SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

4210/1 SOIL MOISTURE INVESTIGATION

TERMINAL REPORT Cat No.: 1362

Object: To examine the soil moisture characteristics and crop water withdrawal patterns of the Chisumbanje basalt derived vertisols, in order to provide an understanding of sugarcane responses to irrigation scheduling deficits recorded in Trials 4200/10 and 4200/9.

Duration of Investigation: Third ratoon crop of 4200/10 Irrigation x Nitrogen Trial 1981-82.

Location: Chisumbanje Experiment Station.

Soil type: Chisumbanje 3B.2 series, heavy basalt clay ± 120 cm deep.

Statistical: Randomised soil sampling was imposed on 4200/10 and adjacent fallow land.

Treatments: Whole plot treatments of 4200/10 were four irrigation scheduling regimes based on accumulative evaporation deficits from an U.S.W.B. modified Class 'A' open pan, viz.

I1. Irrigate at accumulated pan deficit of 40 mm
I2. " " " " " " 80 mm
I3. " " " " " " 120 mm
I4. " " " " " " 160 mm

An in-row furrow system of irrigation was practised in the trial and the amount of water applied per irrigation was measured onto the plots to approximate the estimated deficit plus an efficiency factor.

Conduct

1. Bulk density was determined at various sites to obtain an adequate range of soil moisture conditions. Samples were taken from depths of 0-25 cm, 25-50 cm, 50-75 cm.

2. Drainage plots were established and both covered and uncovered plots were sampled to a depth of 1m at intervals until 39 days after saturation.

3. The moisture content of the soil profile was determined by augar sampling on a number of occasions, in all 4 treatments, on the days prior to and following a scheduled irrigation.

4. Pressure membrane apparatus was used to determine the moisture retention characteristics of this soil at soil suction potentials of 0,33; 1,0; and 15 bars.

2/Results....

RESULTS

a) Bulk density: Single bulk density values cannot be used for swelling soils, such as these Chisumbanje basalts, as the bulk density changes with soil moisture content. Figure 1 shows the relationship between bulk density and gravimetric moisture content, including data from 3 soil depths.

Linear regression lines were fitted to the data with the following equations:

Depth	Equation	n	r^2
0 - 25 cm	B.D. = 1,35 - 0,0061 W	38	0,41
25 - 50 cm	B.D. = 1,39 - 0,0070 W	41	0,32
50 - 75 cm	B.D. = 1,39 - 0,0068 W	40	0,42
All depths	B.D. = 1,38 - 0,0066 W	119	0,37

where B.D. = Bulk density g cm^{-3}.
and W = Soil moisture content by weight.

There was a slight increase in bulk density with depth at equivalent moisture content, due to increasing compaction with depth, but this was small and the general relationship for all depths has been used in this report in converting gravimetric to volumetric moisture contents.

b) Drainage moisture profiles: The total moisture contents of the 1m soil profile up to 39 days after ponding, for both the covered and uncovered sampling areas, are shown in Figure 2.

The covered profile curve represents the loss of moisture through soil drainage. The highest rate of loss by drainage occurs in the first 6 days after ponding and there is a gradual but continuous loss therafter. However, the initial higher rate of loss (16 mm in 6 days) is small, representing only 2,8% of the total initial soil profile moisture.

The uncovered profile curve shows loss of water in time by both drainage and evaporation, with the greatest rate of loss occurring in the first 6 days. A comparison of the two curves indicates that a high proportion of the loss from the uncovered site was by evaporation.

c) Post-irrigation moisture profiles:(Table 1). The highest moisture contents in the soil profile 1 day after irrigation are recorded in the upper horizon grading down to relatively low levels in the lowest horizon, reflecting the poor water infiltration that occurs after surface saturation. There is some variability between sampling occasions but higher values of moisture content after irrigation are not apparently related to drier soil moisture conditinns before irrigation. The Standard Deviation and C.V. % are sufficiently acceptable to indicate that the mean figures of post-irrigation soil moisture content are a reasonable representation of the average field capacity, and will be used hereafter as such.

3/d) Laboratory....

d) Laboratory determination of soil moisture retention: Results of pressure-membrane determination of soil moisture retention at suction potentials of 0,33, 1,0 and 15 bars are presented in Table 2 in both gravimetric and volumetric terms. The soil moisture content at a tension of 0,33 bars is considerably higher than that obtained for field capacity, particularly in the lower horizons of the soil profile (cf Table 1), and the field data are more representative of the upper limit of available moisture under irrigation conditions.

The readily available moisture (RAM) and total available moisture (TAM) values obtained in this investigation are shown in Table 3. RAM values are very low, approximately 20% of TAM.

e) Soil Moisture withdrawal: (Table 4.) For all treatments, soil moisture withdrawal was less than open pan deficits between irrigations, and this was particularly marked in the high deficit treatments.

In the I1 treatment $\geq$ 70% of the total water used was withdrawn from the upper 25 cm of soil and in the other 3 treatments about 60% of the water was obtained from this horizon. Approximately 80% of moisture withdrawal in all treatments was from the upper 50 cm, indicating that even under conditions of severe moisture stress, there is only limited root penetration into the lower soil horizon because of reduced readily available moisture at those depths.

Limited root sampling was undertaken which indicated that 50% of the root development was in the upper 25 cm of the soil profile.

DISCUSSION

The drainage plots showed that the highest rate of loss occurred in the first 6 days and a gradual loss continued thereafter. An irrigated growing crop would utilise a proportion of this drainage loss, particularly as it is retained by the soil at low moisture tensions, and the loss would be even lower under these conditions. If field capacity measurements are delayed until 6 days after ponding when the bulk of the drainage is completed this would not represent the true upper limit of available water to the crop. A more satisfactory indication of the upper limit of available water to the crop was obtained from measurements recorded after free water had drained from the soil surface. In practice this was done a day after irrigation and an adjustment made for the evaporation that occurred between irrigation and sampling. The moisture status of the soil after irrigation is termed irrigation saturation and is used in preference to field capacity.

The RAM values representing the moisture available to the crop at a soil suction potential of less than 1 bar (28 mm in a 1 m profile) indicate that, even with the most frequent irrigation treatment at a 40 mm pan deficit, cane growth would be restricted.

Crop moisture withdrawal data suggests that once the readily available moisture had been withdrawn less water was used by the crop (i.e. I1 33 mm between irrigations) because it is retained by the soil at increasingly higher suction potentials.

4/Conclusions...

CONCLUSIONS

The results of this investigation show that the reason for the positive cane yield response to high frequency irrigation observed in the trials on basalt soils is that irrigation at 40 mm pan deficits nearly approximates the depletion of the RAM. Nevertheless, irrigation at a pan deficit of 25-30 mm, equivalent to the RAM and representing a 20% depletion of TAM, is likely to result in greater cane yield responses.

An alternative approach would be to increase the amount of moisture retained in the soil after irrigation, resulting in higher values of RAM and TAM, providing an opportunity for less frequent irrigations. The variability obtained in the measurement of irrigation saturation suggests that it may be possible to achieve this situation and research on this is warranted.

The application of the results of this investigation to the problem of ratoon decline are discussed in the terminal report of trial 4200/10.

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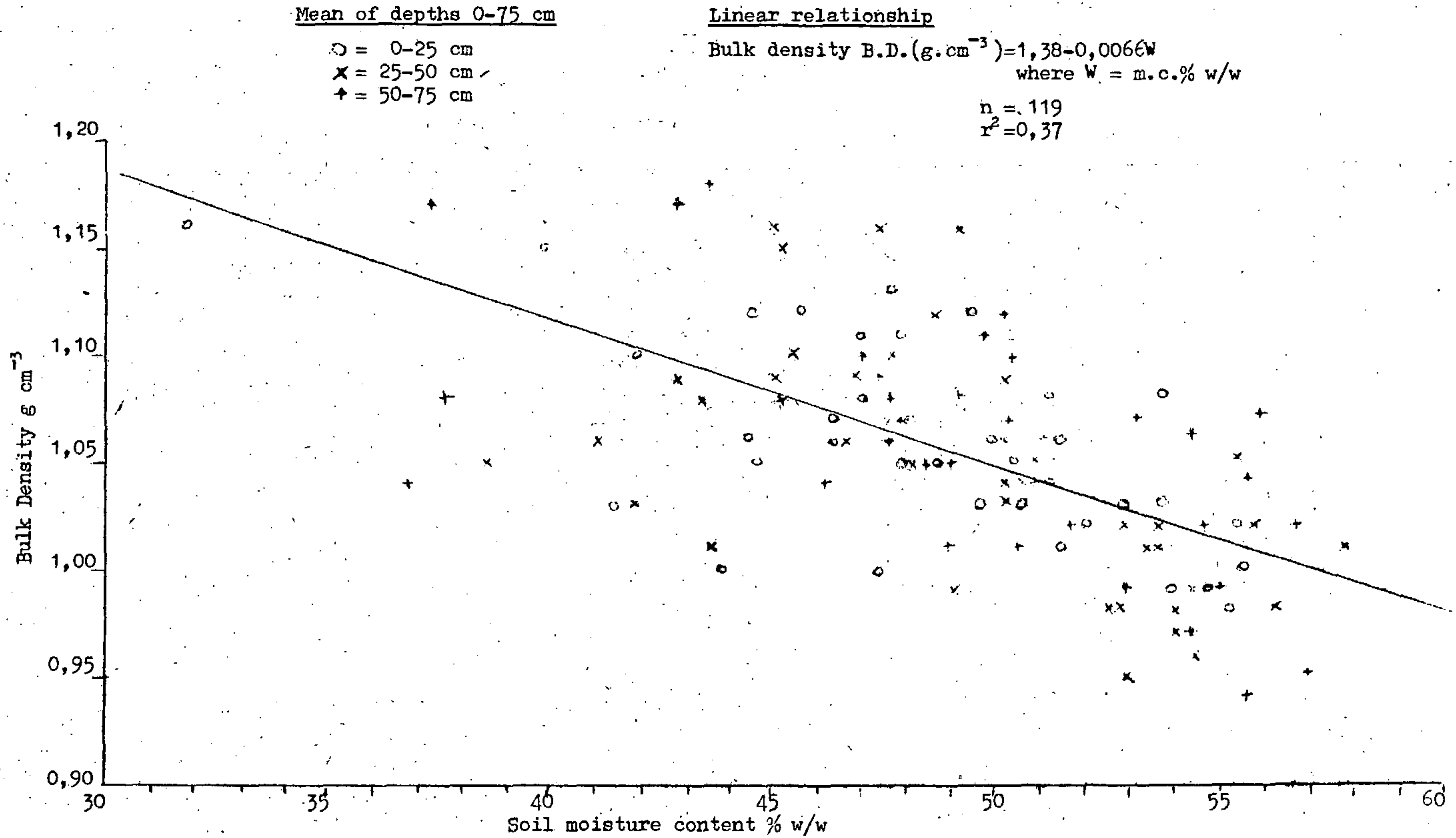

Figure 1. Variation of core bulk density with gravimetric soil moisture content

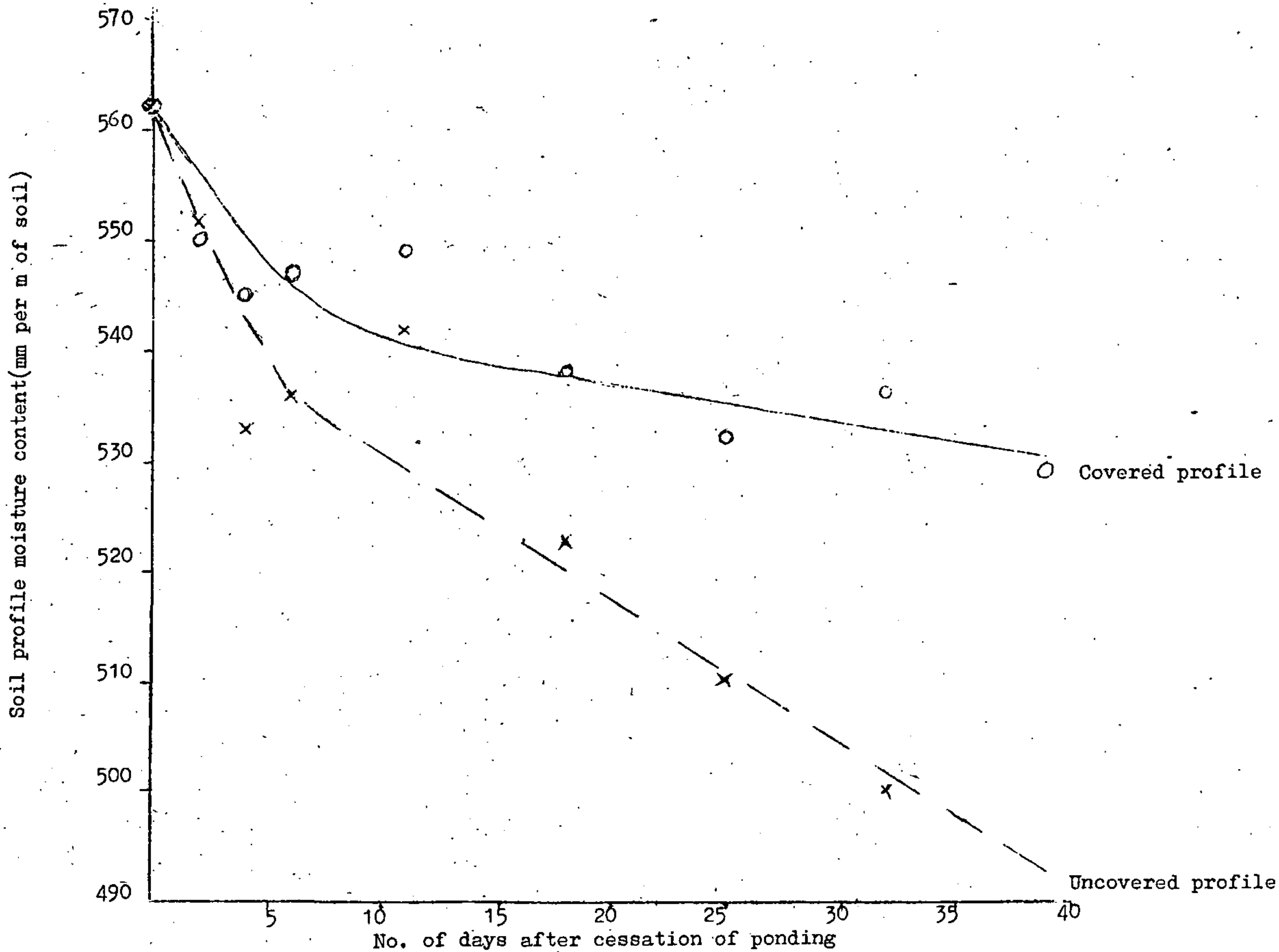

Figure 2. Profile moisture contents

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Table 1. Soil moisture status immediately after irrigation

Sample depth cm	Soil moisture content % w/w on various sampling occasions											Bulk Density g cm^{-3}	M.C. % V/V
	1	2	3	4	5	6	7	8	MEAN	S.D. ±	C.V. %		
0-25	56,7	64,4	62,8	59,0	65,6	64,4	69,4	59,1	62,7	4,2	6,7	0,97	60,6
25-50	49,6	52,9	50,6	51,1	51,1	56,5	61,5	55,2	53,6	4,0	7,5	1,03	55,0
50-75	48,2	51,1	50,0	52,1	49,6	53,4	57,8	52,9	51,9	3,0	5,7	1,04	53,8
75-100	46,4	47,7	45,9	52,3	50,6	52,6	57,8	51,4	50,6	3,9	7,8	1,05	52,9

Table 2. Moisture content of soils at different soil moisture tensions

Sample depth cm	0,33 bar			1,0 bar			15,0 bar		
	M.C.% w/w	B.D. g cm^{-3}	M.C.% v/v	M.C.% w/w	B.D. g cm^{-3}	M.C.% v/v	M.C.% w/w	B.D. g cm^{-3}	M.C.% v/v
0-25	73,9	0,89	65,9	48,6	1,06	51,5	37,4	1,13	42,4
25-50	75,3	0,88	66,5	51,3	1,04	53,4	36,9	1,14	41,9
50-75	77,2	0,87	67,2	51,4	1,04	53,5	36,9	1,14	41,9
75-100	78,6	0,86	67,7	52,9	1,03	54,5	37,0	1,14	42,0

Table 3. Total Available Moisture and Readily Available Moisture

Sample depth cm	Irrigation Saturation I.S. M.C. % v/v	Total Available Moisture			Readily Available Moisture		
		Wilting Pt. M.C. % v/v	A.M.C.% I.S.-W.P.	T.A.M. mm/25 cm	1 bar M.C.% v/v	A.M.C. % I.S.-1 bar	R.A.M. mm/25 cm
0-25	60,6	42,4	18,2	45,5	51,5	9,1	22,8
25-50	55,0	41,9	13,1	32,8	53,4	1,6	4,0
50-75	53,8	41,9	11,9	29,8	53,5	0,3	0,8
75-100	52,9	42,0	10,9	27,3	54,5	-	-
Total	-	-	-	135,4	-	-	27,6

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Table 4. Soil moisture withdrawal by crop

TREATMENT	SOIL DEPTH cm	IRRIGATION SATURATION M.C. % v/v(a)	MOISTURE CONTENT PRIOR TO IRRIGATION % w/w	BULK DENSITY g cm^{-3}	MOISTURE CONTENT PRIOR TO IRRIGATION % v/v(b)	MOISTURE USED BY CROP % a - b	MOISTURE USED BY CROP mm/25 cm.
I.1 Irrigate at 40mm pan deficit	0-25 25-50 50-75 75-100	60,6 55,0 53,8 52,9	48,1 51,2 50,3 49,3	1,06 1,04 1,05 1,05	51,1 53,4 52,7 52,0	9,5 1,6 1,1 0,9	23,8 4,0 2,8 2,3
	TOTAL per m depth	-	-	-	-	-	32,9
I.2 Irrigate at 80mm pan deficit	0-25 25-50 50-75 75-100	60,6 55,0 53,8 52,9	42,5 48,0 47,8 46,5	1,10 1,06 1,06 1,07	46,7 51,0 50,9 49,9	13,9 4,0 2,9 3,0	34,8 10,0 7,3 7,5
	TOTAL per m depth	-	-	-	-	-	59,6
I,3 Irrigate at 120mm pan deficit	0-25 25-50 50-75 75-100	60,6 55,0 53,8 52,9	38,2 45,0 47,2 46,0	1,13 1,08 1,07 1,08	43,1 48,7 50,4 49,5	17,5 6,3 3,4 3,4	43,8 15,8 8,5 8,5
	TOTAL per m depth	-	-	-	-	-	76,6
I.4 Irrigate at 160mm pan deficit	0-2 25-50 50-75 75-100	60,6 55,0 53,8 52,9	37,8 46,1 48,8 47,1	1,13 1,08 1,06 1,07	42,7 49,6 51,6 50,4	17,9 5,4 2,2 2,5	44,8 13,5 5,5 6,3
	TOTAL per m depth	-	-	-	-	-	70,1