when the country depends on imported onions to satisfy the local demand.

During the technological review workshops and other interactive meetings between the research and extension staff of AREU and the onion growers of La Marie/Glen Park, the lack of irrigation facilities was identified as a serious constraint to the conduct of late production of onions in the month of late December/early January.

2. Aim of the project

The aim of this project is to study the prospects of producing high quality onions in the late season in the region of La Marie. If onions could be produced during that period, these can be cured and stored by the farmers for sale as from February a period when the country depends on imported onions to satisfy the local requirement. This will further assist in cutting down on the storage cost and losses incurred by the surplus crop produced during the peak harvest season of October to November.

3. Objectives of the project

The project was implemented with the following objectives

1. To study the performance of the onion crop at 3 planting dates namely the 28th of May, the 16th of June, and the 17th of July 1999 raised under drip irrigation.
2. To study the performance of the onion crop under 3 different water regimes namely, 0.5 ET_{crop} (I_1), 1.0 ET_{crop} (I_2) and 1.5 ET_{crop} (I_3) compared to the rainfed crop (I_0).

3. To study the storage potential of the onion crop harvested at the 3 different planting dates and 4 water regimes mentioned under objectives 1 and 2.

4. Materials and method

4.1 Experimental design and layout

The project was implemented in an on-site field trial in a planter's field at La Marie. The trial was performed using a split plot design with 4 replicates. The 3 planting dates were tested in the main plots and the 4 water regimes in the sub plots. The experimental layout is illustrated in the appendix annex 1.

4.2 Installation of the irrigation network

The source of water was obtained from river Tatamaka which is located 25m from the experimental plot. A water pump (fuel type having a discharge of 500 l/min at pressure head of 50m) was used to enable supply of water to the field. To prevent the clogging of the drippers along the dripper lines, a 50 mm screen filter was installed just after the pump. The irrigation system constituted of a main pipeline of 63mm and sub-main of 25mm. 3 Dripper lines, of the T-tape non-pressure compensated type, were connected to the sub-mains and were laid on each bed. (see layout in annex 1)

4.3 Cultural and crop management practices

4.3.1 Raising of onion seedlings

The onion seedlings required for the trial were raised on seedbeds. The land was prepared mechanically using power tillers so as to obtain a fine tilth. Gravels and pebbles were removed and beds of one metre large and 15cm deep were raised manually. Poultry manure and the complex fertilizer 13:13:20:2 were incorporated in the soil at the respective rate of $3kg/m^2$ and $60g/m^2$. The beds were then levelled. Onion seeds of the cultivar Sivan were then broadcasted on the beds at the rate of

10g/m^2. Sowing was performed on 3 dates namely, the 28th of May, 16th of June and the 17th of July 1999. 400g of seeds were used each time.

4.3.2 Land preparation and fertiliser application

The land was prepared mechanically at first with a tractor driven disc plough to loosen the soil and then later, a power filter was used to incorporate manure into the soil to a depth of 15cm. A fine tilth was obtained. Beds of one metre wide were raised manually to a length of 30m to constitute experimental plot of size of 30m^2. Manure was broadcasted at the rate of 2.5kg/m^2. The complex fertilizer 13:13:20:2 was applied at the rate of 60g/m^2 on the beds on the day of transplanting.

4.3.3 Transplantation

Onion seedlings were transplanted when they reached the 3-4 leaf stage which was attained at a plant height of 15-20 cm. The seedlings for the 3 sowing dates were transplanted on the 23rd of July, the 3rd of September and the 22nd of September 1999 respectively. Seedlings were transplanted at the spacing of 15 x10cm.

4.3.4 Pest and disease control

Just after sowing, the seedbeds were drenched with a mixture of Dithane M45 (2g/lt of water), Benlate (0.5g/Lt of water) and Dursban (4ml/lt of water) as a preventive control measure against damping off and ants.

Leaf miners were a major pest in nursery and were controlled with alternate applications of Vertimec (0.5ml/lt of water) and Patron (0.25g/lt of water). Yellow sticky traps were also used as a physical control. Weeds were controlled manually at two intervals before transplanting.

4.4 Management of the water regimes and Irrigation scheduling

The 4 water regimes namely $0.5ET_{crop}(I_1)$, $1.0\ ET_{crop}\ (I_2)$, $1.5\ ET_{crop}\ (I_3)$ and the rainfed level (I_0) over the crop cycle according to the different growth stages as shown in table 1.

Table 1: Crop coefficients and rooting depth of onion at different growth stages

Crop Growth Stages	Crop Coefficients (K_c)	Rooting depth, D (m)
Initial stage Soil surface is hardly covered by the crop at < 10%	0.500	0.005
Crop development stage From end of initial stage to attainment of effective full ground cover (70-80%)	0.750	0.075
Mid-season stage (bulb formation stage) From attainment of effective full ground cover to time of start of maturing	1.000	0.150
Late season stage From end of mid season stage until full maturity or harvest	0.875	0.200

4.4.1 Depth of irrigation and irrigation interval

The depth of irrigation water to be applied is calculated from the formula:

Depth of irrigation (d) = (P.Sa) D / Ea

Where P.Sa = readily available soil water (m)
D = Root zone depth (m)
Ea = Application efficiency (which is 0.9 for drip irrigation system)

The irrigation interval is calculated from the formula:

Irrigation interval (I) = (P.Sa) D / ET_{onion}

The methodology used for calculating the different water regimes to be applied to the experimental plots planted with crops of different planting dates is shown in annex 3.

Rainfall and evaporation data were taken from the National Meteorological Services on a weekly basis. These data were used to adjust the amount of water to be supplied under the different water regimes. The exact amount of water to be supplied to the experimental plots was controlled by volumetric valves that were operated weekly as shown in table 2 (see appendix- annex 2).

The three water regimes were independent of each transplanting date since the onion plants for each transplanting date were at different growth stages and were subject to different natural climatic conditions. In working out the irrigation schedule, 3 different irrigation intervals were obtained. As it was not possible for the farmer to cope, it was thus decided to operate the pump 3 times per week for 1 hour each time until the zero value was reached from the volumetric valves. This procedure was repeated on weekly basis.

Irrigation was stopped 15 days before the harvest when onion tops started to fall.

4.5 Harvesting

The onion bulbs were harvested when the tops began to break and fall, well before the complete drying of the foliage. The onion crop was pulled by hand and arranged into windows so that the bulbs were partly covered by the tops and hence preventing any sunscalding damage. After a field-curing period of 3 to 7 days, the tops were fairly well dried down, they were cut off using knives and scissors, at a length of 3 to 4 cm away from the bulbs. The roots were also trimmed.

4.6 Curing

Onion bulbs were thoroughly cured in a solar curing unit. The bulbs were placed in metallic crates, which were stacked vertically inside the facility until the onions were well cured. This was achieved in 7 to 10 days.

4.7 Cleaning and grading

Onions cured in the crates were cleaned and graded before they go into storage. Split and thick-necks bulbs were picked out. The loose outer scales are rubbed off, leaving the onion bright and clean.

4.8 Storage

The storage trial was carried out with fully cured onions at ambient conditions in a ventilated store at the planter's place in the region of La Marie. Onion bulbs weighing between 20 to 30 kg, from each treatment, were piled in onion bags. The storage trial was started at three respective dates after harvest and curing, namely 29th of November 1999, 20th of December 1999 and 27th December 1999. The onion bags for storage were laid on shelves in a factorial experiment using a completely randomised block layout with two replicates. Measurements of marketable weight were taken at monthly intervals after removal of rotten and sprout bulbs. The storage trial was completed by the 24th March 2000.

Onion bulbs were then graded into three categories according to size, namely category 1 ($\leq$ 4cm), Category 2 (4 $\leq$ Diameter $<$ 7cm) and Category 3 ($\geq$ 7cm). The onion bulbs were then piled in onion bags for storage.

5. Results and Discussion

The irrigation water requirement was supplied at the 3 water regimes under test namely, 0.5 ET_{crop}, 1.0 ET_{crop} and 1.5 ET_{crop}, taking into consideration the calculated crop evaporation rate, the crop development stage, the plant rooting depth and the weekly precipitation rate.

The total amount of water (in mm) supplied to the crop throughout the whole crop cycle for each plating date under the 3 respective water regimes (I_1, I_2, I_3) and the rainfed regime (I_0) is illustrated in table 3.

Table 3: Total amount of water supplied to the crop under different water regimes and planting dates

Planting dates		Water from drip irrigation (mm)			Total amount of water received from drip & rainfall (mm)		
	I_0	I_1	I_2	I_3	I_1	I_2	I_3
Planting date 1	207	56	125	194	263	332	401
Planting date 2	84	76	186	301	160	270	385
Planting date 3	104	81	224	359	185	328	463

It should be observed that the total amount of water supplied to the crop is composed of 2 fractions namely the amount derived from rainfall and the amount supplemented by drip irrigation.

5.1 Crop performance at different planting dates and water regimes

The performance of the onion crop cultivar Sivan at the 3 planting dates and 4 water regimes in terms of the marketable onion bulb yield is shown Table 4.

Table 4: **Marketable onion bulb yields of onion cultivar Sivan at different planting dates and water regimes.**

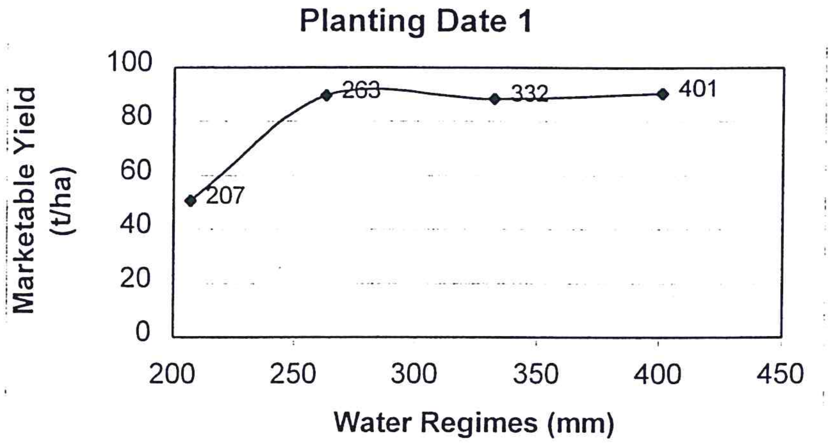
Irrigation Regimes	Marketable bulb yield (t/ha)			Average Yield
	Planting. Date 1	Planting. Date 2	Planting Date 3	
I0	50.60	25.0	13.0	29.53
I1	89.60	39.9	20.8	50.10
I2	88.30	45.3	24.2	52.60
I3	90.50	62.0	23.4	58.63
Average yield	79.70	43.00	20.30	
S.E.	4.39	2.59	1.21	

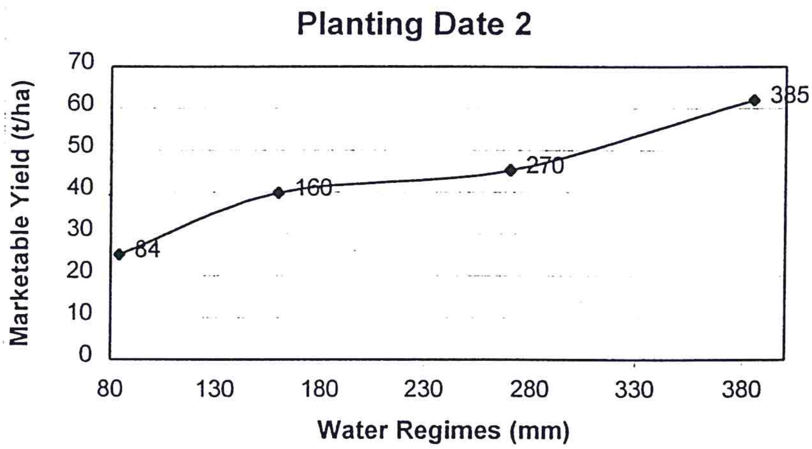
A significant increase in the marketable bulb yield from 50.6 to 90.5 t/ha (for the first planting date), from 25.0 to 62 t/ha (for the second planting date) and from 13 to 23.4 t/ha (for the third plating date) was observed with increasing water regimes from the rainfed situation (I_0) to 1.5 ET_{crop} (I_3).

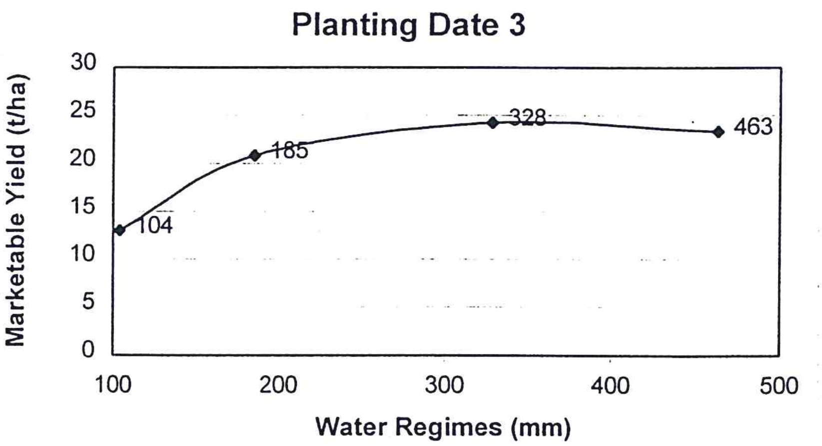
With a delay in planting date from the 28th of May (PD1) to the 17th of July 99 (PD3), a significant drop in yield from 89.60 to 20.8 t/ha (for the 0.5 ET_{crop} regime), from 88.3 to 24.2 t/ha (for the 1.0 ET_{crop} regime) and from 90.5 to 23.4 t/ha (for the 1.5 ET_{crop} regime) was observed. This represented a quarter-fold decrease in yield on the average.

The yield response with respect to increasing water regimes for each planting date is graphically represented in Figure 1.

Figure1: Marketable onion bulb yield of onion cultivar Sivan at different planting dates and water regimes.







It can be observed that for the first planting date, 263 mm of water was enough to produce a significant increase in marketable yield whereas, for the second and third planting dates, 385 mm and 328 mm of water were required to bring about any significant increase in bulb yield.

Any increase in water regimes beyond 263 mm, 385 mm, and 328 mm for the 3 respective planting dates did not contribute towards a significant increase in yield as indicated by the trend observed in Figure 1.

5.2 Water deficit under the rainfed regimes

The water regimes namely 263, 385 and 328 mm that produced highest bulbs yields at the 3 different respective planting dates were compared with the 3 prevailing rainfed water regimes namely 207, 84 and 104 mm. It can be observed that the percentages of water deficit occuring in the three different situations were 27%, 358% and 215% respectively.

The weekly rainfall distribution prevailing at the experimental site from the date of transplantation until crop maturity is graphically shown for each planting date under test (see figure 2, 3 and 4). These were matched with the most suitable water regime for the three respective planting dates, that is 263 mm for planting date 1, 385 mm for planting date 2 and 328 mm for planting date 3.

Figure 2: Distribution of the applied water regime (I1) and rainfall from time of transplantation until crop maturity (planting date 1)

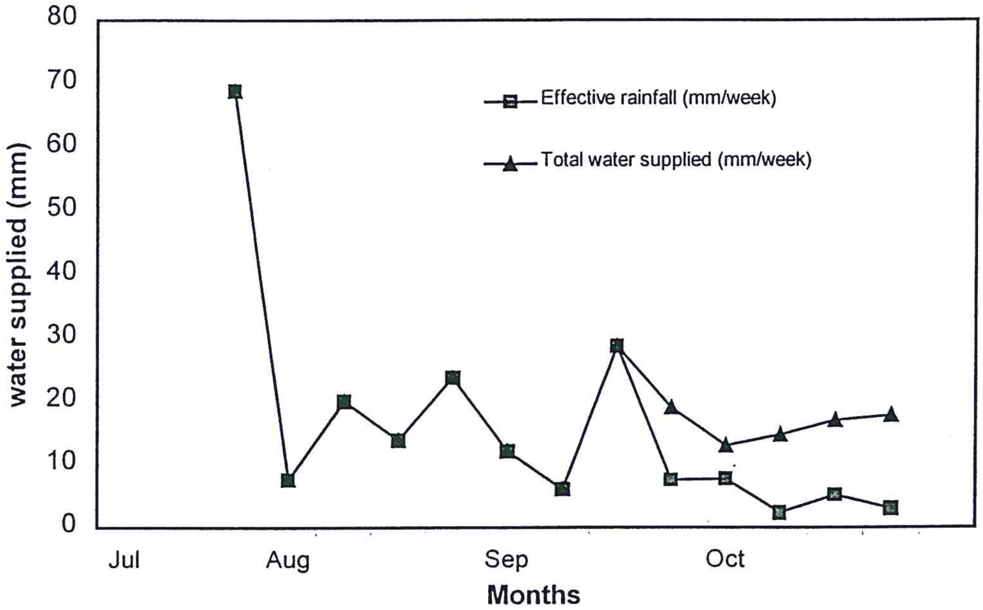


Figure 3: Distribution of the applied water regime (I3) and rainfall from the time of transplantation until crop maturity (planting date 2)

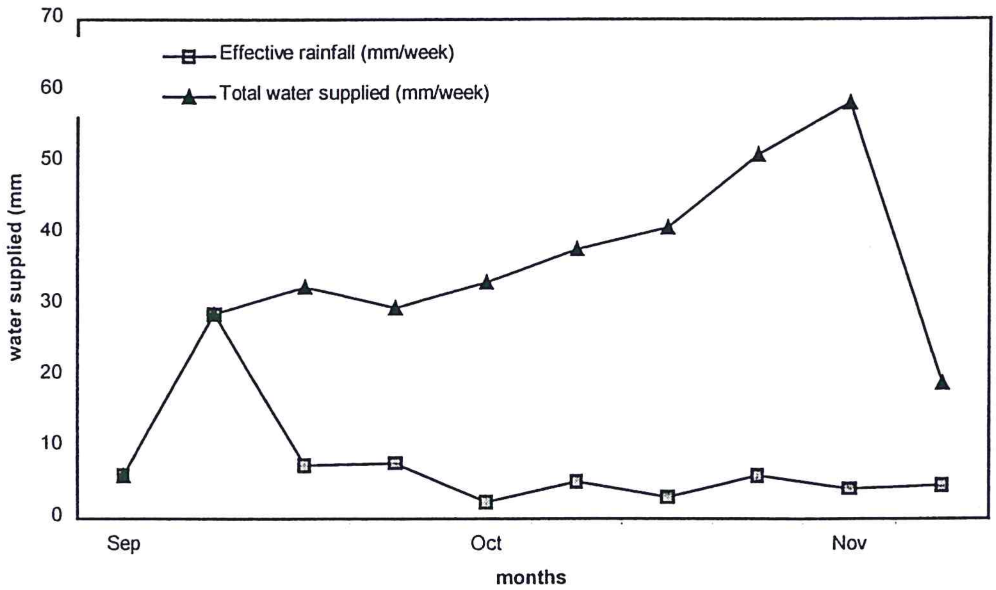
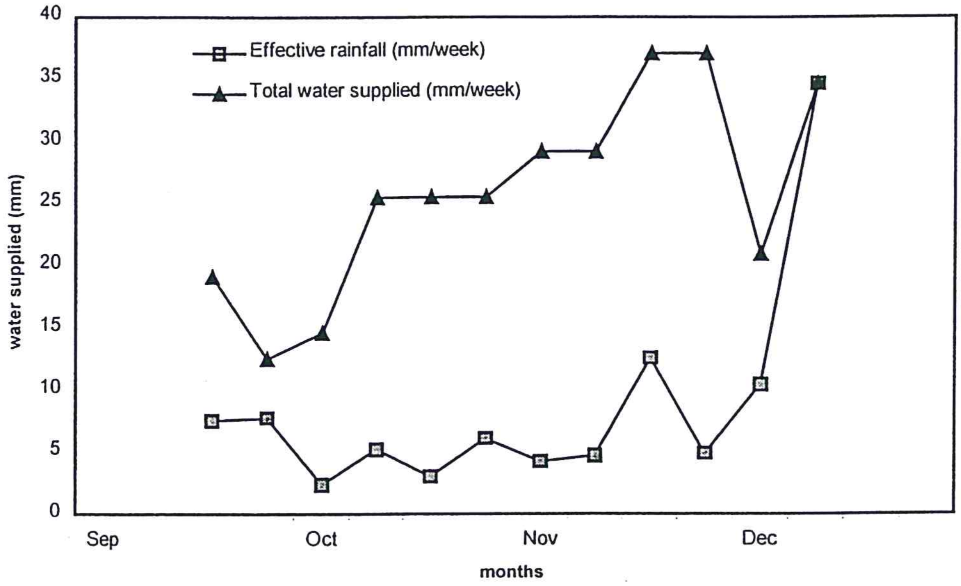


Figure 4: **Distribution of the applied water regime (I2) and rainfall from the time of transplantation until crop maturity (planting date 3)**



It can be observed that in all the three situations, highest crop water supply was required at the bulbing phase which normally starts at 2 to 2 1/2 months after transplantation. This also indicates that under the rainfed water regimes, highest water deficit occurred during the bulbing phase.

When bulbification is delayed to the summer months as in the second and third planting dates, a water supply of the order of 40 to 60 mm/weekly is required. If the bulbing phase occurs in late winter/ early summer, a lower water supply of the order of 20 to 25 mm is required.

5.3 Effect of plating date and water regime on the onion bulb size

The harvested onion bulbs for the 3 planting dates and under the 4 water regimes were separated into 3 bulb sizes namely, small, medium, and large with bulb diameters of < 4 cm, 4 –7 cm, and > 7 cm respectively. The harvested fraction belonging to each bulb size was expressed as a percentage of the total marketable yield for each planting date and water regime. The results are illustrated in Table 5 and figure 5.

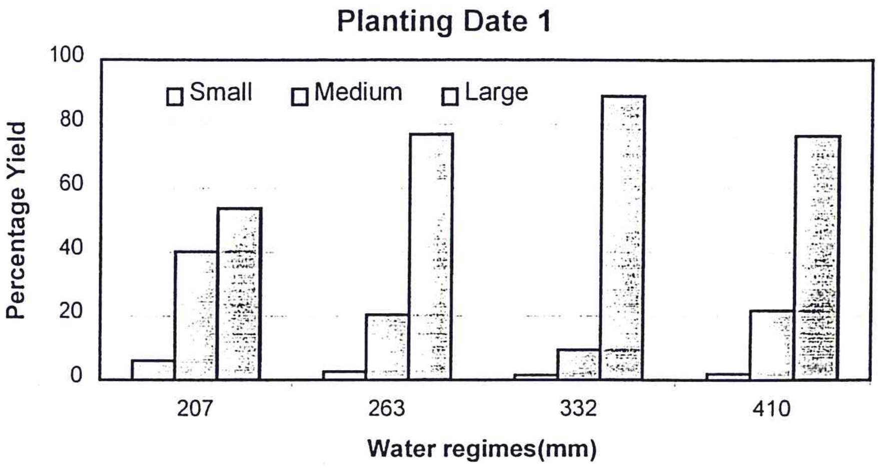
Table 5: Size distribution (% total marketable yield) of onion bulbs harvested from different planting dates and water regimes.

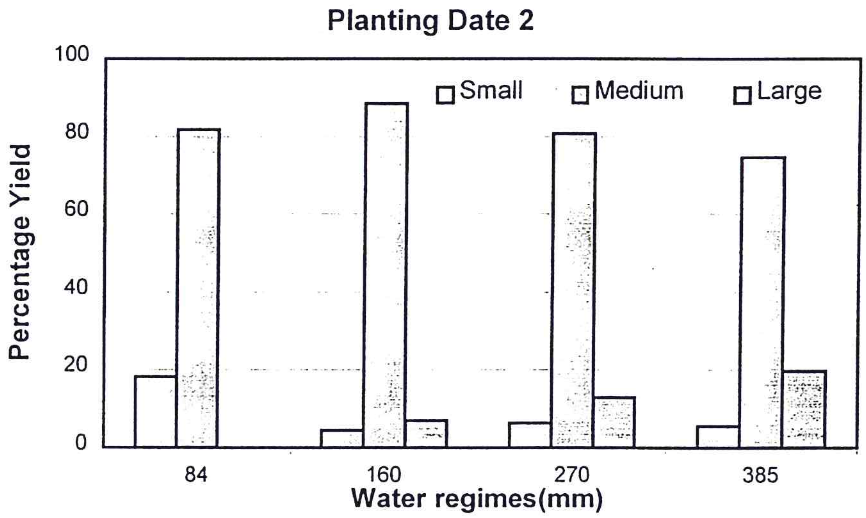
	Planting Date 1			Planting Date 2			Planting Date 3		
Water Regimes	Small	Medium	Large	Small	Medium	Large	Small	Medium	Large
I0	6.05	40.14	53.81	18.18	81.82	0.00	53.29	46.71	0.00
I1	2.64	20.43	76.93	4.48	88.6	6.92	20.13	79.87	0.00
I2	1.57	9.53	88.90	6.38	80.72	12.90	13.48	86.52	0.00
I3	1.98	21.70	76.32	5.61	74.62	19.77	14.54	85.46	0.00
S.E.	0.28	2.01	5.89	0.37	2.95	1.66	0.63	1.74	0.00

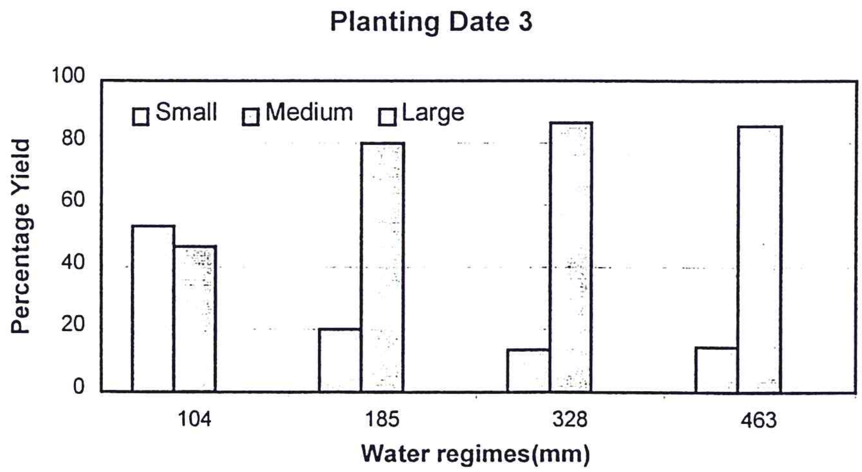
It was observed that a higher percentage of large bulbs, ranging from 53.81 to 76.32 %, was obtained from the crop produced at the first planting date compared to the second and third planting date. No large bulbs were obtained at the third planting date. The crops produced from the second and third planting dates contained a higher percentage of medium sized bulbs ranging from 74.62 to 88.6% for the irrigated treatments.

Considering the effect of water regimes on bulb sizes, it was observed that increasing water regimes tend to produce onion bulbs of bigger sizes irrespective of planting dates.

Figure 5: Size distribution of onion bulbs harvested from different planting dates and water regimes.







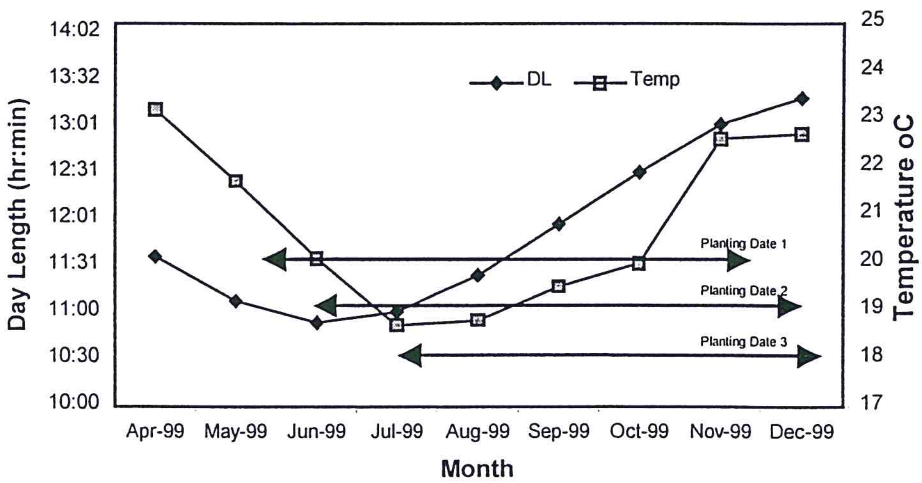
5.4 Effect of plating date on crop duration and performance

The vegetative crop development in onion is normally favoured by a period of short daylength coupled with low temperatures around 18°C. The bulbing phase, on the other hand, is triggered by a period of increasing daylength coupled with increasing temperatures.

The shift in the onion planting date from the 28th of May (the first planting date) to the 17th of July 1999 (the third planting date) has been observed to cause o reduction in the crop cycle from 175 days (23 weeks) to151 days (21 weeks).

The mean daily temperature and daylength prevailing throughout the experimental period were collected as secondary data from the Meteorological Services. These fluctuations were graphically represented from the month of May to December 1999 as shown in Figure 6. The 3 planting dates under test have been located and matched to the existing daylength and temperature fluctuations shown in the figure 6.

Fig. 6: Day Length Variation for the Onion Planting Season at La Marie



It can be seen that the crop raised from raised from the first planting date benefited from a longer period of exposure to conditions of low temperature and short daylength resulting in a better and more vigorous vegetative crop growth and development when compared to the crops raised from the second and third planting dates. This has led to the best crop performance in terms of a high average marketable onion yield of 79.70 t/ha recorded over a crop cycle of 175 days (23 weeks) for the first planting date.

The crop raised from the third planting date underwent a shorter and less vigorous vegetative phase resulting in a reduced average bulb yield of 20.3 t/ha over a crop cycle of 151 days (21 weeks).

5.5 Storage performance

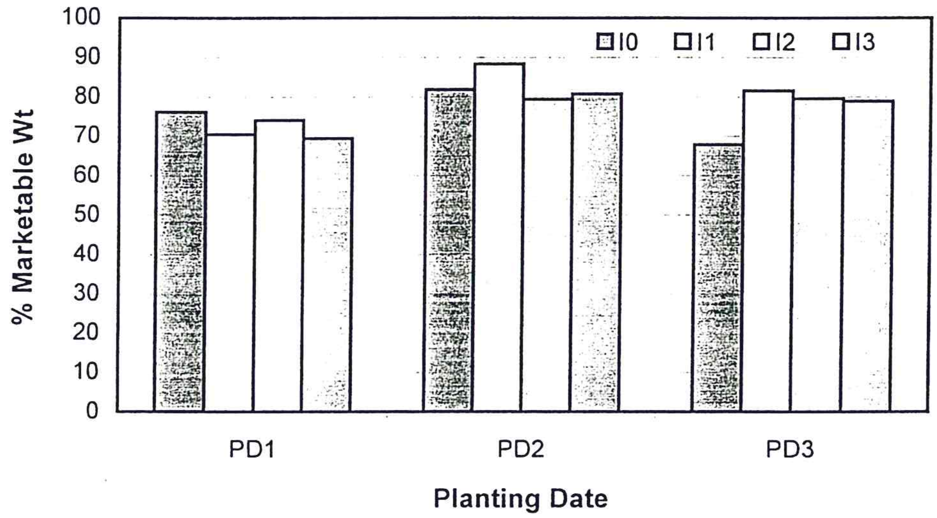
The storage performance of the onion bulbs harvested at the 3 different planting dates and under the 4 water regimes was evaluated at ambient conditions at the farmer's premises in La Marie. Regular assessment of the storage losses was performed which consisted of recording the actual weight of the marketable onion bulbs after deduction of the sprouted and rotten bulbs.

The results of the storage performance in terms of the percentage of marketable onion bulbs recovered after a storage period of 3 months are illustrated in Table 6 and Figure 7.

Table 6: storage performance of onion bulbs after 3 months in La Marie

Irrigation Regimes	Percentage of marketable onion bulbs (%)			Average
	Planting. Date 1	Planting. Date 2	Planting Date 3	
I0	76.2	81.9	67.9	75.3
I1	70.6	88.3	81.6	80.2
I2	74.1	79.4	79.6	77.7
I3	69.5	80.8	78.9	76.4
Average	72.6	82.6	77.0	

Figure 7: Storage performance of onion bulbs after 3 months in La Marie



It was observed that irrespective of water regimes, the onion bulbs harvested from the second planting date produced the best storage performance with a higher percentage of marketable bulbs (82.6 %) compared to the first planting date (72.6 %) and the third planting date (77.0 %). However, no significant difference was found between the treatments at the 5% level

Considering the crop storage performance with increasing water regimes at each planting date, a reduction in the amount of marketable onion bulbs varying from 1 to 8 % was observed from the crop at the highest water regimes.

Conclusion

1. A significant increase in the marketable onion bulb yield was obtained with increasing water regimes from the rainfed situation to 1.5 ET crop.

2. With a delay in planting date from the 23rd of May to the 17th July, a significant drop in yield was obtained irrespective of water regimes. This represented a quarter fold decrease in yield on the average. The Sowing date can be delayed up to the 16th of June when the average yield of 43t/ha was still profitable. At the third planting date, the average low yield of 203t/ha was not profitable taking into account that the estimated break-even yield is 16t/ha.

3. The most suitable water regimes for optimum crop yield was 263, 385 and 328mm for the 3 respective planting dates.

4. The highest crop water supply was required at the bulbing phase which starts at 2 to 2½ months after transplantation. When bulbification is delayed to the summer months, a high water supply of 40 to 60mm was required weekly. If the bulbing phase occurs in late winter/early summer, a lower water supply of 20 to 25mm was required.

5. A high percentage of large bulb (> 7cm in diameter) was obtained from the corps produced at the first planting date. The onion crop produced at the second planting date produced mostly medium sized bulbs of 4 to 7cm in diameter.

6. Onions harvested from the second planting date produced the best storage performance with 82.6% of marketable onion, recovered after a storage period of 3 months.

7. Late production of onion in La Marie/Glen Park with the cultivar, Sivan is possible with a delayed sowing date of up to the 16th of June coupled with an appropriate water regime of 385 mm. A yield of about 42t/ha can be expected. Beyond the sowing date of 16th of June, the yield potential of the crop is adversely affected even with adequate water supply. This is due to less favourable short day length and low temperature conditions which adversely affect the vegetative crop growth and development.

Annex 1

MRC project: Late production of onion at La Marie - Lay out

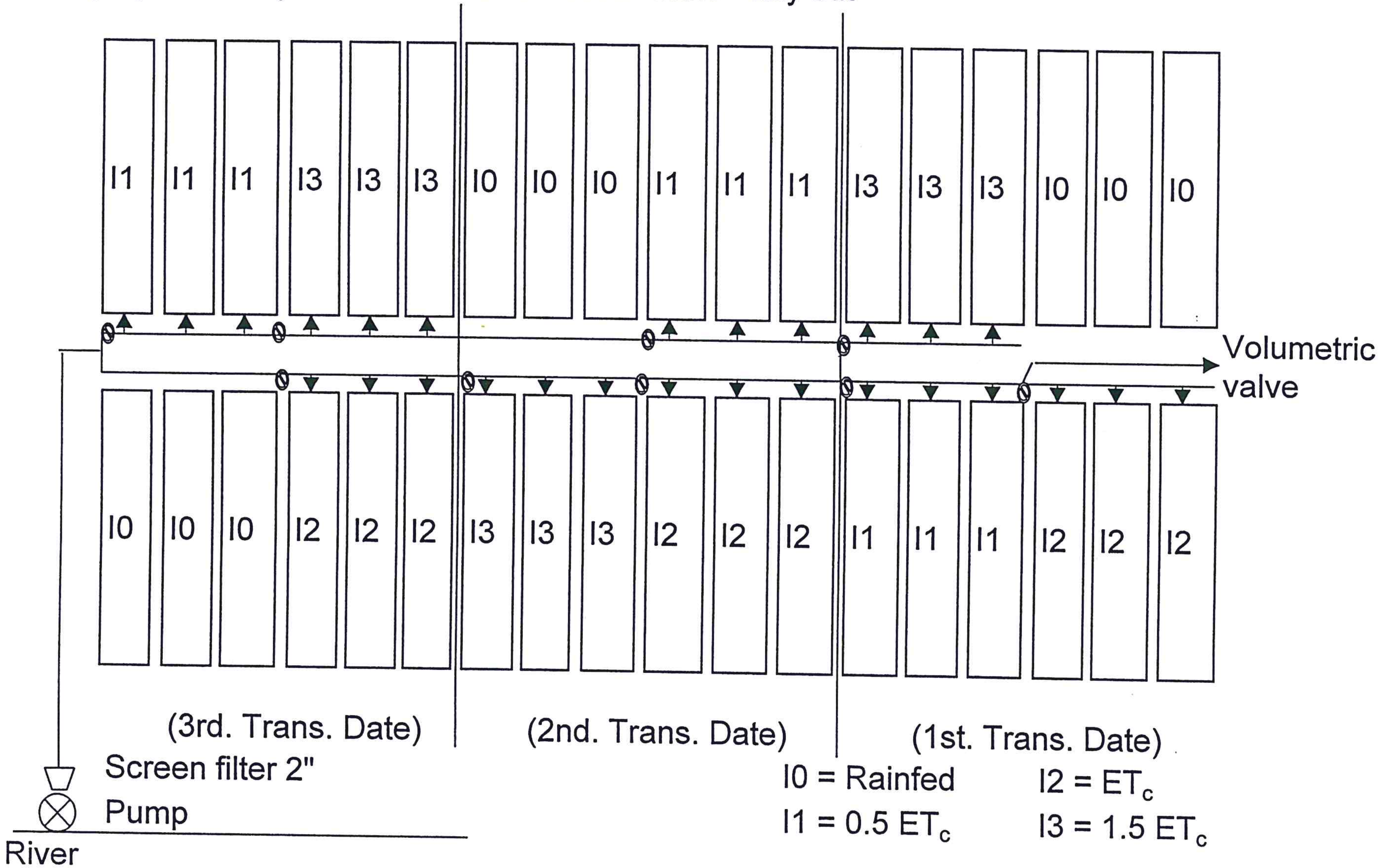


Table 1.0: Irrigation scheduling for the project entitled "Late production of onion at La Marie"

First transplanting date: 23/07/99

Crop stage	Dates	Rainfall (mm/week)	Evaporation (mm/week)	Evapotranspiration (mm/day)				Rooting depth, D (m)	Irrigation depth, d (mm)	Irrigation interval I (days)			Irigation water requirement mm/week			Irigation water requirement m^3/week		
				Control	0,5 ET_c	ET_c	1,5 ET_c			0,5 ET_c	ET_c	1,5 ET_c	0,5 ET_c	ET_c	1,5 ET_c	0,5 ET_c	ET_c	1,5 ET_c
Mid-Season	9/29/99	9.4	25.9	0	1.48	2.96	4.44	0.15	7.58	4.6	2.3	1.5	8.75	17.50	25.00	2.0	3.75	6.0
	10/6/99	9.7	29.0	0	1.65	3.30	4.95	0.15	7.58	4.1	2.1	1.4	5.18	17.54	30.14	1.0	3.0	5.0
	10/15/99	3.0	32.9	0	1.88	3.76	5.64	0.15	7.58	3.6	1.8	1.2	12.34	27.08	41.82	2.0	4.5	7.0
	10/22/99	6.5	37.8	0	2.16	4.32	6.48	0.15	5.83	2.4	1.2	0.8	11.80	28.80	45.80	2.0	5.0	7.5
	10/29/99	3.8	39.3	0	2.25	4.50	6.75	0.15	5.83	2.3	1.2	0.8	17.74	34.00	51.00	2.5	5.0	8.0
												Total	55.81	124.92	193.76	9.5	21.3	33.5

Second transplanting date: 03/09/99

Crop stage	Dates	Rainfall (mm/week)	Evaporation (mm/week)	Evapotranspiration (mm/day)				Rooting depth, D (m)	Irrigation depth, d (mm)	Irrigation interval I (days)			Irigation water requirement mm/week			Irigation water requirement m^3/week		
				Control	0,5 ET_c	ET_c	1,5 ET_c			0,5 ET_c	ET_c	1,5 ET_c	0,5 ET_c	ET_c	1,5 ET_c	0,5 ET_c	ET_c	1,5 ET_c
Crop devlopment stage	9/29/99	9.4	25.9	0	1.11	2.22	3.33	0.005	0.25	0.2	0.1	0.07	8.75	17.50	25.00	1.5	3.0	4.0
Crop devlopment stage	10/6/99	9.7	29.0	0	1.24	2.48	3.71	0.075	3.80	2.8	1.4	0.9	1.74	11.24	21.84	0.5	2.0	4.0
Crop devlopment stage	10/15/99	3.0	32.9	0	1.41	2.82	4.23	0.075	2.40	2.4	1.2	0.8	8.65	19.71	30.76	1.5	3.25	5.0
Crop devlopment stage	10/22/99	6.5	37.8	0	1.62	3.24	4.86	0.075	2.92	1.6	0.8	0.54	7.58	20.32	32.65	1.5	3.5	5.5
Crop devlopment stage	10/29/99	3.8	39.3	0	1.69	3.38	5.06	0.075	2.92	1.6	0.8	0.5	9.74	22.51	37.84	1.75	3.75	6.25
Mid-Season stage	11/6/99	7.6	37.1	0	2.12	4.24	6.36	0.15	5.83	2.5	1.2	0.8	10.25	27.93	44.93	2.0	4.5	7.5
Mid-Season stage	11/13/99	5.3	43.2	0	2.50	5.00	7.50	0.15	5.83	2.1	1.05	0.7	15.20	34.63	54.06	2.0	4.0	6.0
Mid-Season stage	11/19/99	5.9	42.4	0	2.44	4.88	7.32	0.15	5.83	2.15	1.1	0.7	14.26	32.38	53.38	2.5	5.25	9.0
												Total	76.17	186.22	300.46	13.3	29.3	47.3

Annex 2 (b)

Third transplanting date: 22/09/99																		
Crop stage	Dates	Rainfall (mm/week)	Evaporation (mm/week)	Evapotranspiration (mm/day)				Rooting depth, D (m)	Irrigation depth, d (mm)	Irrigation interval I (days)			Irigation water requirement					
													mm/week			m^3/week		
				Control	0,5 ET_c	ET_c	1,5 ET_c			0,5 ET_c	ET_c	1,5 ET_c	0,5 ET_c	ET_c	1,5 ET_c	0,5 ET_c	ET_c	1,5 ET_c
Initial Stage	9/29/99	9.4	25.9	0	0.74	1.48	2.22	0.005	0.25	0.3	0.15	0.1	5.83	11.60	17.50	1.00	2.00	3.00
Initial Stage	10/6/99	9.7	29.0	0	0.83	1.65	2.48	0.005	0.25	0.3	0.14	0.1	0.00	4.74	9.74	0.00	1.00	2.00
Initial Stage	10/15/99	3.0	32.9	0	0.94	1.88	2.82	0.005	0.25	0.24	0.12	0.08	4.89	12.18	19.48	1.0	2.0	3.25
Crop devlopment stage	10/22/99	6.5	37.8	0	1.62	3.24	4.86	0.075	2.92	1.6	0.8	0.54	7.58	20.32	32.65	1.5	3.5	5.5
Crop devlopment stage	10/29/99	3.8	39.3	0	1.69	3.38	5.06	0.075	2.92	1.6	0.8	0.5	9.74	22.51	37.84	2.0	4.0	6.0
Crop devlopment stage	11/6/99	7.6	37.1	0	1.59	3.18	4.77	0.075	2.92	1.7	0.8	0.6	5.94	19.47	27.99	1.0	3.25	4.5
Crop devlopment stage	11/13/99	5.3	43.2	0	1.88	3.75	5.63	0.075	2.92	1.4	0.7	0.5	10.36	24.96	36.64	2.5	5.5	9.0
Crop devlopment stage	11/19/99	5.9	42.4	0	1.83	3.66	5.49	0.075	2.92	1.4	0.7	0.5	9.88	24.48	36.16	2.0	4.0	6.0
Mid-Season stage	11/24/99	15.7	40.3	0	2.3	4.60	6.9	0.15	5.83	2.3	1.1	0.8	5.18	24.54	38.45	1.0	4.0	6.25
Mid-Season stage	11/27/99	6.1	42.5	0	2.44	4.88	7.32	0.15	5.83	2.15	1.1	0.7	14.10	32.22	53.42	2.5	5.25	9.0
Mid-Season stage	12/4/99	13.1	40.6	0	2.32	4.64	6.96	0.15	5.83	2.3	1.1	0.8	7.26	26.62	40.52	1.25	4.5	6.75
Mid-Season stage	12/10/99	43.3	32.1	0	1.84	3.68	5.52	0.15	5.83	2.85	1.43	0.95	0.00	0.00	8.32	0.0	0.0	1.5
												Total	80.76	223.64	358.71	15.8	39.0	62.8

Annex 3

Calculation of irrigation schedule

Example: 4 th. schedule

(1) Rainfall: 6.5 mm/week (09/10/99 to 15/10/99)
(2) Effective rainfall: 6.5 × 0.8 = 5.2 mm/week
Where 0.8 is the rainfall coefficient
(3) Evaporation: 37.8 mm/week (5.4 mm/day)
(4) ET_0 = Evaporation × K_p = 5.4 × 0.8 = 4.32 mm/day
where K_p is the pan coefficient
(5) Evapotranspiration (ETcrop)

(a) First transplanting date
Growth stage: Mid season (Kc = 1.0)
(i) 0.5 ETcrop = 0.5 × 4.32 × 1.0 = 2.16 mm/day
(ii) ETcrop = 4.32 × 1.0 = 4.32 mm/day
(iii) 1.5 ETcrop = 1.5 × 4.32 × 1.0 = 6.48 mm/day

(b) Second transplanting date
Growth stage: Crop Development (Kc = 0.75)
(i) 0.5 ETcrop = 0.5 × 4.32 × 0.75 = 1.62mm/day
(ii) ETcrop = 4.32 × 0.75 = 3.24 mm/day
(iii) 1.5 ETcrop = 1.5 × 4.32 × 0.75 = 4.86 mm/day

(c) Third transplanting date
Growth stage: Crop Development (Kc = 0.75)
(iv) 0.5 ETcrop = 0.5 × 4.32 × 0.75 = 1.62mm/day
(v) ETcrop = 4.32 × 0.75 = 3.24 mm/day
(vi) 1.5 ETcrop = 1.5 × 4.32 × 0.75 = 4.86 mm/day

(6) Depth of irrigation (d) = (P.Sa)D / Ea
Where P.Sa = readily available soil water
D = root zone depth
Ea = Application efficiency (0.9 for drip irrigation)

(a) First transplanting date (D = 0.15m)
d = (35 × 0.15)/ 0.9 = 5.83 mm

(b) Second transplanting date (D = 0.075m)
d = (35 × 0.075)/ 0.9 = 2.92 mm

(c) Third transplanting date (D = 0.075m)
d = (35 × 0.075)/ 0.9 = 2.92 mm

(7) Irrigation interval (I) = (P.Sa)D / ETcrop

(a) First transplanting date

I1 = (35 × 0.15)/ 0.5 ETcrop = (35 × 0.15)/ 2.16 = 2.4 days

I2 = (35 × 0.15)/ ETcrop = (35 × 0.15)/ 4.32 = 1.2 days

I3 = (35 × 0.15)/ 1.5 ETcrop = (35 × 0.15)/ 6.48 = 0.8 day

(b) Second transplanting date

I1 = (35 × 0.075)/ 0.5 ETcrop = (35 × 0.075)/ 1.62= 1.6 days

I2 = (35 × 0.075)/ ETcrop = (35 × 0.075)/ 3.24 = 0.8 days

I3 = (35 × 0.075)/ 1.5 ETcrop = (35 × 0.075)/ 4.86 = 0.54 day

(c) Third transplanting date

I1 = (35 × 0.075)/ 0.5 ETcrop = (35 × 0.075)/ 1.62= 1.6 days

I2 = (35 × 0.075)/ ETcrop = (35 × 0.075)/ 3.24 = 0.8 days

I3 = (35 × 0.075)/ 1.5 ETcrop = (35 × 0.075)/ 4.86 = 0.54 day

(8) Irrigation water requirement

(a) First transplanting date

I1 = 11.8 / 1000 × 162 = 1.9 m^3

I2 = 28.8 / 1000 × 162 = 4.7 m^3

I3 = 45.8 / 1000 × 162 = 7.4 m^3

note: 5.83 mm → 2.4 days

17mm ← 7 days

17 mm – effective rainfall = 17 – 5.2 = 11.8mm

(b) Second transplanting date

I1 = 7.575/ 1000 × 162 = 1.2 m^3

I2 = 20.32 / 1000 × 162 = 3.3 m^3

I3 = 32.65 / 1000 × 162 = 5.3 m^3

(c) Third transplanting date

I1 = 7.575/ 1000 × 162 = 1.2 m^3

I2 = 20.32 / 1000 × 162 = 3.3 m^3

I3 = 32.65 / 1000 × 162 = 5.3 m^3