Optimum Water Requirements for the Commercial Production of Lucerne in Khartoum State

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Introduction

Khartoum state is an important area for fodder production to satisfy the requirements of increasing animal numbers for meat and dairy products, the demand for which is continuously increasing due to the normal population growth and mass immigration of rural communities to the capital towns and other settlements. In addition to this, a remarkable activity for cattle and sheep for export has resulted in increasing the area of fodder crops. Irrigation cost and management, no doubt, plays an important role for the production of fodder crops. Efficient utilization of the land and water resources will therefore be reflected directly to the interest of the farmer, the consumer, and also to the interest of export trade.

This paper is a joint contribution of five researchers who worked during the last thirty years. The objective of this series of experiments is to maximize income from irrigation water at the farm level for the production of lucerne which is the main leguminous fodder crop in Khartoum State. The final goal is to:

(1) Establish an all-year-round irrigation schedule in which the varying amounts and intervals are identified.

2) Extend the use of the F.A.O model (1984) by including the variations in the available water holding capacity of different soils, so that the irrigation interval can be added to the original Penman Monteith Model which was recommended by F.A.O 1984.

Experimental Procedures

The experimental site and irrigation system were as described in the paper on sorghum and maize fodders. Therefore, no description is given here. Figure A illustrates this system (described by El Nadi 1969). Four experiments were carried out during the course of the last thirty years and are summarized below.

Experiment 1 and 2

The effects of different irrigation regimes on the productivity and water use efficiency of Lucerne (Alfalfa)

Objective:

To study the effects of different irrigation regimes on the productivity and water use efficiency of alfalfa in the arid environment of Khartoum State.

Materials and Methods

The irrigation treatments were introduced after the crop was 75 days old. Sowing was done in 10th November 1983 on flat in plots 4 × 4 m. Water was supplied by the described irrigation system in the forage sorghum paper, by the same author (After El Nadi, 1968) shown in Figure 1.

Treatments:
All the treatments received 8 mm/day but applied in different intervals as follows:

A: 56 mm applied every 7 days
B: 80 mm applied every 10 days
C: 104 mm applied every 13 days

Experimental Design:
Completely Randomized Block design with four replications.
The experiment continued for six months.

Results

The results are summarized in Tables 2 & 3 and Figures 1-8.

Experiment No 3

Productivity of Lucerne under different irrigation levels

Objective:
To compare the response of Lucerne to three watering regimes with and without prophetic fertilization.

Treatments:
Three Irrigation interval W1,W2 and W3 of 7 11 and 13 days respectively in combination with triple super phosphate at the rates of 100 kg/ha (p1) and without super phosphate, control (p_0) The amount of water/day was 7 mm/day during Sep – Feb. and 10 mm/day during March – Aug

Results:
The results are presented in Table (4) and Figure 9.

Experiment 4

The production of Lucerne fodder and water use efficiency under different water regimes

Objective:
To study the effect of the irrigation intervals of 10, 15 and 20 days and irrigation at the rate of 7 mm/day on the productivity and water use efficiency of Lucerne in Khartoum State.

Materials and Methods

The crop was sown in 21 November 1978. The Treatments were introduced after the first cut (50 days after sowing). The treatments continued for 155 days only and each treatment received irrigation of 7 mm/day but at different intervals (and amounts/irrigation).

Results

The results are summarized in Table (5).

Experiment No 5.
The significance of leaf area variation and season in the crop factor of Lucerne (Medicago sativa)

Objectives:

1. To determine the variation in the value of the crop coefficient of Lucerne (Kc) with variation area in leaf and level of irrigation.

From the relation:
Kc = Et/E_0
Kc = the crop coefficient
Where; Et = Actual crop evapotranspiration
E_0 = calculated potential evapotranspiration

2. To determine the value of the crop coefficient (Kc) for Lucerne as influenced by different irrigation inputs.

Materials and Methods

Treatments and experimental design
The treatments were:
A irrigation every 7 days
B irrigation every 10 days
C irrigation every 13 days
The irrigation treatments were in combination with three cutting frequencies of 20, 25 and 30 days designated as T_1, T_2 and T_3 in an attempt to vary leaf area. Thus the combined Treatments were :-
AT_1, AT_2, AT_3
BT_1, BT_2, BT_3
CT_1, CT_2, CT_3

Pre –experimental period
All treatments received ten irrigations of 10 mm/irrigation for the first 100 days before the treatments were introduced.

Results

The Results are shown in Tables (7) to (10)

It can be noted that there is practically no difference in the Et/day for Lucerne for the different cutting frequencies (20, 25, 30 days). This suggests that complete ground cover was attained by Lucerne from the ages of 20, 25 and 30 days after the last cut. Mutual shading of leaves may explain the similar rate of Et for the different cutting frequencies. This is further confirmed by the fact that there were no significant differences in the yield obtained from the different cutting frequencies as shown in **Table (9).**

Recommendations

1) The best fodder yield of Lucerne and highest water use efficiency can be obtained by irrigation at the rate of 7 mm per day and interval of 7 days compare to intervals of 10 days or longer with the same daily rate of water application (7 mm per day). This recommendation is based on the result of four experiments conducted during the last thirty years. However, in one experiment only the best fodder yield resulted from irrigation intervals of 10 days delivered at the rate of 7 mm per day in comparison with interval of 15 and 20 days applied at the same daily rate (7 mm per day).
2) Phosphotic fertilization at the rate of 100 Kg/ha P2O5 (obtained from triple super phosphate (45% P2O5) will result in further increase in fodder yield when coupled with irrigation at 7 days intervals.
3) The water requirements of Lucerne can be estimated from the relation; Et = Eo × Kc as explained in the paper of sorghum and maize fodder presented in this conference.
4) The data in Table (5) of this paper can be considered as evidence for the reliability of the crop coefficients found in the present studies and therefore, there is justification for the proposal of using them for estimating the crop water requirements of the mentioned fodder crops.
5) A similar irrigation schedule, as shown in the paper on Sorghum and Maize Fodders can be made for other crops by using the appropriate values for Eo, Kc and the irrigation interval X.
6) Provided that the crops are of similar physiological age (i.e. similar Kc), the CWR determined in any location (e.g. Khartoum State) can be used as a reference value. Therefore the CWR of the same crop grown in any other location in the Sudan can be calculated from the Relation:

$$\text{CWR in the new location} = \text{Reference CWR} \times \frac{\text{Reference Eo}}{\text{Eo for the New Location}}$$

7) In order to complete the requirements of the all-year-round irrigation schedule, the available soil moisture capacity of the soil of the different irrigated farms should be determined for the grown crops (with different effective rooting depths). This will determine the length of the irrigation interval (X).

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Acknowledgements

The authors are obliged to express thankful appreciation to Prof. H.S. Adam, Gezira University, for his very useful publication cited above. Thanks are extended to Dr. Abdel Hadi Abdel Wahab, Agric. Research & Technology for technical help in electronic presentations of the figures presented in this paper and last but not least, grateful acknowledgment is also made for my nephew Eng. Imad A.H. Elnadi for his patience and help in revising and preparing the text, tables and figures of this paper.

Table 1. Irrigation treatments, number of irrigations and total applied water (mm)

Treatment	Total Number of Irrigations	Total irrigation applied (mm)
A	25	1400
B	18	1440
C	13	1352

Table 2. Seasonal changes in dry matter production of Lucerne per cut under three irrigation treatments (yield in Tons ha^{-1})

Cut Number	1	2	3	4	5	6
Cut Date	March	April	May	June	July	Aug
Treatments			Yield (Tons ha^{-1})			
A	3.5	2.8	2.7	3.0	1.5	1.8
B	3.1	2.3	2.3	2.2	1.3	1.7
C	2.9	2.2	2.1	1.8	1.1	1.1
Mean	3.2	2.4	2.4	2.3	1.3	1.5
S.E. ±	0.10	0.17	0.17	0.21	0.14	0.16
L.SD at 5%	0.96	-	-	0.71	-	0.55
C.V. %	11.1*	14.0 ^{NS}	14.6 ^{NS}	17.6*	22.3 ^{NS}	20.8*

* = Significant at 5% Level, NS = Not significant

Table 3. Water Use Efficiency (M^3 of water kg^{-1} dry matter) of Lucerne grown under the different treatments during the different cutting cycles

Cut Number	1	2	3	4	5	6
Cut Date	March	April	May	June	July	Aug
Treatments						
A	0.69	0.86	0.89	0.80	1.60	1.33
B	0.77	1.04	1.o4	1.09	1.85	1.41
C	0.83	1.09	1.14	1.33	2.18	2.18

Note: Smaller numerical numbers reflect higher WUE which was lower during the humid months of June, July and August during which growth was suppressed.

Table 4. Green and dry fodder production and water use efficiency of Lucerne

Treatment	Season 1971/72 average fresh wt of 12 cuts Tons ha^{-1}	Average dry wt of green cuts (Tons ha^{-1})	Water use efficiency M^3/kg dry matter average of 12 cuts
W_1P_1	77.30	6.76	1.63
W_2P_1	62.52	7.16	1.62
W_3P_1	48.99	5.63	1.99
W_1P_0	71.31	5.86	2.12
W_2P_0	61.71	5.45	2.64
W_3P_0	58.39	4.74	2.54
P_1	62.95	6.57	-
P_0	63.80	5.38	-
W_1	74.30	6.69	1.79
W_2	62.14	5.94	1.88
W_3	53.69	5.29	2.27

Table 5. The effect of different irrigation regimes on fodder yield and water use efficiency of Lucerne

Treatment	No. of irrigations	Amount per irrigation	Total irrigation in Season	Yield of fresh wt (Ton/ha)	Yield of dry wt (Ton/ha)	W.U.E (Kg/ha/mm)
A, every 10 days	9	70	630	10.4	3.1	4.9
B, every 15 days	6	105	630	8.9	2.7	4.3
C, every 20 days	4	140	560	7.4	2.3	3.1

Table 6. Number of Irrigations, amount per irrigation and total irrigations in the season

Treatment	Irrigation interval (days)	No. of Irrigations	Amount-per Irrigation (mm)	Total irrigation Applied (mm)
A	7	42	49	2758
B	10	29	70	2730
C	13	13	91	1883

*The total irrigation applied also include 700 mm, applied during the pre experimental period of 100 days

Table 7. the crop factor of Lucerne (Kc) based on monthly values under irrigation interval of ten days, different cutting frequencies and different months

Month	Cutting frequency (days)		
	20	25	30
		KC	
May	0.85	0.86	0.85
June	0.88	0.88	0.88
July	0.97	0.97	0.97
Aug	1.15	1.14	1.15
Sep	1.13	1.15	1.14
Oct	1.21	1.13	1.14
Nov	1.12	1.13	1.13
Dec	1.28	1.29	1.28

$K_c = E_t/E_0$ where; E_t = actual monthly evapotranspiration. E_0 = monthly E_0 according to the mean of long-term values of Adam 2005.

Table 8. Mean values for actual evapotranspiration for the different irrigation intervals and different cutting frequencies for the period April to September 1979

Irrigation Interval	A (7 days)			B (10 days)			C (13 days)		
Cutting Frequencies	20	25	30	20	25	30	20	25	30
Mean E_t/day (mm)	7.0	7.1	7.3	7.4	7.4	7.4	7.3	7.3	7.3

Table 9. Dry weight yield under three irrigation intervals of 7, 10 and 13 days (A, B and C) and three cutting intervals (20, 25 and 30 days), during cuts number 1, 2, 3, 4, 5

Treatment	1	2	3	4	5
			Yield (dry wt in tons ha^{-1})		
A	2.42	1.86	2.32	1.88	2.40
B	2.85	1.57	1.84	1.79	2.03
C	1.91	1.31	1.17	1.13	1.19
SE ±	0.25	0.09	0.11	0.05	0.12
LSD 0.05	NS	0.25	0.30	0.14	0.33
CV %	22.9	12.6	13.3	7.7	13.5
20 days	2.38	1.45	1.27	0.96	1.11
25 days	2.33	1.77	1.70	1.65	1.71
30 days	2.46	1.51	2.37	2.20	1.85
SE ±	0.22	0.18	0.23	0.11	0.12
LSD 0.05	NS	NS	0.50	0.24	0.26
CV %	19.7	24.9	28.3	14.6	14.5
A 20	2.46	1.69	1.73	1.23	1.24
A 25	2.22	1.90	1.92	1.90	2.03
A 30	2.57	1.98	3.30	2.50	3.94
B 20	2.94	1.44	1.37	1.07	1.22
B 25	2.48	1.60	1.55	1.64	1.69
B 30	3.13	1.68	2.61	2.67	3.33
C 20	0.75	1.23	0.69	0.57	0.87
C 25	2.30	1.81	1.64	1.39	1.41
C 30	1.66	0.88	1.18	1.42	1.29
SE ±	0.38	0.31	0.39	0.19	0.20
LSD 0.05	NS	NS	NS	0.41	0.43

Note:

Table 9 shows the following facts:

1) The dry matter yield of Lucerne under irrigation of 7 and 10 days interval was higher than the yield under 13 days irrigation interval, but the differences in yield were not statistically significant.
2) There were no significant differences in the dry matter yield due to the different cutting frequencies.

Table 10. Comparison of the values of the crop factor (K_c) determined under different environments

Crop and Source of Information	Stage of Crop Growth			Remarks
	Kc1	Kc2	Kc3	
Lucerne(Shambat), Sudan Lat.15.40	→ 0.4	→	1.2	Value of depends on age after the last cut
Lucerne (Barka) Sultanate of Oman Lat.22° N.	→ 0.33	→	1.1	
Lucerne Dry climate (location not named) FAO. pup (1977)NO 24, page 45	→ 0.45	→	1.1	
Maize planted Mid-May Cairo. Egypt Lat.30 FAO Pup. (1984) No 24 page 39.	→ 0.35	→ Fodder	1.14	0.6 (grain harves)

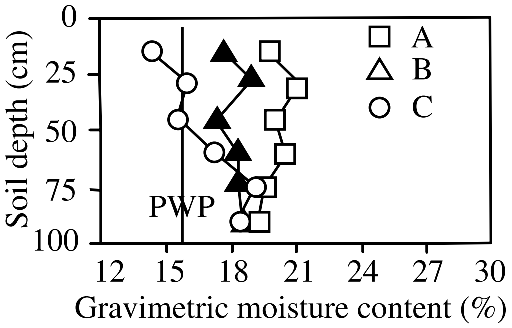

Figure 1
Moisture content vs soil depth

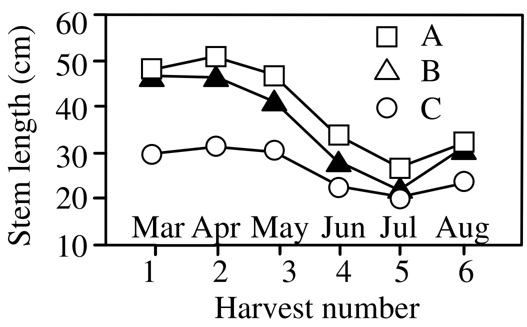

Figure 2
Stem length vs harvest number

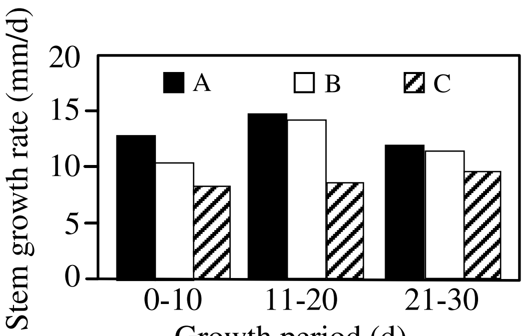

Figure 3
Growth rate (mm/d) vs growth period

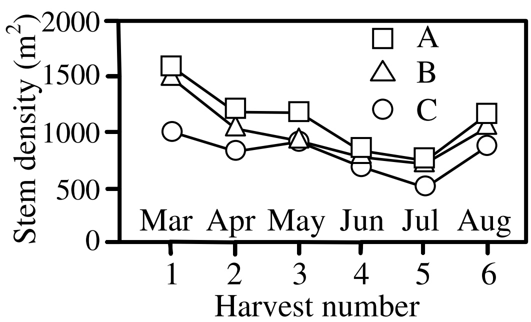

Figure 4
Stem density vs harvest number

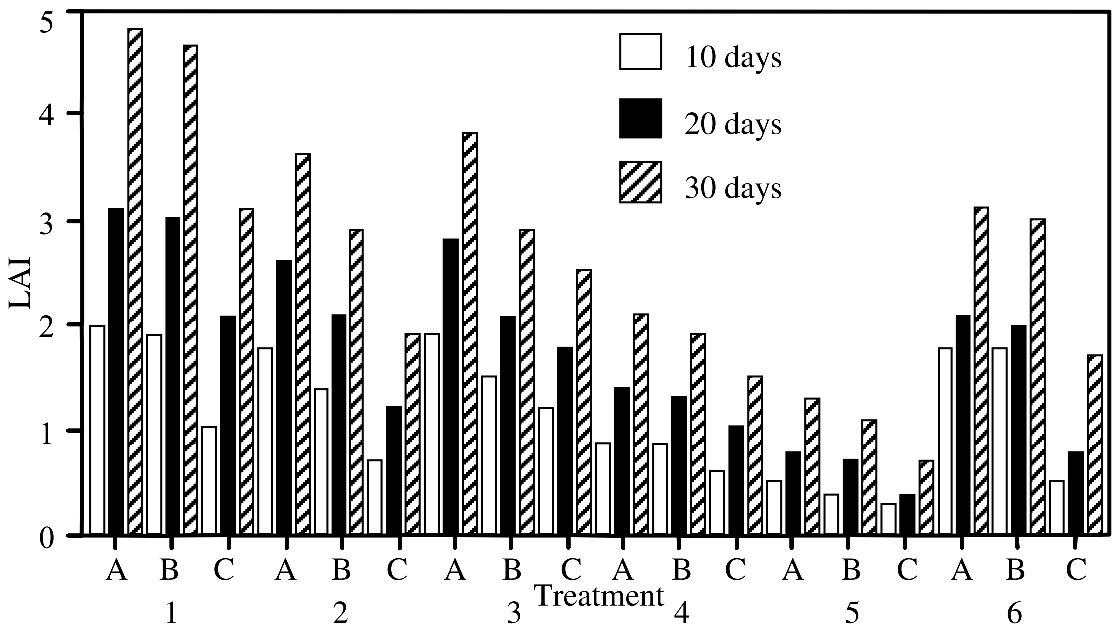

Figure 5. Alfalfa LAI measured at initial (0-10 days), intermediate (11-20 days), and final growth periods (21-30 days) for the 6 harvests under the 3 water regimes

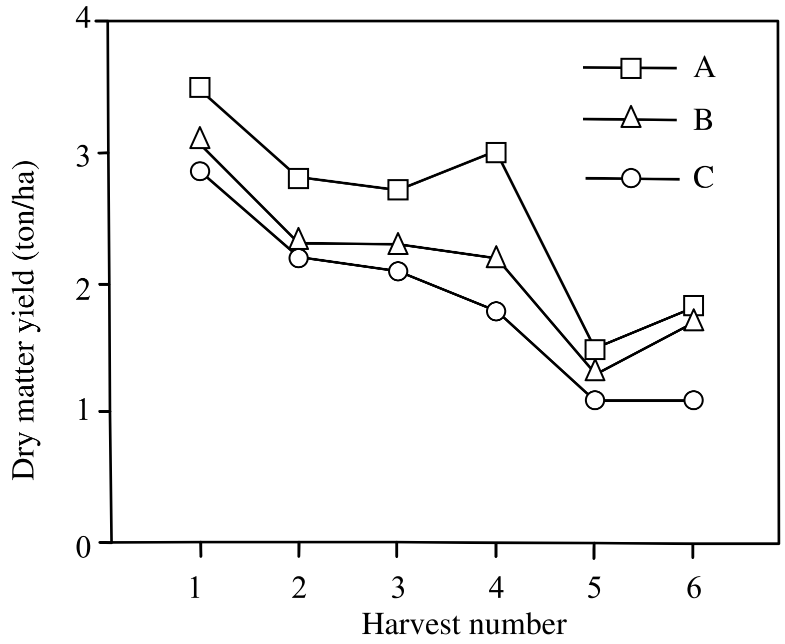

Figure 6. Alfalfa dry matter yield (ton/ha) for the six cutting cycles under the 3 water regimes. Each value is an average of 4 measurements.

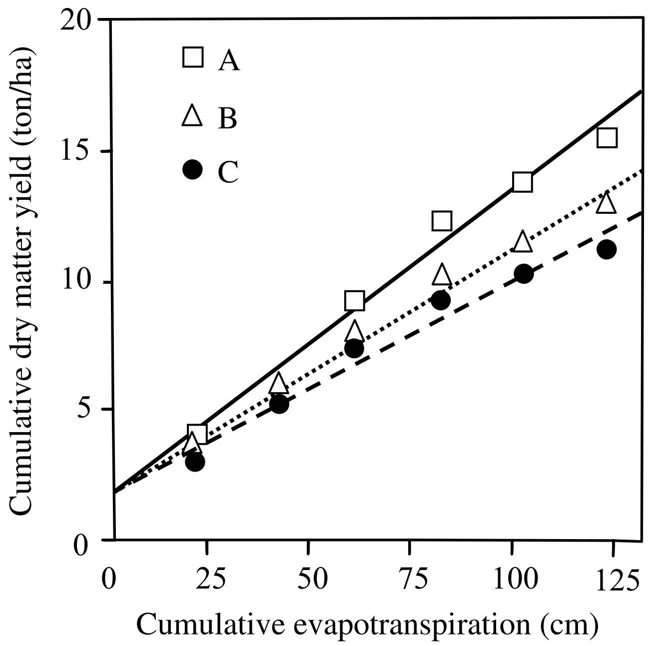

Figure 7. Cumulative dry matter yield (ton/ha) vs. cumulative evapotranspiration (cm) of alfalfa for the 3 water regimes. Each value is an average of 4 measurements.

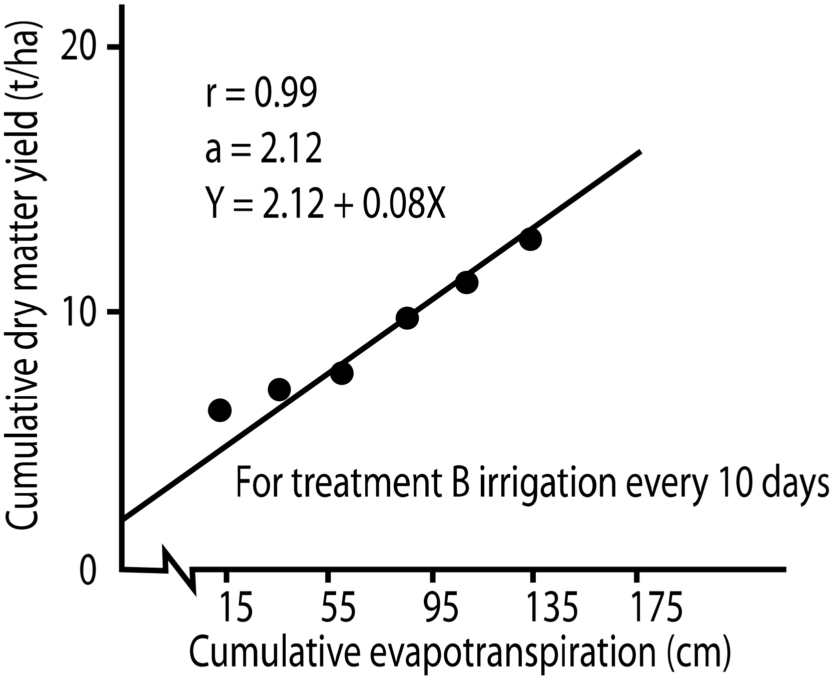

Figure 8. Relationship between cumulative dry weight and cumulative evapotranspiration

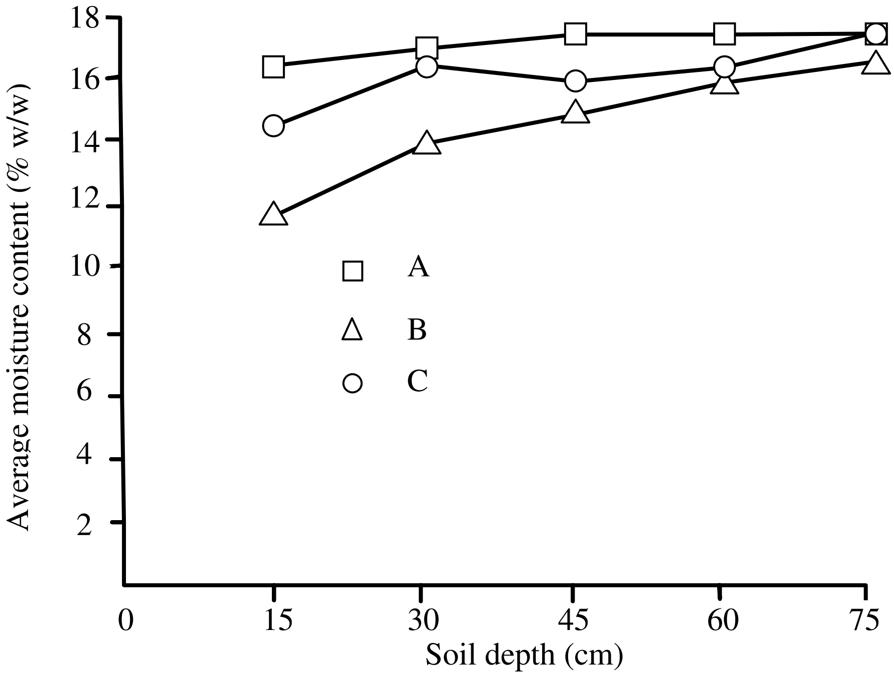

Figure 9. Changes in Soil moisture just before irrigation (dry cycle) with soil depth