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Research activities conducted during the fifth six-month period ending December 1985 includes

I. A field experimental design and the experimentation of soil salinity control system.

II. Wind turbine - water pumping system

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Part I A field experimental design and the experimentation of soil salinity control system

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A field experiment for soil salinity control system was designed by using CRD method with two treatments and four replications corresponding to treatment 1 and treatment 15 in a done pot experiment in order to study comparative changes of soil moisture content, E.C. values, and soil pH among treatments after each leaching.

A field experiment was carried out in 3 steps.

Step 1 Soil moisture content, E.C. values, pH and monthly rainfall at research site during two rainy seasons were determined and recorded. Amount of monthly rainfall at the experimentation station between July to November in 1984 and 1985 were recorded directly from a pan of 0.54 metre diameter and 0.20 metre depth collecting rainfed. At the end of each month soil samples were taken at 5 spots from each plot in order to determine soil moisture content, E.C. values, and pH using oven dry weight method, electrical conductivity meter, and pH meter respectively. The results are described in table 1. The E.C. values of field soil were plotted against the accumulated amount of rainfed during rainy seasons in 1984 and 1985 in order to study a relationship between these two variables as shown in figure 1.

Fig. 1 E.C$_3$ values v.s. rainfed

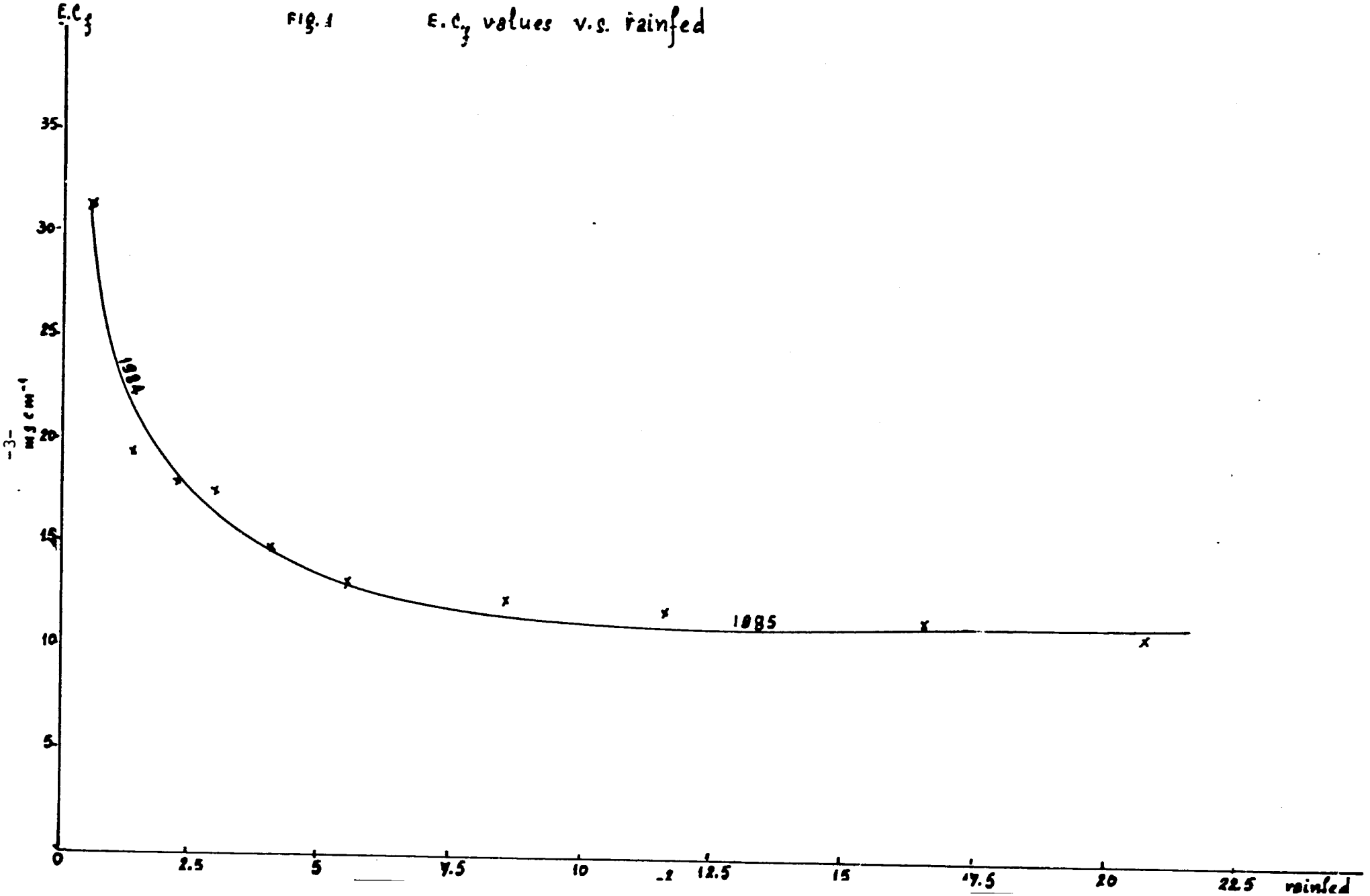


Table 1 Moisture content, E.C. values, and pH of field soil and monthly rainfall at research site in 1984 and 1985

Month	1984				1985			
	moist cont %	E.C(1:5) at 25 °C ms cm^{-1}	pH(1:1)	rainfall mm^{-2}	moist. cont %	E.C(1:5) at 25 °C ms cm^{-1}	pH(1:1)	rainfall mm^{-2}
July	36.08	31.29	8.1	.635	38.79	13.69	7.8	1.456
August	38.54	19.20	7.9	.702	40.35	12.51	7.9	3.155
September	36.17	17.93	7.7	.829	33.96	12.40	8.0	2.912
October	38.39	17.50	7.9	.808	33.96	11.60	7.4	4.982
November	38.60	14.60	7.8	1.067	39.76	11.05	7.7	4.207

Step 2 A field experiment was conducted after two seasonal rainfeds by following the previous design. There are two treatments and four replications. Each replication covers a size of 40 x 8 m^2. Treatment 1 and treatment 2 refer to check plot and 3% rice husk + 6% gypsum (7 tons rice husk + 14 tons gypsum for rooting region at 0.5 metre depth in each replication). Every replication soil was ploughed thoroughly deep to 0.5 metre from a surface before the application of leaching process. (Fig 2 Fig 3).

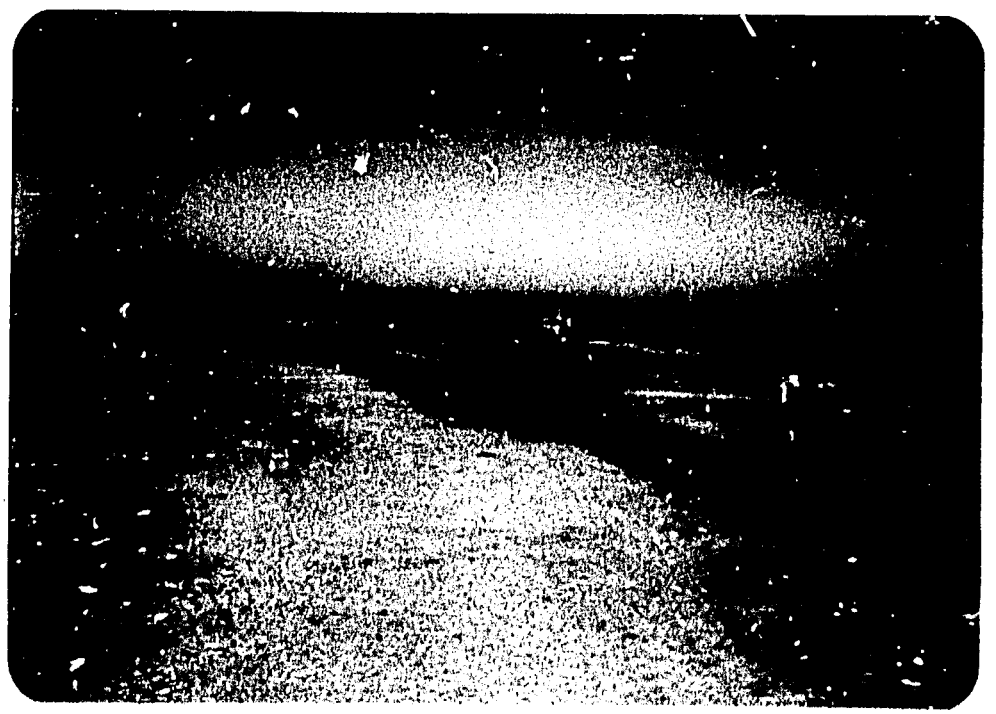


Fig 2 Demonstration of ploughing field soil.

Fig 3 Ploughed field soil.

Step 3 The excess salt in soil solution of each subplot (replication) was removed by four leachings with artesian water. The amount of water pumped to individual subplot for each leaching was 50 m^3. Soil samples were taken from each subplot after each leaching for determining soil moisture content, $E.C._f$ values, and pH. Analytical methods for such determinations were similar to those mentioned in step 1. The results are illustrated in table 2. The $E.C._f$ values was plotted against accumulated amount of leaching water in order to study the drop of soil salinity with the increment of delution as shown in figure 4. At the same time leachate flowed out of each drain pipe during leaching was collected for monitoring $E.C._d$ values, pH, and SAR_d in order to study changes of electrolyte concentration in drainage water with the applied water and the level of soil salinity. The $E.C._d$ values and pH were measured

directly by using the same methods mentioned before. The SAR_d values were determined from the Gapcn equation which is given below.

$$SAR_d = \frac{Na^+}{\sqrt{(Ca^{++} + Mg^{++})/2}}$$

Na^+, Ca^{++} and Mg^{++} were determined by flame photometry and EDTA titration method respectively. The results of electrolytic analysis are described in table 3. Changes of electrolyte concentration in drainage water with the applied water and the level of soil salinity were investigated through graphs plotted $E.C._d$ VS. leaching water, SAR_d VS. leaching water, $E.C._d$ VS. $E.C._f$ and SAR_d VS. $E.C._f$ as shown in figure 5, 6, 7 and 8 respectively. Strong physic nut trees were transplanted from pot soil to field soil. Each replication plot contains 100 trees locating 1.50 metre apart from each other (Fig 9 and Fig 10). All plants were irrigated twice a day by dripping irrigation method alternated with sprinkling water. Growth development was observed after planting for one week (Fig 11, Fig 12, Fig 13, Fig 14, Fig 15, Fig 16, Fig 17 and Fig 18).

Table 2 Moisture content, EC_f values, pH of field soil in each 40x8 m^2 subplot subsequently leached with 50 m^3 of artesian water

Treatment No.	Replication No.	% Moisture content				EC_f (1:5) ms cm^{-1} at 25°C				pH (1:1)			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
T_1	R_1	33.25	31.76	31.02	31.50	10.60	10.0	9.60	8.80	7.40	7.90	7.90	7.60
	R_2	33.05	31.53	33.40	33.10	10.60	10.30	9.65	8.50	7.70	7.30	7.40	7.70
	R_3	34.10	35.77	35.70	32.50	10.56	10.20	9.60	8.70	7.80	7.80	7.80	7.80
	R_4	33.80	38.64	39.50	36.20	10.54	10.10	9.60	8.60	7.50	7.60	7.60	7.60
	$\bar{R}$	33.55	34.42	34.91	33.32	10.58	10.15	9.61	8.65	7.60	7.65	7.68	7.68
T_2	R_1	30.04	31.61	30.72	30.12	10.40	9.80	9.10	8.20	7.90	7.30	7.30	7.10
	R_2	31.10	30.15	30.60	30.50	10.40	9.50	9.20	8.10	7.80	7.80	7.60	7.40
	R_3	30.70	30.70	30.60	30.50	10.40	9.50	9.10	7.70	7.90	7.50	7.50	7.30
	R_4	32.40	31.20	30.10	30.60	10.50	9.60	8.90	7.60	8.10	7.60	7.60	7.50
	$\bar{R}$	31.06	30.92	30.51	30.43	10.42	9.60	9.08	7.90	7.92	7.55	7.50	7.32

Table 3 $E.C_d$ value, pH, and SAR_d of leachate from each drain pipe

Treatment No.	Replication No.	$E.C_d$ µs cm^{-1} at 25 °C				pH				SAR_d			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
T_1	R_1	17,500	28,000	27,800	25,000	8.4	8.1	8.6	8.3	493.13	48.54	50.30	48.54
	R_2	15,500	28,500	28,000	26,000	8.6	8.5	8.4	8.6	135.31	50.60	50.88	49.76
	R_3	19,500	28,300	28,000	27,000	8.9	8.4	8.5	8.6	145.11	50.30	50.60	50.30
	R_4	19,000	28,000	26,500	26,000	8.6	8.4	8.4	8.4	159.37	50.40	50.40	49.76
	$\bar{R}$	17,875	28,200	27,575	26,000	8.62	8.35	8.48	8.48	233.25	49.96	50.54	49.59
T_2	R_1	16,000	31,000	32,000	30,500	8.9	8.5	8.8	8.7	145.11	54.67	38.00	40.20
	R_2	14,500	31,000	32,000	31,000	9.0	8.6	8.8	8.8	126.24	53.84	36.20	40.00
	R_3	14,000	31,000	31,000	31,000	8.7	8.8	8.5	8.4	238.31	48.00	37.41	39.54
	R_4	14,200	30,800	32,000	32,000	9.1	8.8	8.7	8.7	236.95	50.05	37.49	41.00
	$\bar{R}$	14,675	30,950	31,750	31,125	8.92	8.68	8.7	8.65	186.65	51.69	37.28	40.18

Fig. 4 E.C.$_f$ values v.s. leaching

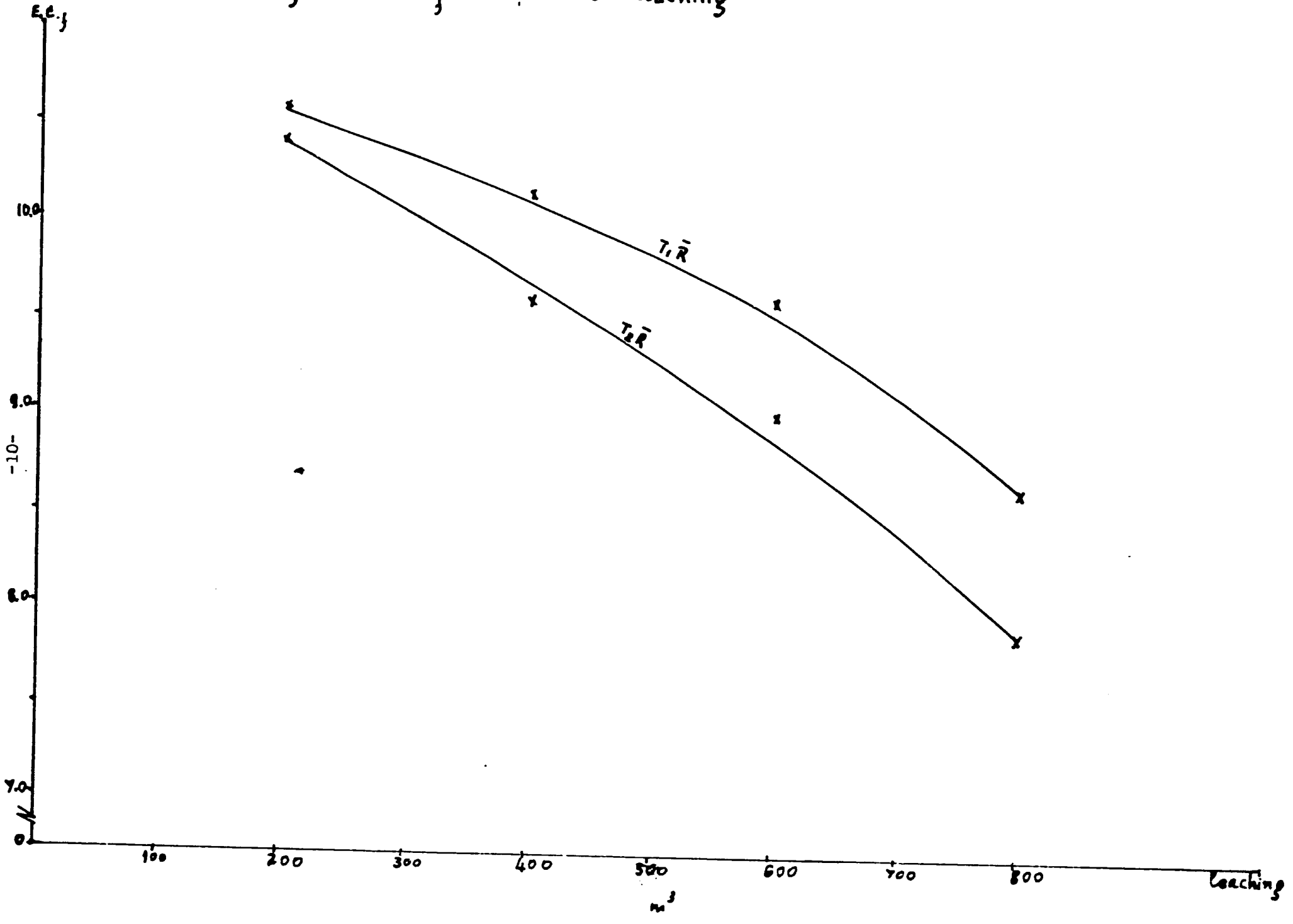


Fig. 5 $E.C._d$ vs. leaching

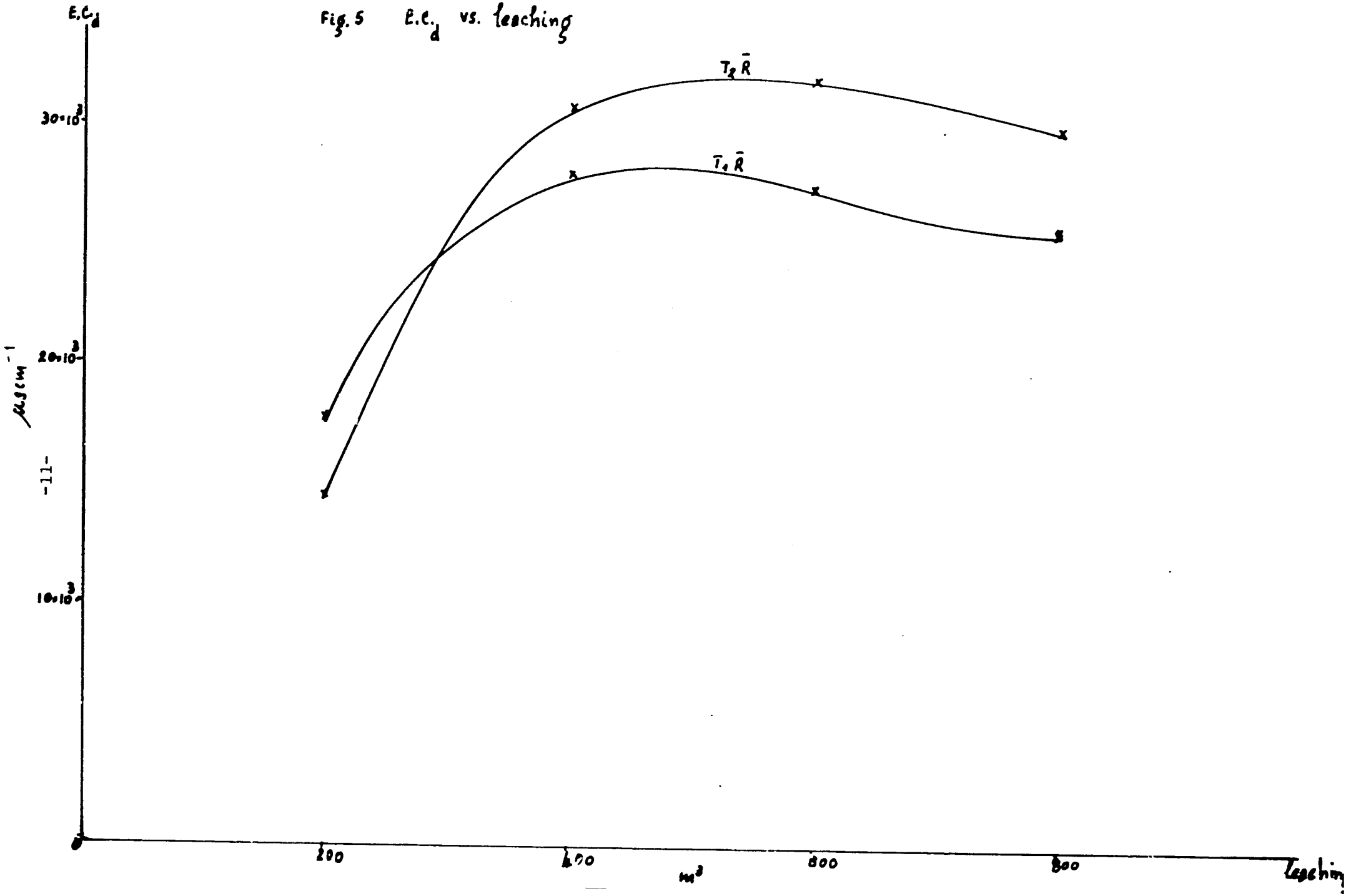


FIG.8 SAR vs. leaching

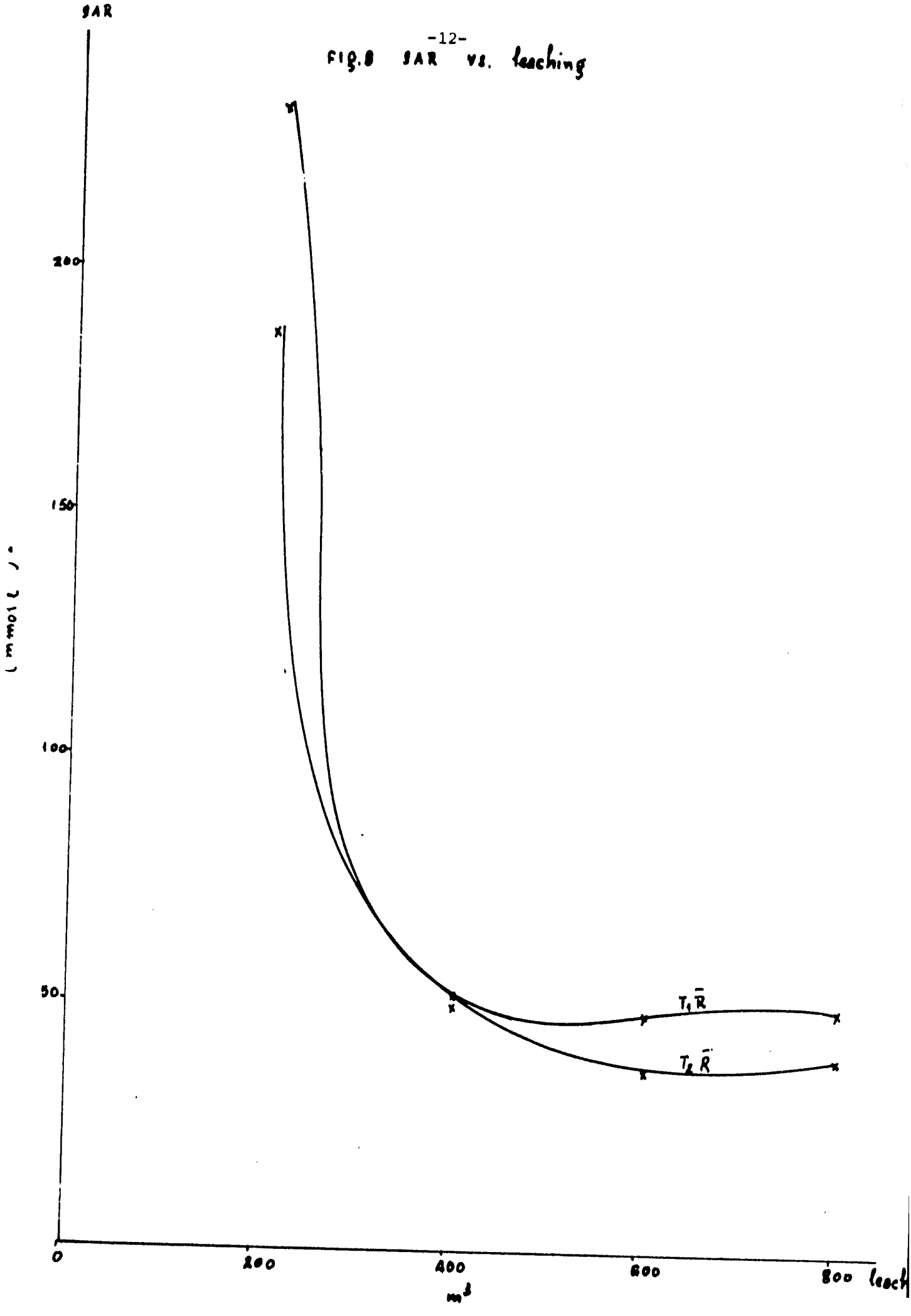


Fig. 7 E.C.$_d$ vs. E.C.$_f$

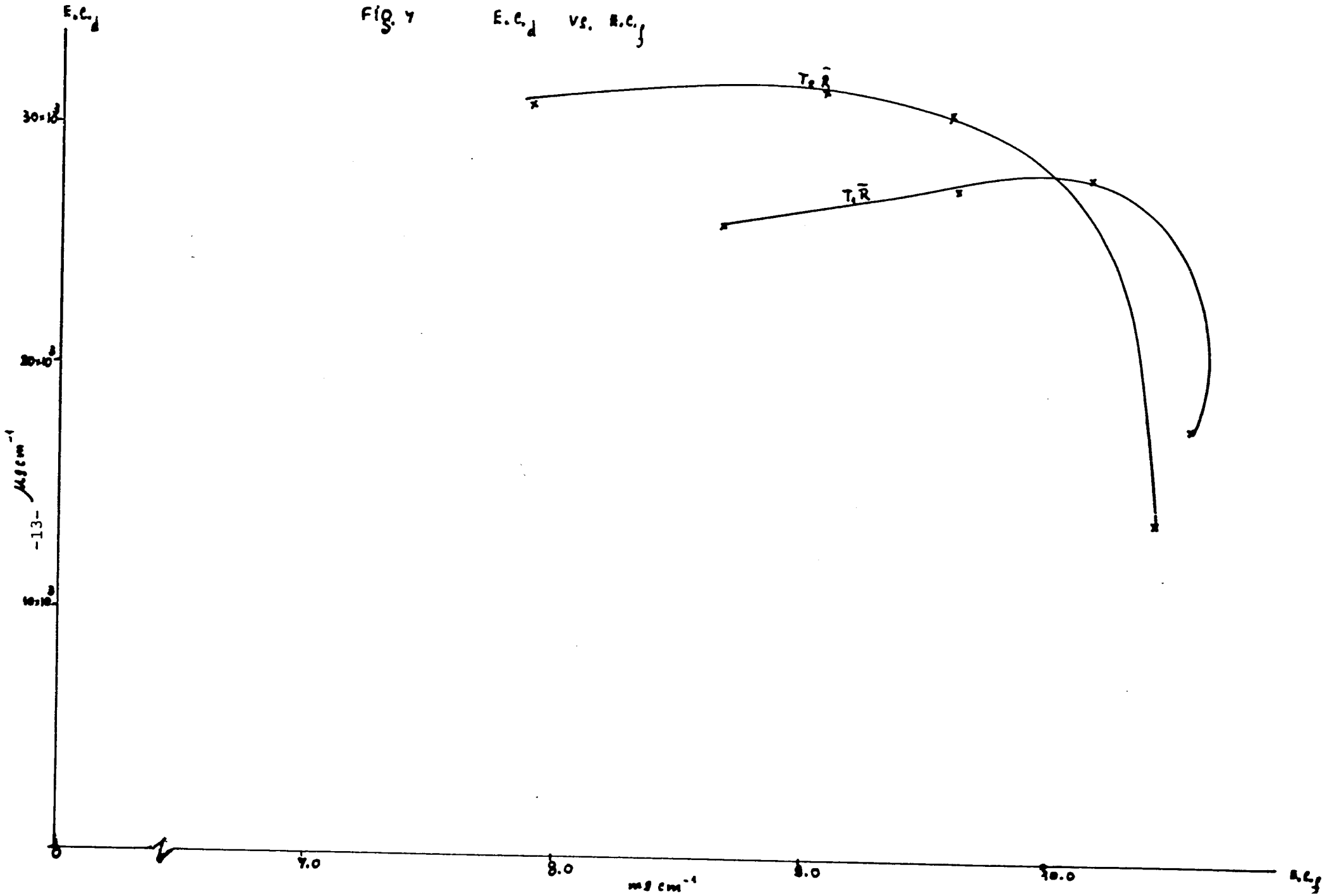
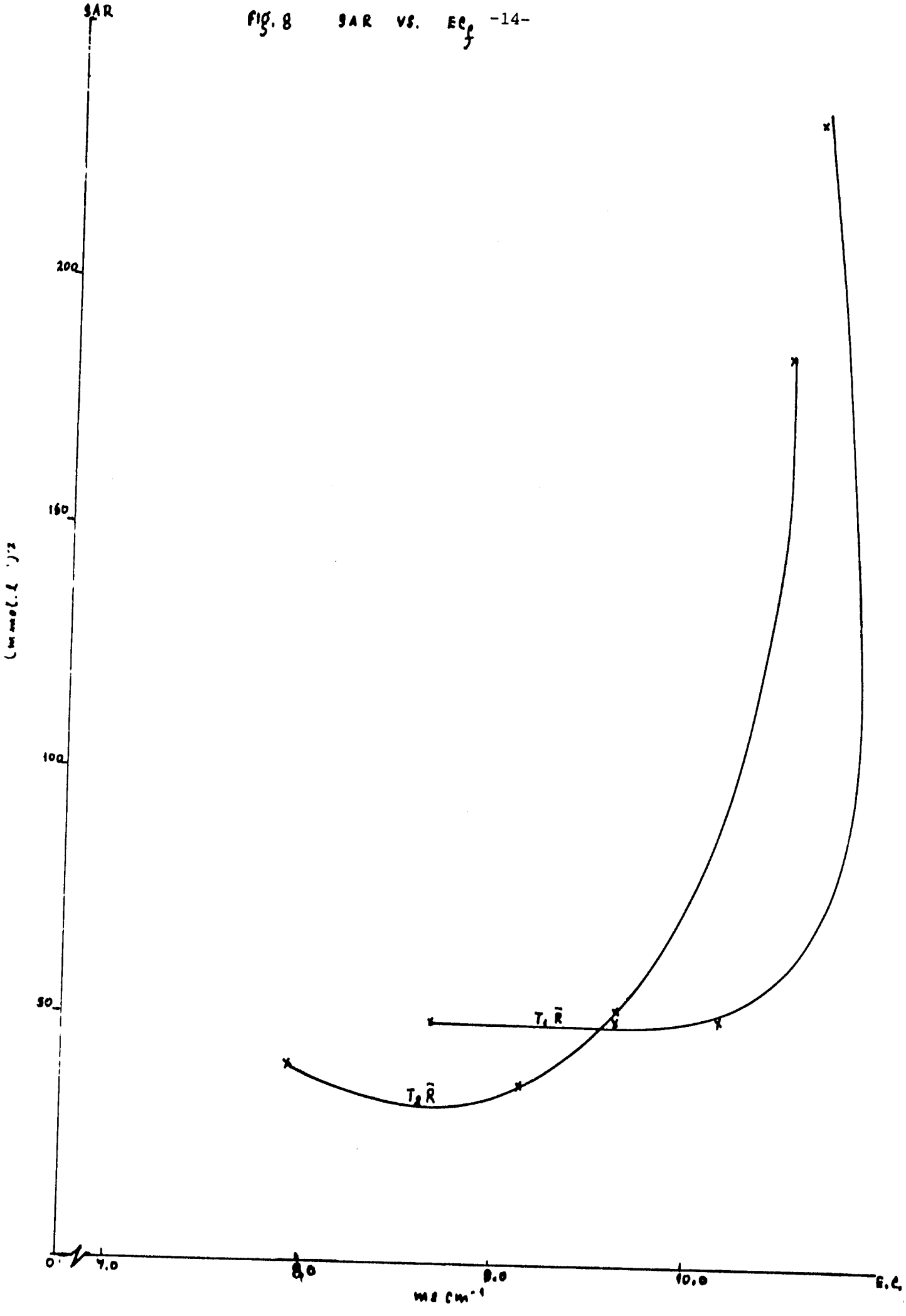


Fig. 8 SAR vs. EC_f



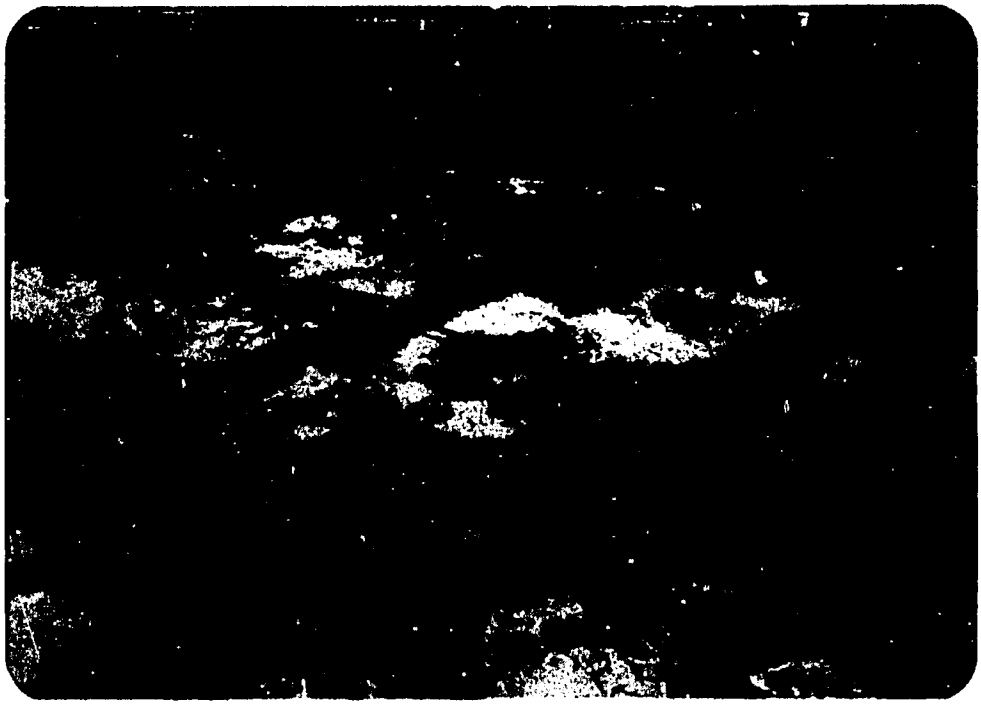


Fig 9 Side view of physic nut trees grown in field soil

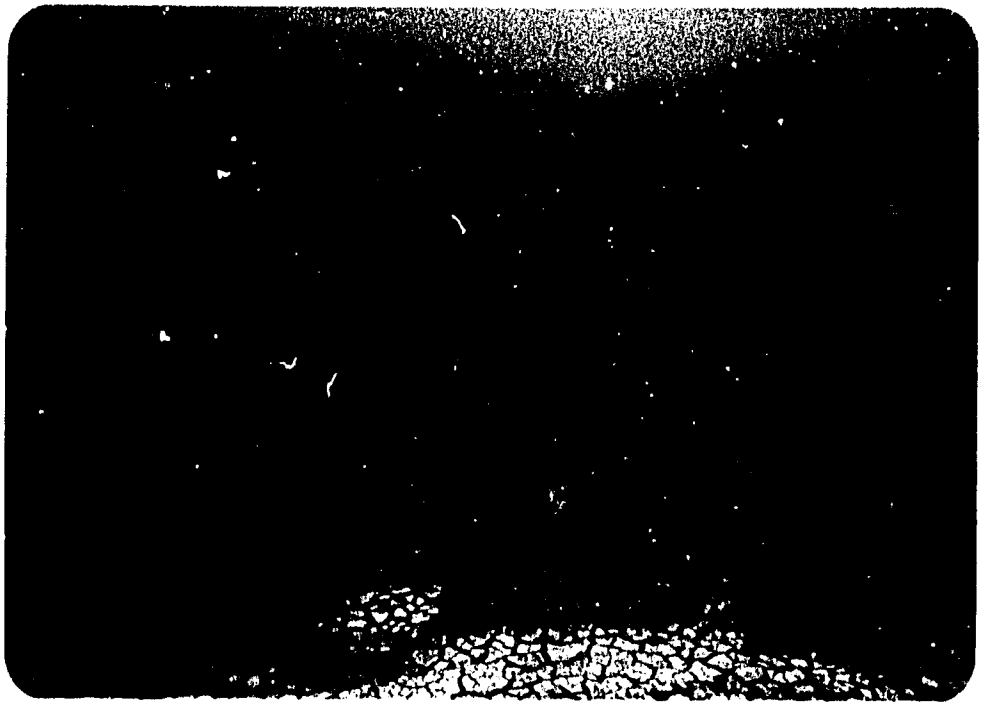


Fig 10 Front view of physic nut trees grown in field soil

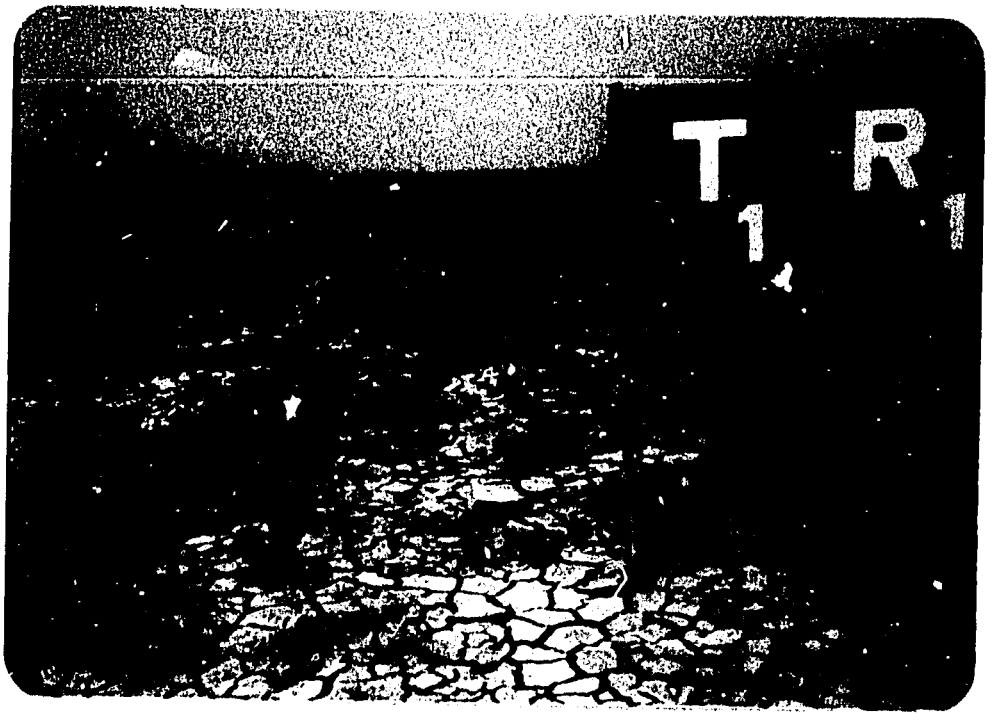


Fig 11 Growth of physic nut trees in T_1R_1

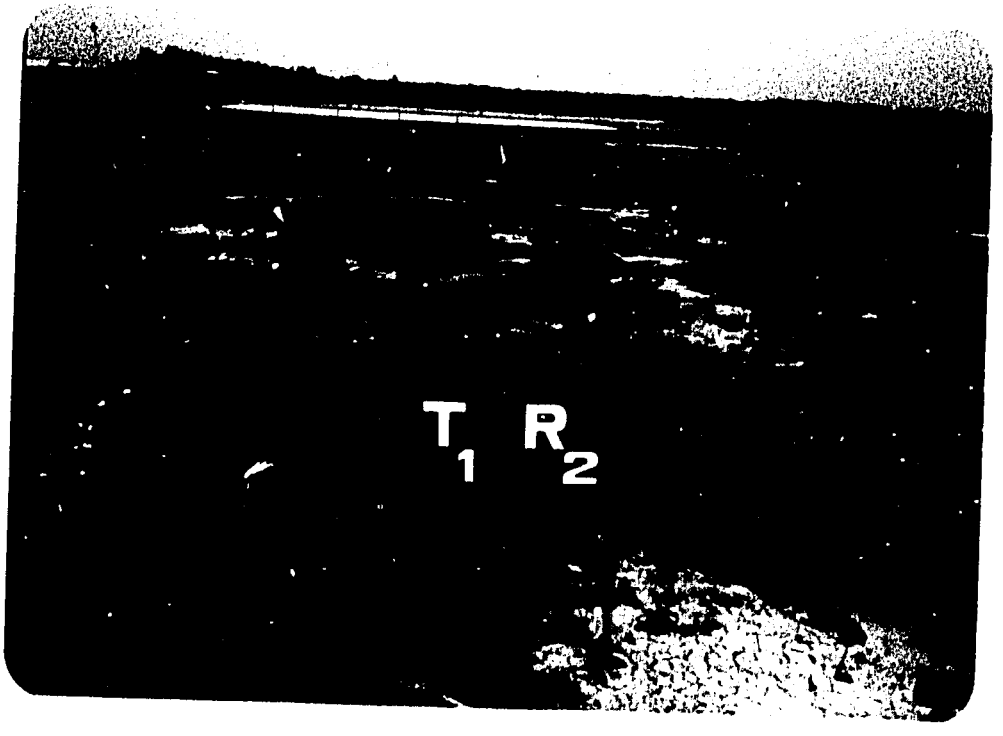


Fig 12 Growth of physic nut trees in T_1R_2

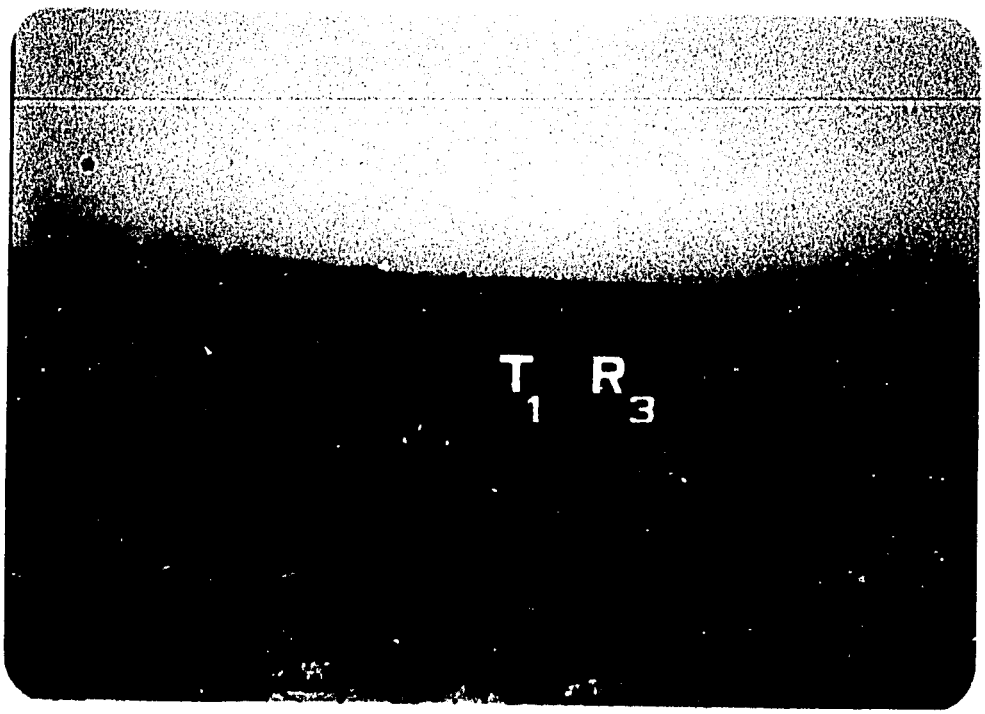


Fig 13 Growth of physic nut trees in T_1R_3

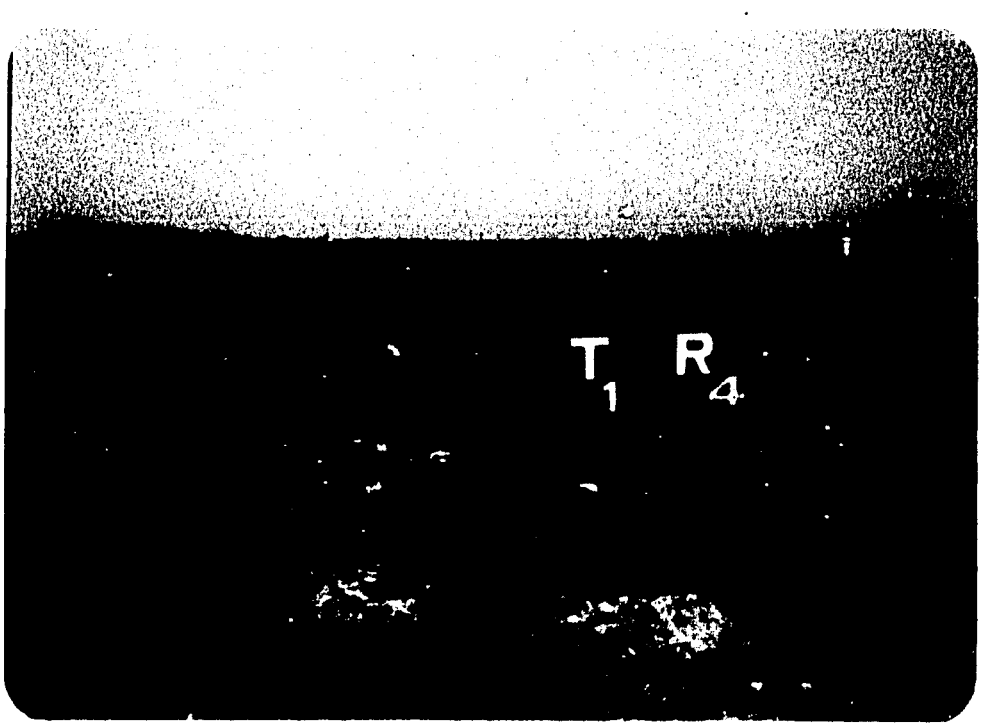


Fig 14 Growth of physic nut trees in T_1R_4

Fig 15 Growth of physic nut trees in T_2R_1

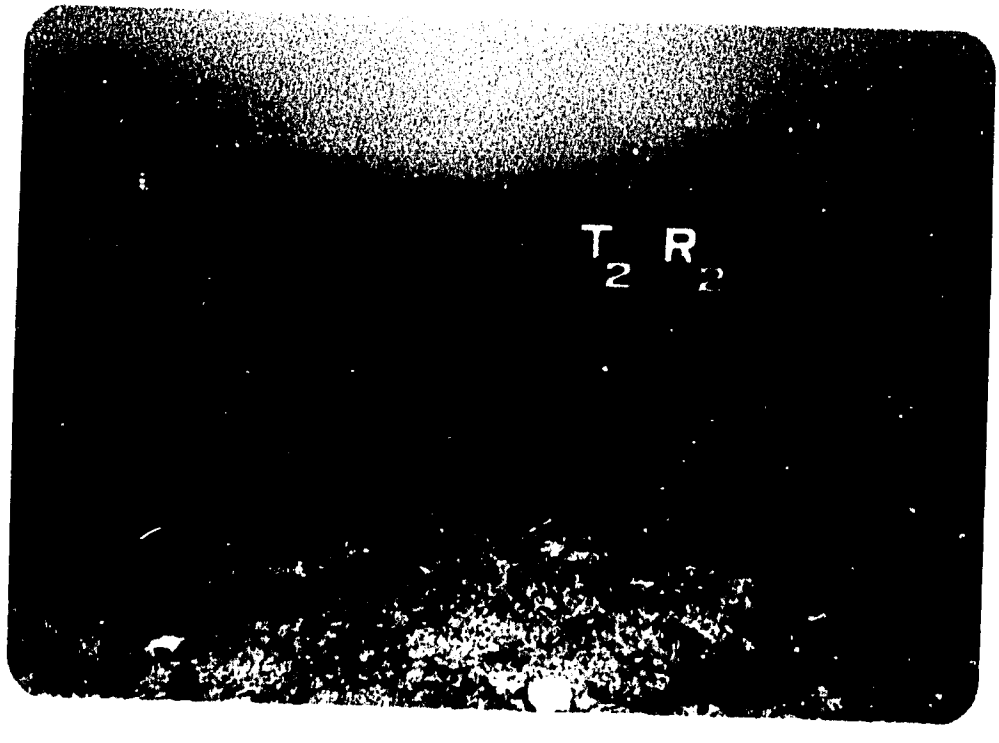


Fig 16 Growth of physic nut trees in T_2R_2

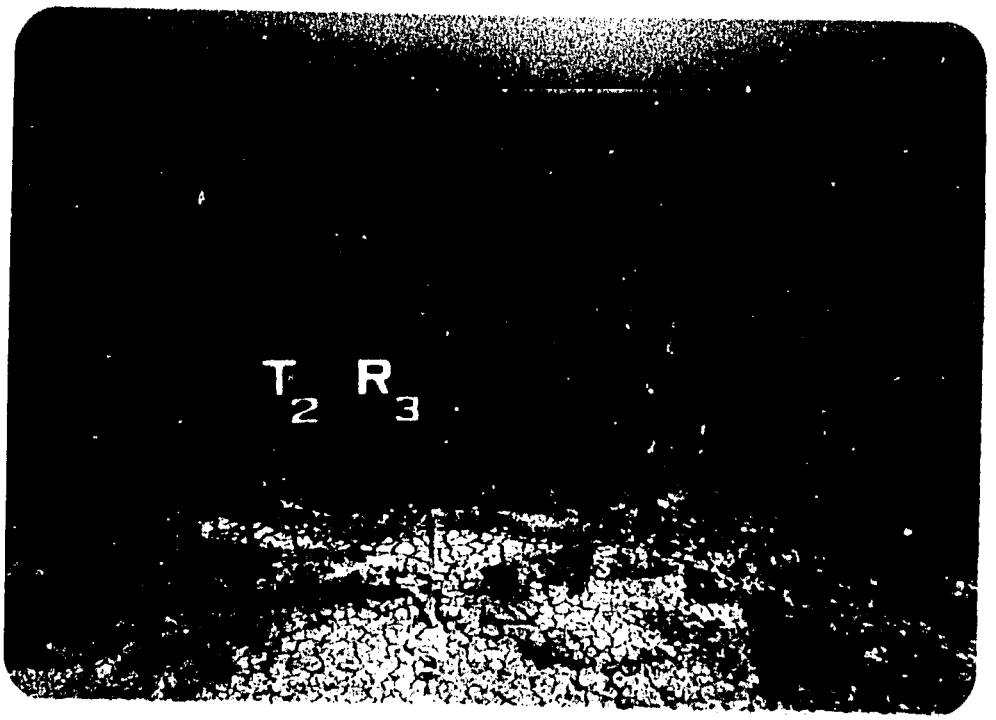


Fig 17 Growth of physic nut trees in T_2R_3

Fig 18 Growth of physic nut trees in T_2R_4

References

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Wind Turbine-Water Pumping System

Bundit Fungtammasan

A. Performance Characteristics

Field measurements have been carried out to determine the overall performance characteristics of the wind turbine-water pumping system. The measured data include the rotational speed of the turbine and the water flow rate at different wind speeds. The results are tabulated in table 1.

Due to its fluctuating nature, the measured wind speeds are five-minute averages of wind speeds sampled at 10 seconds intervals. Similarly, the water flow rate and turbine rotational speed were averaged over five-minute intervals from totalizing meter readings. The data obtained to date has been limited to a very narrow wind speed range of 2.64 to 4.04 m/sec. The data base thus has to be extended over a wider range when higher wind speeds are available. The measured speed of rotation for the 4.3 m diameter wind turbine varied from 35.1 to 52.4 rpm which is typical of a low speed wind device. The water discharge rate from the pump which is a piston pump of 3 inch bore diameter and 4 inch stroke, ranges from 10.8 to 14.2 litre/min. (648-852 litre/hr). The combined capacity for two such wind turbine-pumping systems would be about 1.3-1.7 m^3/hr for the range of wind speeds tested. This range of flow rate matches the discharge rate of approximately 1.0 m^3/hr. from the storage tank to the field for irrigation purposes. However, since the above range of wind speed is not available for all hours of the day, the output from the system is not sufficient for soil leaching which requires a steady and continuous supply of water to reach the 1000 m^3 target.

Therfore an air-lift pump was obtained to supplement the shortfall (See section B of this report for details).

A plot of the pump output versus wind speed is shown in figure 1 which exhibit a rising trend for the pump output (water flow rate) as the wind speed increases. The scatter of the data could be attributed mainly to the fact that the averaging process fails to account for the fluctuating strength contained in the wind speed and that, due to the high inertia of the system, there is a considerable time lag between the wind energy input and the pump output.

The power coefficient (C_p) of the system was calculated as the ratio of the actual power output of the system (P_a) to the available power in the wind at a given wind speed (P_w). That is

$$C_p = P_a/P_w$$

$$P_w = \tfrac{1}{2}\rho_a \overline{V}^3 A$$

$$P_a \simeq \rho_w g Q H$$

where ρ_a = air density

$\overline{V}$ = average wind speed

A = turbine area

ρ_w = water density

Q = water flow rate

H = Total dynamic head

The velocity coefficient (λ) of the system was calculated as the ratio of turbine blade tip speed ($\overline{U}$) to wind speed ($\overline{V}$). These results are also tabulated in table 1 as a standard method of performance evaluation for different types of wind devices. The power coefficient varied from 0.060 to 0.103 for the range of velocity coefficient measured (0.44-0.59)

The values are on the low side which is not untypical of a high torque and low speed machine. Note that the power coefficient values could have been higher, had they been calculated on the basis of actual power output of the turbine rotor, as is done for standard measurements but was omitted here because of lack of proper instrumentation. Figure 2 shows a plot of the power coefficient versus velocity coefficient. The power coefficient is seen here to increase as the velocity coefficient increases.

B. Modification of the Water Pumping System

As mentioned in the previous section, the wind driven pump output was not adequate to meet the stringent demand for soil leaching. It was then decided to supplement the shortfalls during calm periods using air-lifting whereby compressed air is injected into the well-shaft of the deepwell and water is thus pumped up to the storage tank. The air-lift method was chosen because the air compressor can be driven directly by a diesel engine which is already available, and an air compressor can be secured for the leaching period. The modified water supply system now is shown schematically in Figure 3.

Water from the well is pumped up from the well (1) by two piston pumps (2), each driven by a wind turbine (3), and fed through a totalizing turbine meter (4), a check valve (5), and then recombines in the common supply line to the storage tank at 3.72 m from the ground. To control the water level in the storage tank, a float valve (7) was installed at the discharge point of the supply line. And to prevent unnecessary loss of ground water when the supply to the tank is shut off by the float valve, a relieve valve (8) was installed in the supply line of each pump. Thus, when the pressure builds up in the supply line, the water supply is

discharge back into the pump suction line. For the air-lift system, compressed air from the engine-driven air compressor (9) is injected into the well-shaft. The water supply is routed either to the storage tank or directly to field (for even higher flow rates).

A ball valve (10) was installed to control the water supply from the tank to the field. At the supply point on site, the water passes through totalizing turbine meters (11) and gate valves (12) before being discharged to the field(13).

TABLE 1

Field test results of the wind turbine-water pumping system

$\bar{V}$ (m/s)	σ^2 (m^2/s^2)	N (rpm)	Q (l/min)	P_w (w)	P_a (w)	λ	C_p
2.64	0.71	43.8	12.4	163.7	31.7	0.59	.193
2.70	0.38	35.6	10.8	175.1	27.6	0.47	.157
2.79	0.66	35.1	11.2	193.2	28.7	0.45	.145
2.97	0.36	48.3	13.6	233.0	34.8	0.58	.145
3.34	0.40	52.4	14.2	331.4	36.4	0.56	.110
3.49	0.67	44.2	12.8	378.1	32.8	0.45	.086
3.52	1.00	45.6	13.2	387.9	33.9	0.46	0.088
3.68	0.96	49.7	13.2	443.3	33.8	0.48	0.075
3.91	1.28	48.3	13.8	531.7	35.3	0.44	0.066
4.04	0.62	50.6	13.8	586.5	35.3	0.44	0.060

$\bar{V}$ = Average wind speed

σ^2 = Wind speed variance

N = Wind turbine rotational speed

Q = Water Flow rate

P_w = Available power at a specific wind speed

P_a = Actual power output

λ = Velocity coefficient = turbine blade tip speed/Wind speed

C_p = Power coefficient = P_a/P_w .

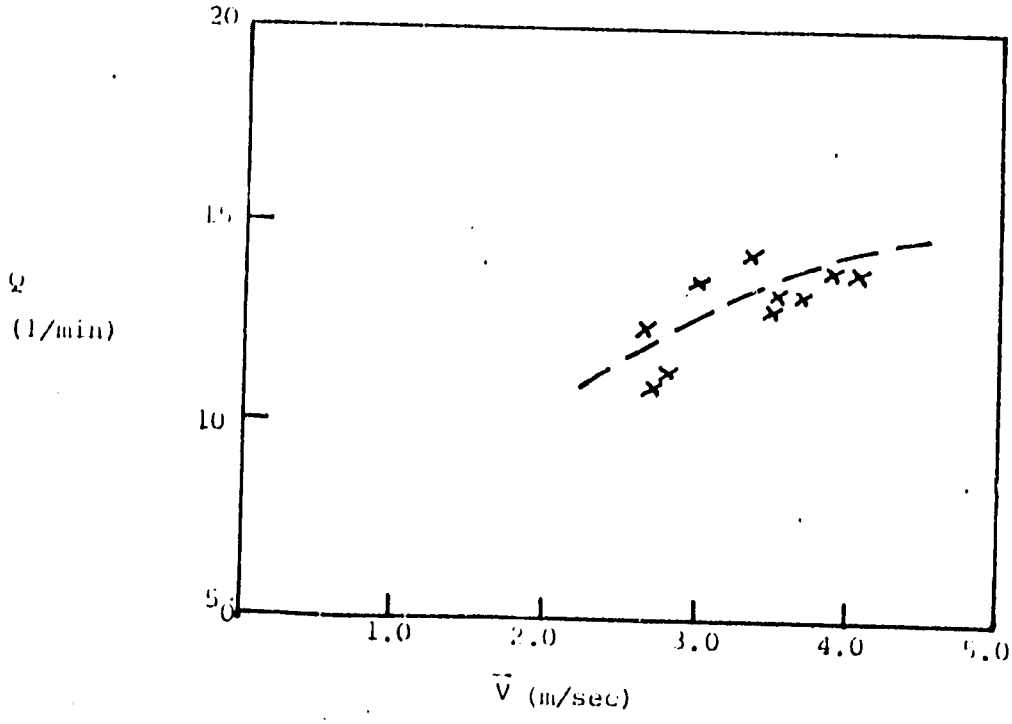

Fig.1 : Pump output (flow rate) as a function of wind speed

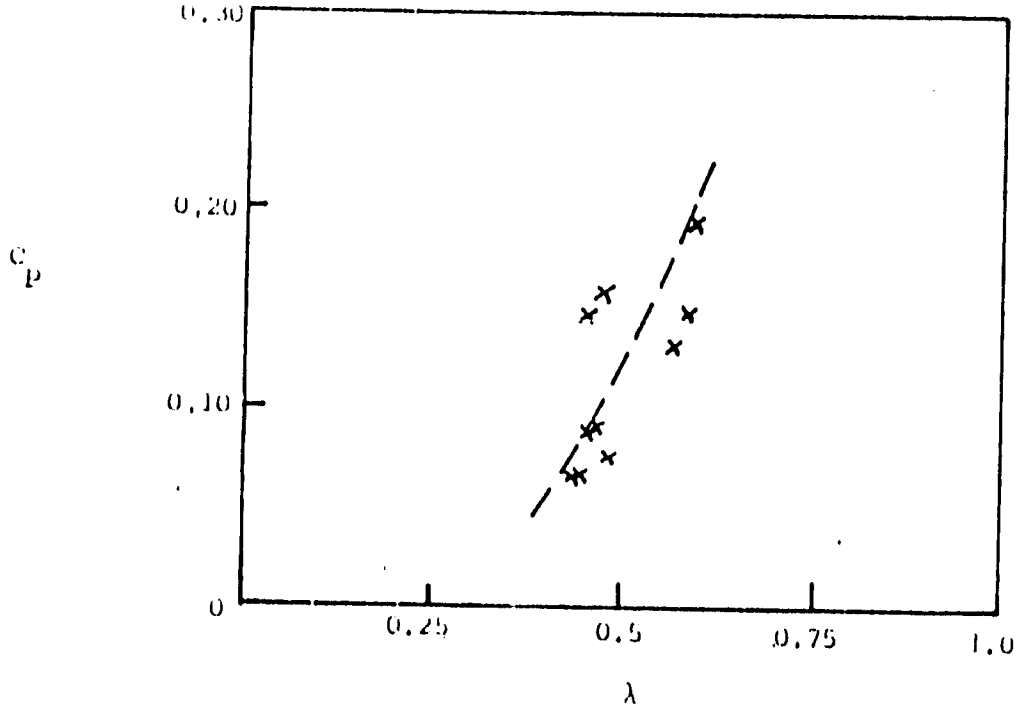

Fig.2 Power coefficient (C_p) as a function of velocity coefficient (x)

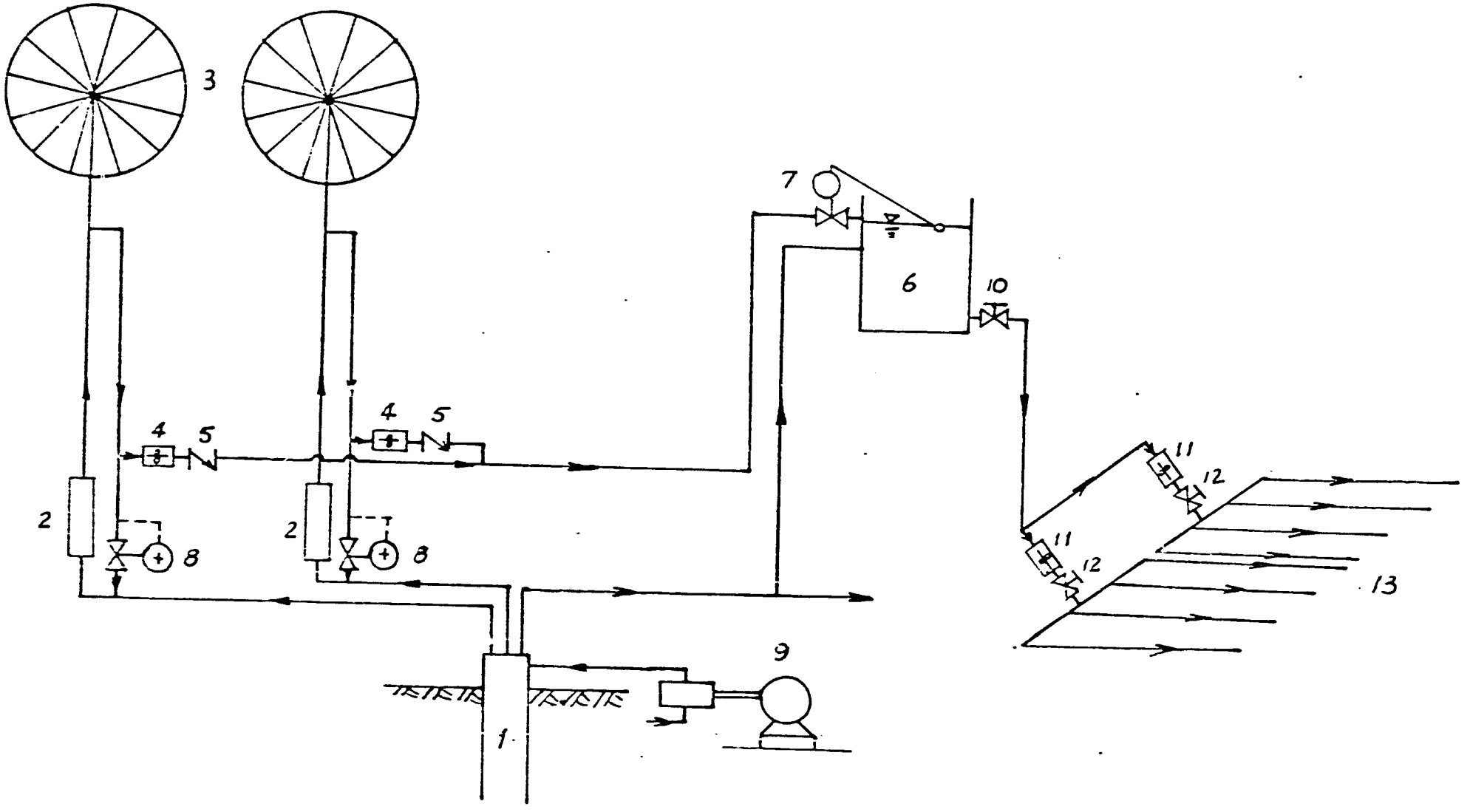

Fig.3 : Schematic diagram of the water supply system