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RESIDUE DECAY EVALUATION FOR SOIL CONSERVATION

by

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SUMMARY: The decomposition of soybean, corn, sunflower and wheat residues was studied under field conditions. The effect of temperature, moisture and carbon/nitrogen ratio on the decomposition rate was evaluated. The experimental data were used to check two residue decay models.

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Abstract

Residue decay study is essential for designing effective crop residue management systems. The decomposition of soybean, corn, sunflower and wheat residues has been studied under field conditions. After 10 months exposure, residue losses were 74, 71, 61 and 36% for soybean, corn, sunflower and wheat residues, respectively. Temperature, moisture and carbon/nitrogen ratio were the most important factors that affected decomposition. The rate was rapid under high temperatures and adequate moisture conditions. Crop residues with a low carbon/nitrogen ratio decomposed at a more rapid rate than crops with high carbon/nitrogen ratio. The interaction effect of the above important factors on decomposition rate was also studied. Experimental data were used to check two residue decay models developed by Gregory et al. (1983).

Introduction

Crop residue is useful for erosion control, maintaining soil productivity, and improving soil physical properties. Poor residue management increases soil erosion, plant nutrient losses, and decreases soil productivity. In order to design effective crop residue management systems, it is necessary to determine the amount of residue that is left on the soil throughout the year.

Crop residue decomposition is affected by temperature, moisture, aeration, pH, available nutrients, C/N ratio, lignin content and age and size of material (Parr and Papendick, 1978). However, experimental data available in the literature indicate that temperature, moisture, C/N ratio, and location on or within the soil profile are the most important factors (Reddy et al., 1980). Previous researchers have selected certain factors such as temperature, moisture or placement in the soil profile and investigated their individual effects on residue decomposition for particular crops (Waksman and Gerretsen, 1931; Pal and Broadbent, 1975; Parker, 1962; Brown and Dicky, 1970).

This paper compares the decomposition rates of soybean, corn, sunflower and wheat residues under field conditions. It also checks two residue decay models developed by Gregory et al. (1983).

Experimental Design and Procedure

Residue decay was studied for four crops at Fleetwood Farm, located eight miles east of Columbia, Missouri. Approximately 25 grams of soybean, corn, sunflower and wheat residues were placed in 8x16" fiberglass cloth bags. A total of 60 bags for twelve month's study were prepared for each residue type. All bags were oven-dried at 105°C for 24 hours to obtain their initial oven dry weights. On January 30, 1981, the bags were taken to the field and randomly placed on the surface of the soil in five rows. The ends of the bags were nailed to the soil to prevent their removal by wind. At monthly intervals five bags from each residue type were removed and loss in weights were measured.

Residue bags were contaminated with soil particles after commencement of intense rains in March. This contamination caused final weights of residue bags to be greater than the initial weights. Corrections were made for the addition of soil by analyzing the decay on an ash-free basis. The procedure described by Parker (1962) was followed in the ash percent determination.

Temperature and precipitation data were collected from Columbia Regional Airport. Monthly values of decomposition, temperature and rainfall are given in Table 1. Carbon and nitrogen determinations were done for the initial crop samples only. In determining the total nitrogen in plant residue, the

Table 1. Decomposition Rates, Mean Monthly Temperature, and Monthly Precipitation Data from February 1981 through November 1981.

MONTH	MEAN MONTHLY TEMP. °C	MONTHLY PRECIP. (INCHES)	DECOMPOSITION RATES (Percent)			
			Soybean Residues	Corn Residues	Sunflower Residues	Wheat Residues
February	0.78	1.09	10.16	7.98	7.82	3.53
March	6.94	1.33	12.19	9.97	14.73	5.60
April	16.11	5.47	22.26	7.66	10.67	2.07
May	15.06	7.71	28.60	22.27	8.16	6.64
June	23.56	8.02	52.49	28.96	25.86	12.11
July	25.61	12.14	64.23	51.90	44.68	30.11
August	23.78	2.48	72.82	57.59	39.54	26.22
September	20.17	0.68	70.55	59.39	41.78	32.24
October	12.78	4.03	72.65	75.36	62.81	40.79
November	8.17	3.60	74.07	71.21	61.45	36.14

procedure described by Nelson et al. (1973) was followed. For carbon analysis, the procedure described by Mebius (1960) was used.

Treatment Results

Soybean residue decomposed at a faster rate than corn, sunflower or wheat residue. After ten months about 75% of the original mass was lost (Fig. 1). Decomposition was slow in February and March due to low temperature. In June and July high temperatures and adequate moisture created favorable conditions for microbial activities to occur and resulted in high decomposition rates. Decomposition proceeded slowly in August, September, October and November as rainfall and temperature decreased.

Figure 2 illustrates the decomposition rate of corn residue. The process was slow from February until June. Only 29% of the original mass was lost by the end of June. It proceeded rapidly in July. About 52% of the total mass was decomposed. August and September were relatively dry and loss in weights were insignificant. Rainfall increased again in October. This stimulated microbial activity and resulted in a significant loss of residue weight. After ten months, decomposition was 71%.

Residue weight losses were not statistically significant from February until May from sunflower residues (Fig. 3). In June almost one-fourth of the total mass was lost, and by the end of July about 45% was decomposed. In August and September decomposition was quite slow due to dry weather but increased again in October. About 62% of the total mass was decomposed after ten month's study.

Rate of decomposition for wheat residues was noticeably slower than soybean, corn, and sunflower (Fig. 4). The 5% LSD comparison applied showed that loss in weights were not significantly different from February until May. Decomposition was slightly higher in June. About 18% of the original mass was lost. Similar to other crop residue types, decomposition slowed in August and September and accelerated in October.

Residue Decay Model

Experimental evidence indicates that decomposition of crop residue best follows first order kinetics described by the following equation:

$$M = M_o e^{-kt} \quad (1)$$

where,

M_o = original mass of residue,
M = amount of residue at time t,
t = time in days, and
k = first order rate constant.

The above equation doesn't take into account important variables such as temperature, moisture and C/N ratio. Recent models developed by Gilmour et al. (1977) and Reddy et al. (1980) take into account the aforementioned variables. Basically, Gilmour and Reddy's models assumed decomposition to follow first order kinetics. However, the kinetic rate constant, k, was adjusted for changes in temperature, moisture, C/N ratio and method of application. These models are difficult and complicated to apply. Gregory et al. (1983) developed two simple residue decay equations described below which are verified in this study using the measured data.

1) Theoretical Residue Decay Model:

The equation was derived based on changes in surface area and is given by:

$$\left[\frac{M}{M_o} \right]^{1/2} = 1 - \frac{u}{R_o} \tau \quad (2)$$

where,

M = present mass of residue,
M_o = initial mass of residue,

u = a constant,
R_o = radius of one stem, and
τ = a time variable adjusted for temperature and moisture conditions and the initial C/N ratio of residue.

t is calculated with the following equation:

$$\tau = \frac{TtA_m}{C/N} \tag{3}$$

where,

T = time (days),
t = temperature (^oC above zero),
C/N = initial C/N ratio, and

$$A_m = \text{moisture index} = \sum_{i=1}^{5} \frac{I}{i}$$

where,

I = depth of rainfall on a given day, and
i = the day number with the present day being 1, the previous day being 2, etc.

2) Modified Exponential Decay Equation:

This is a simple exponential decay equation using a time variable weighted for variations in temperature, rainfall, and initial carbon/nitrogen ratio of the residue. The equation states:

$$\frac{M}{M_o} = e^{-k\tau} \tag{4}$$

where,

M, M_o and τ are defined above, and
k = a calibration coefficient.

Model Results

The theoretical residue decay model given in equation 2 was checked using measured data. Ghidey (1982) described the computational methods of the various parameters. The equation was treated as a linear regression model. The square root of the ratio of the residue remaining, $[M/M_o]^{1/2}$, was the dependent variable while the factor τ was the independent variable of the model. The scatter diagram and linear regression lines showing the relationships between the variables for soybean, corn, sunflower and wheat residues are given in Figures 5, 6, 7 and 8, respectively. The following equations were obtained:

Soybean Residue:

$$\left[\frac{M}{M_o}\right]^{1/2} = 0.948 - 0.0072\ [\tau] \qquad (5)$$

$$r^2 = 0.98$$

Corn Residue:

$$\left[\frac{M}{M_o}\right]^{1/2} = 0.988 - 0.006\ [\tau] \qquad (6)$$

$$r^2 = 0.95$$

Sunflower Residue:

$$\left[\frac{M}{M_o}\right]^{1/2} = 0.981 - 0.0062\ [\tau] \qquad (7)$$

$$r^2 = 0.88$$

Wheat Residue:

$$\left[\frac{M}{M_o}\right]^{1/2} = 0.998 - 0.01\ [\tau] \qquad (8)$$

$$r^2 = 0.94$$

Figures 5 through 8 have generally shown that the linear regression model approach is appropriate for the relationship between the variables $[M/M_o]^{1/2}$ and τ. The fit of data is considered good in all plots. The coefficients of determination, r^2, obtained were all close to one, which indicates that the model is appropriate for the measured data. The plotted data also gave intercept values close to one, which agrees with the theoretical value.

Because it takes initial radius into consideration, the value of u/R_o is not the same for different crop residue types. Residues with smaller R_o are expected to have greater u/R_o values than residues with larger R_o. u/R_o values in the above equations agree with this statement.

According to the model, the value of the constant, u, must be the same for all crop residue types. However, u has not been evaluated because the initial radius of the residue was not measured. For further verification of the equation, the value of u must be checked to evaluate if it is the same for different residue types.

The modified exponential decay model described in equation 4 has also been checked using the same measured data. The curves plotted in Figures 9 through 12 for soybean, corn, sunflower and wheat residues, respectively, gave the following equations:

Soybean Residue:

$$\frac{M}{M_o} = 0.91e^{-0.026\tau} \qquad (9)$$

$$r^2 = 0.98$$

Corn Residue:

$$\frac{M}{M_o} = 0.99e^{-0.021\tau} \qquad (10)$$

$$r^2 = 0.94$$

Sunflower Residue:

$$\frac{M}{M_o} = 0.97e^{-0.019\tau} \qquad (11)$$

$$r^2 = 0.89$$

Wheat Residue:

$$\frac{M}{M_o} = 0.99e^{-0.031\tau} \qquad (12)$$

$$r^2 = 0.94$$

Because of the good fit of data, and higher r^2 values the exponential decay equation is also an adequate residue decay model for the available experimental data.

Summary and Conclusions

The decomposition of soybean, corn, sunflower, and wheat residues has been studied under field conditions at the University of Missouri-Columbia. The effect of temperature, moisture and carbon/nitrogen ratio has also been evaluated. The study has shown that high temperature and adequate moisture created favorable conditions for microbial activity and resulted in more rapid decomposition rates. Decomposition was also affected by the initial carbon/-nitrogen ratio of crop residues. Under similar conditions residues with a low carbon/nitrogen ratio decomposed at a more rapid rate than residues with a high carbon/nitrogen ratio. Wheat residues with high ratios (106.95) decomposed at a significantly lower rate than soybean (30.81) and corn (27.81). Residue decay equations developed by Gregory et al. (1983) have also been checked using the measured data. Both models were found to be adequate for modeling residue decay for soil and water conservation work.

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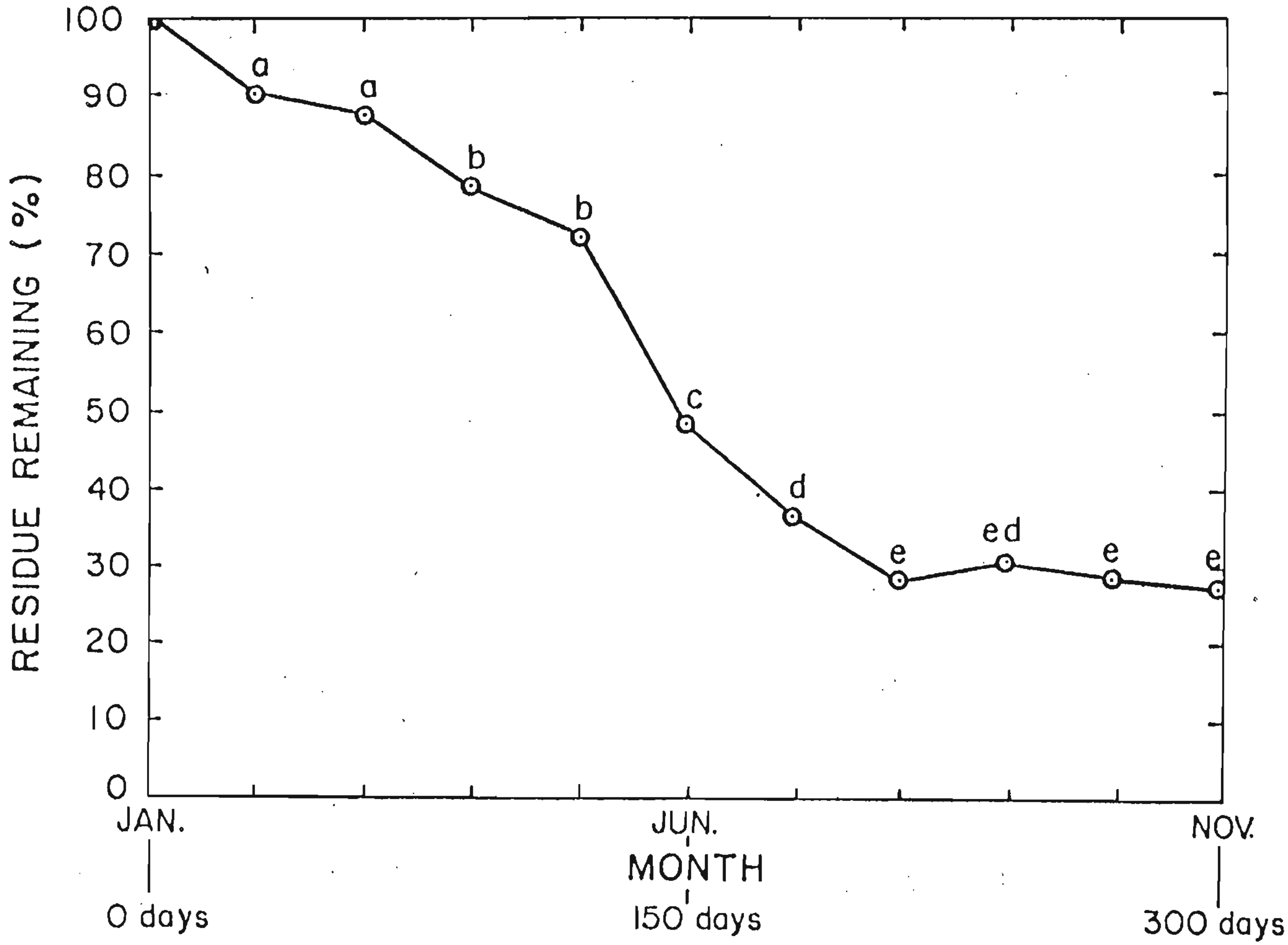

Figure 1: Percent of Soybean Residue remaining from January 1981 through November 1981. Points containing different letters are significantly different at 5% level.

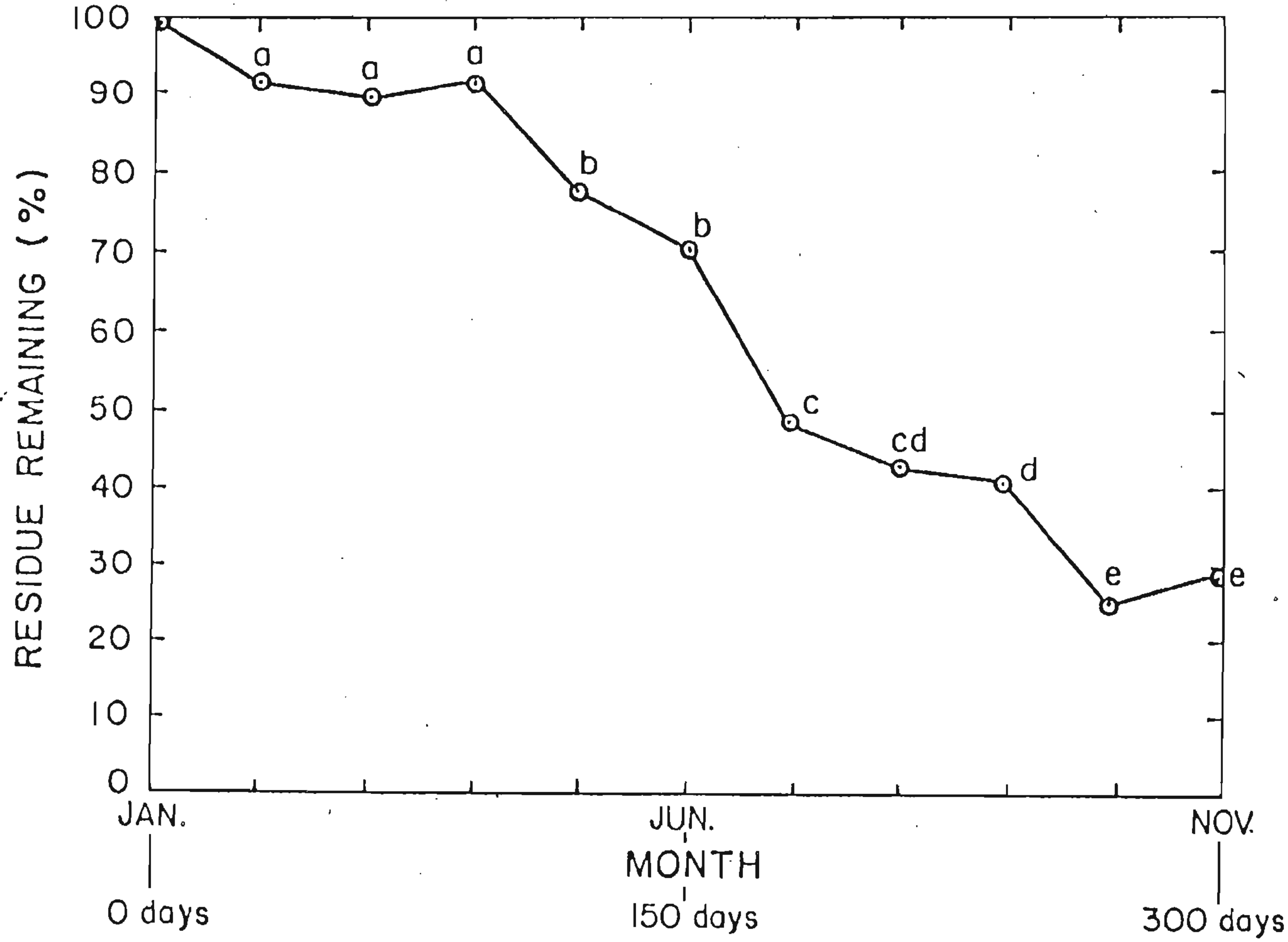

Figure 2: Percent of Corn Residue remaining from January 1981 through November 1981. Points with the same letters are not significantly different at 5% level.

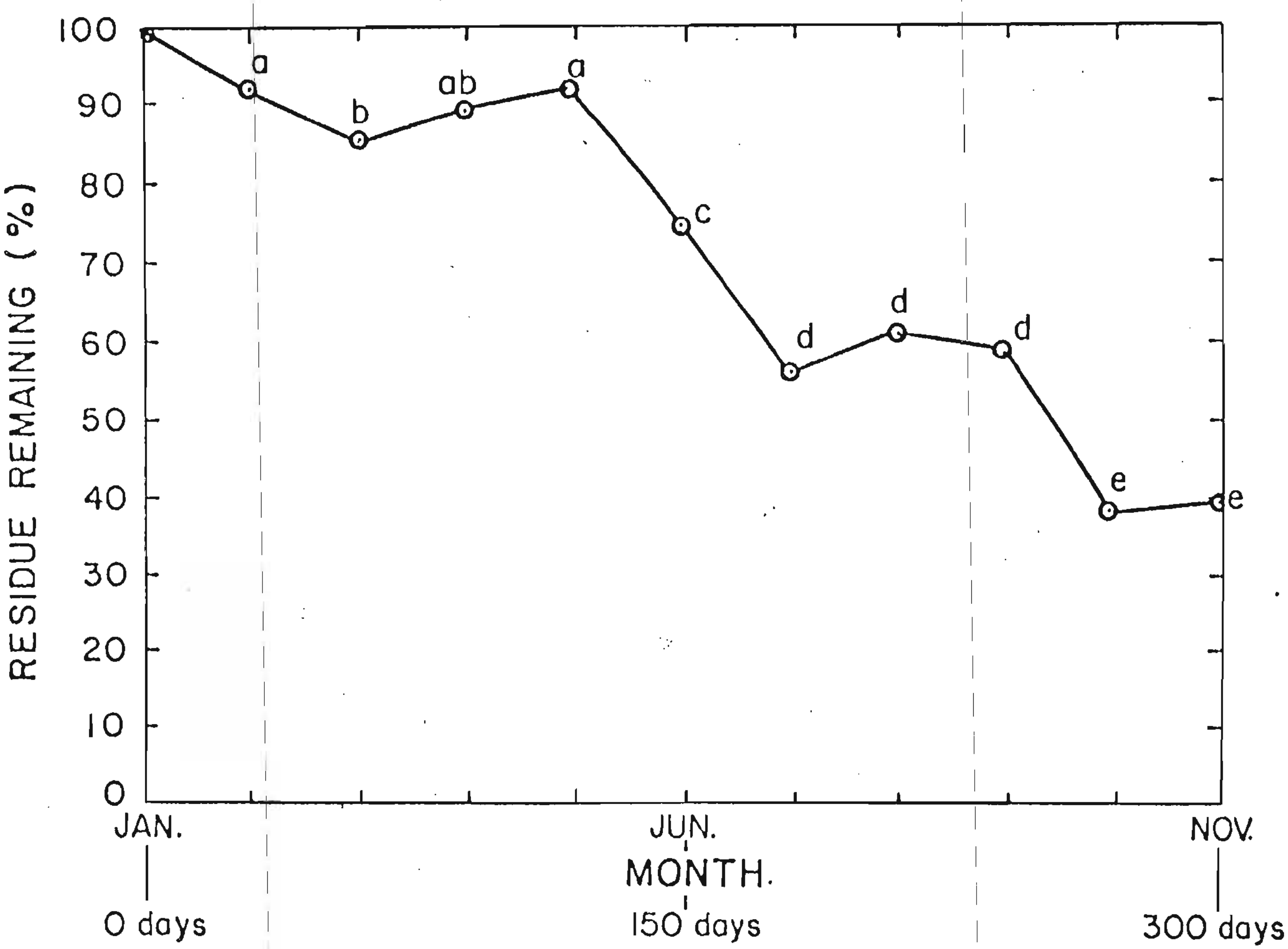

Figure 3: Percent of Sunflower Residue remaining from January 1981 through November 1981. Points associated with the same letters are not significantly different at 5% level.

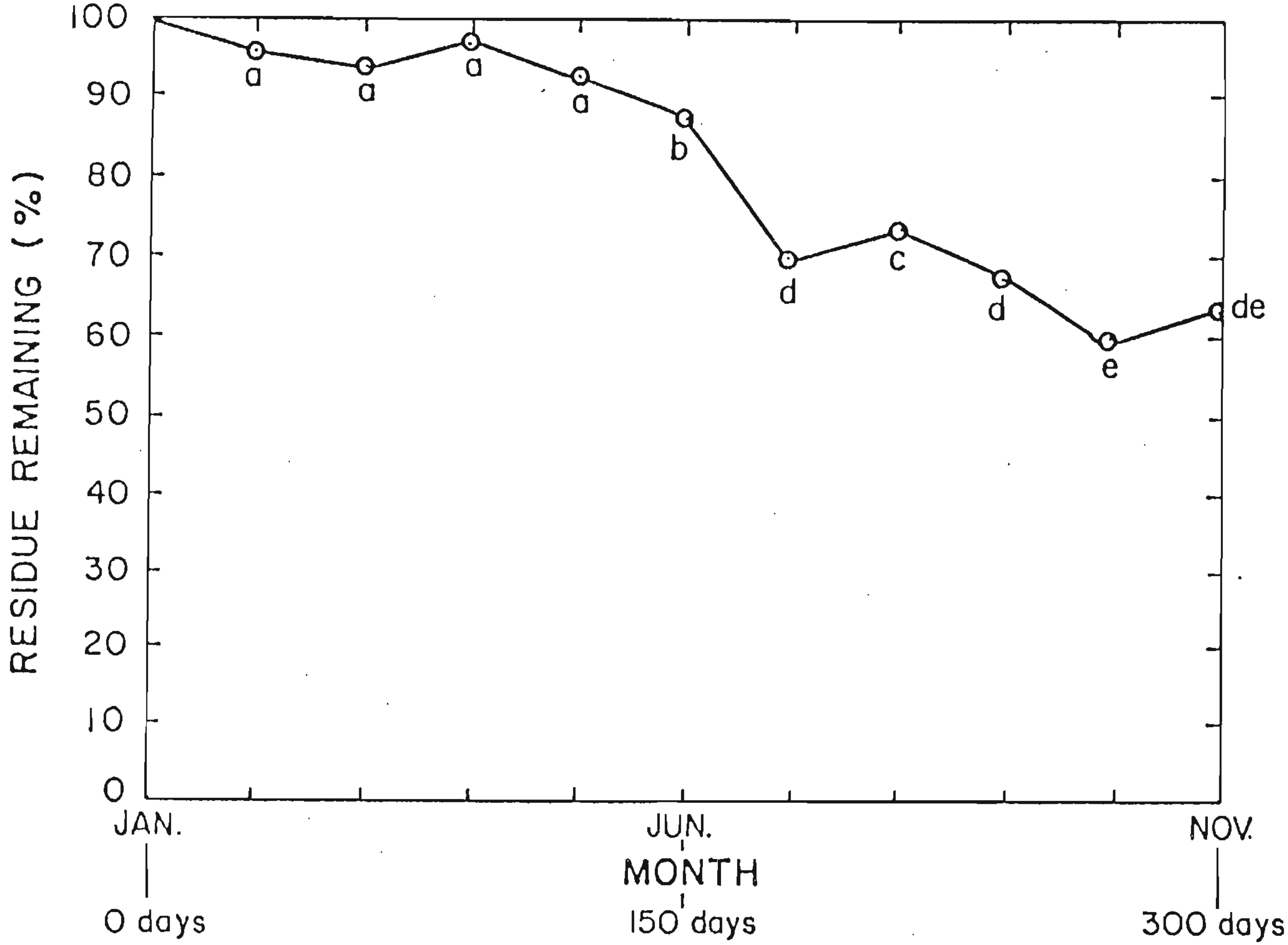

Figure 4: Percent of Wheat Residue remaining from January 1981 through November 1981. Points containing the same letters are not significantly different at 5% level.

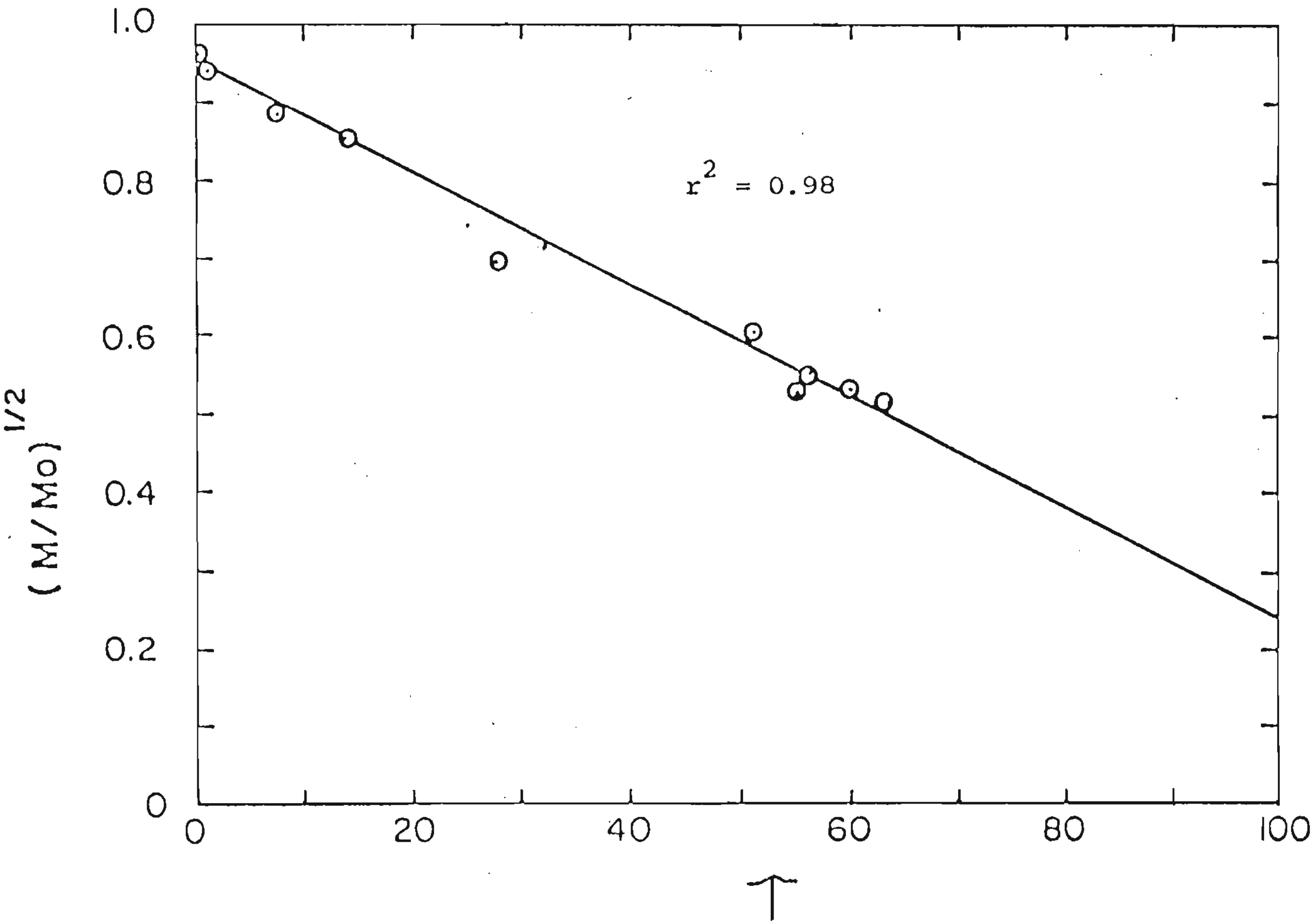

Figure 5: Effect of Climatic and Residue type parameters on rate of decomposition for Soybean Residues.

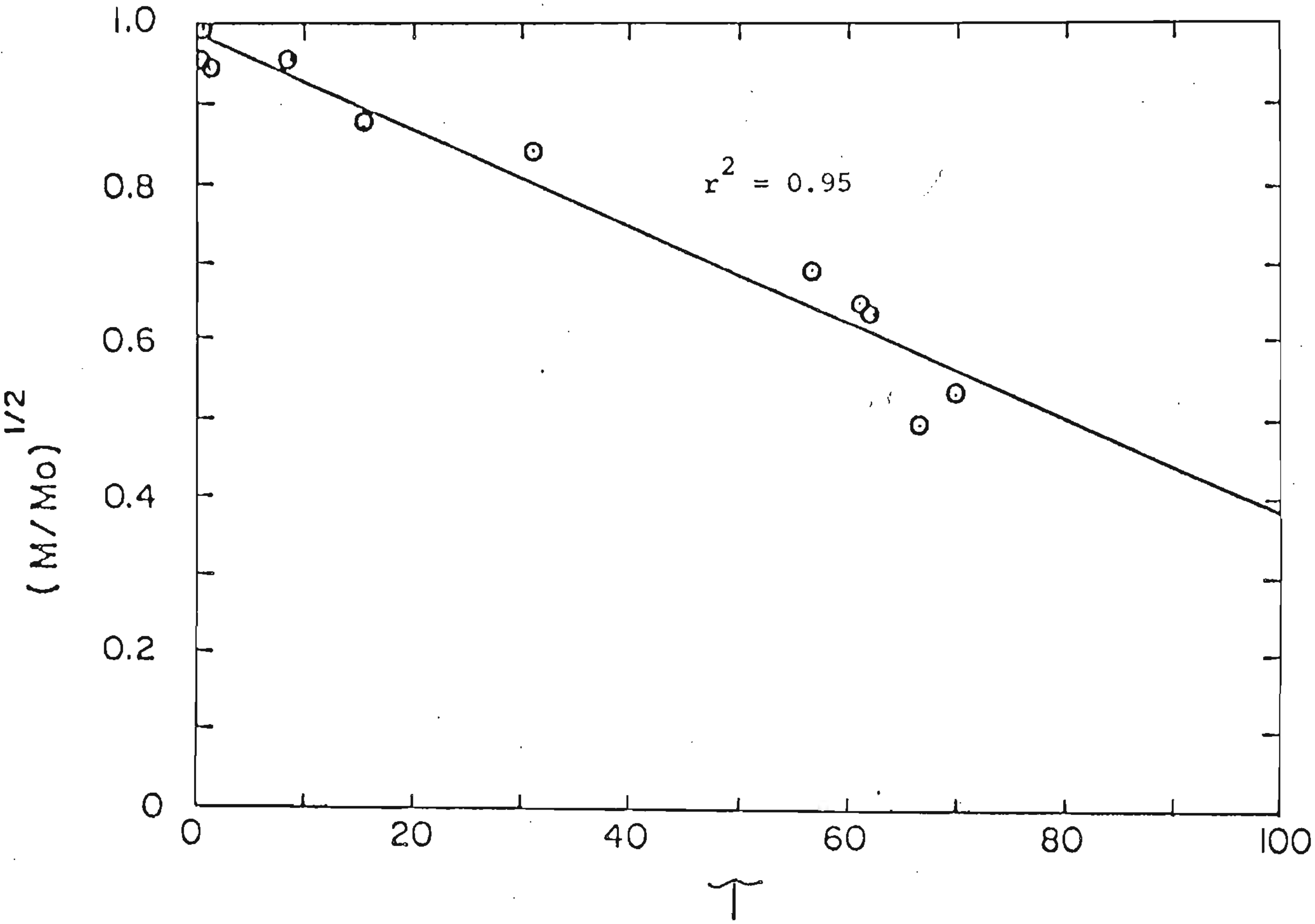

Figure 6: Effect of Climate and Residue type parameters on rate of decomposition for Corn Residue.

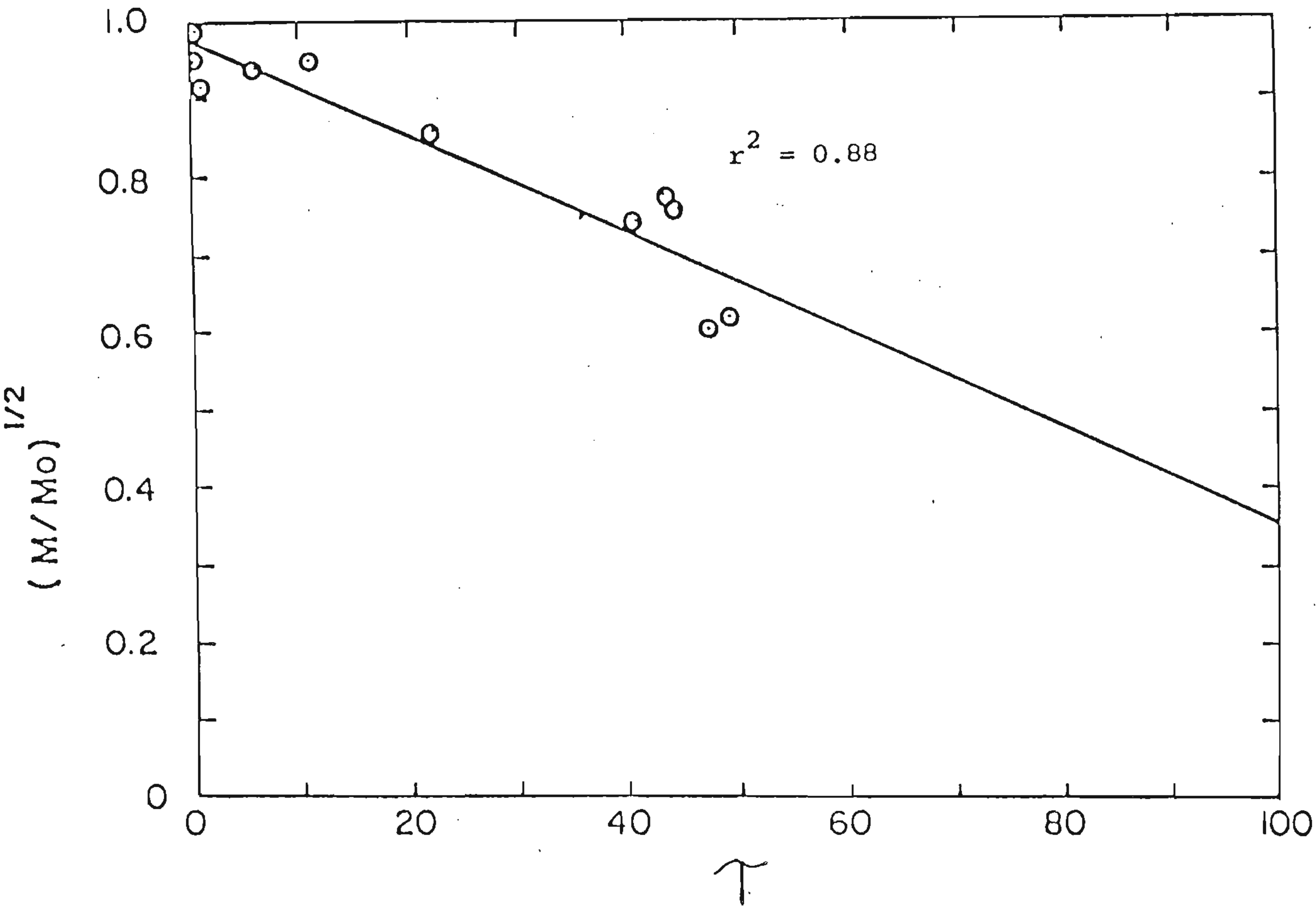

Figure 7: Effect of Climatic and Residue type parameters on the rate of decomposition for Sunflower Residues.

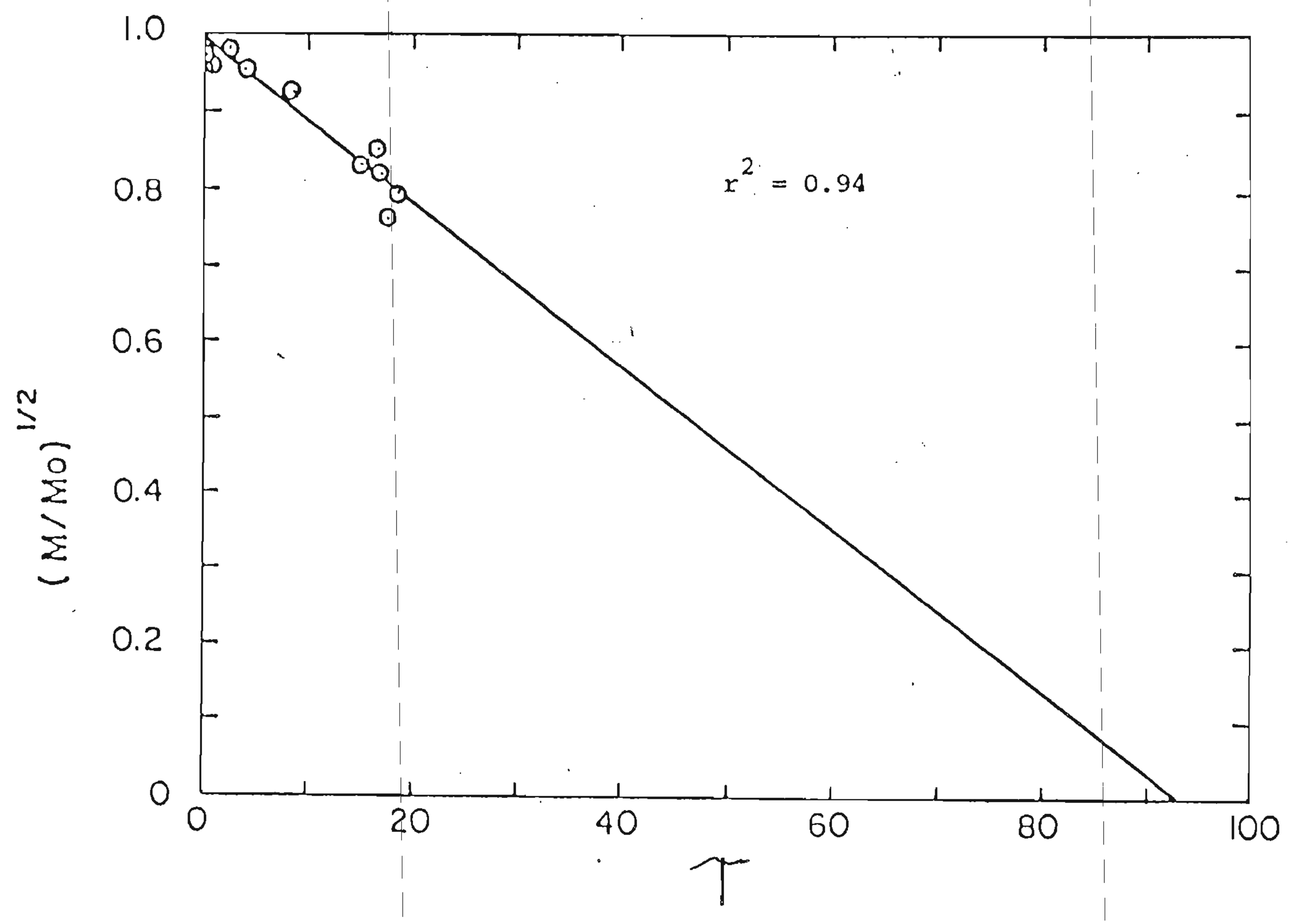

Figure 8: Effect of Climatic and Residue type parameters on the rate of decomposition for Wheat Residues.

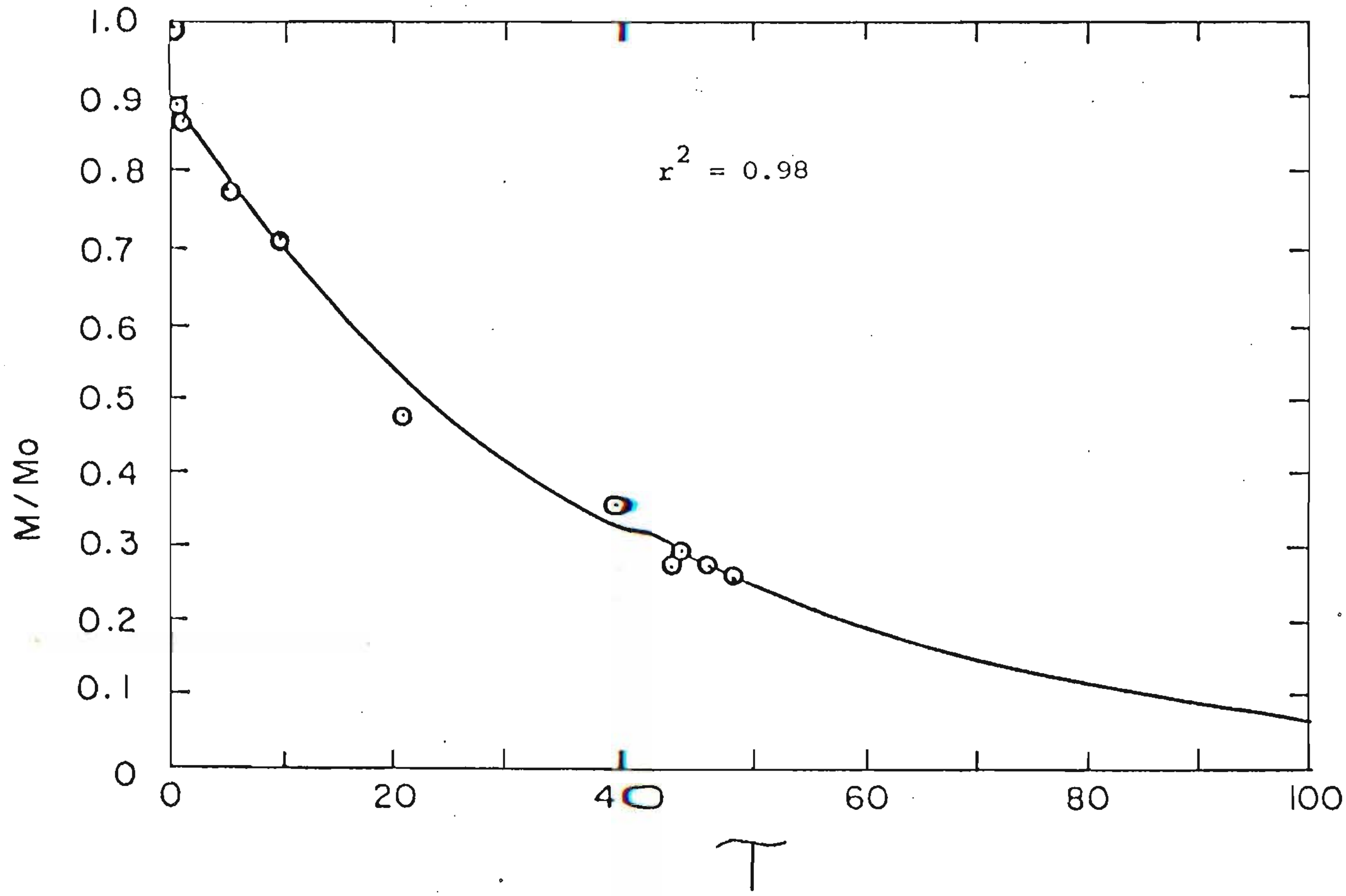

Figure 9 : First order curve fitted for Soybean Residue.

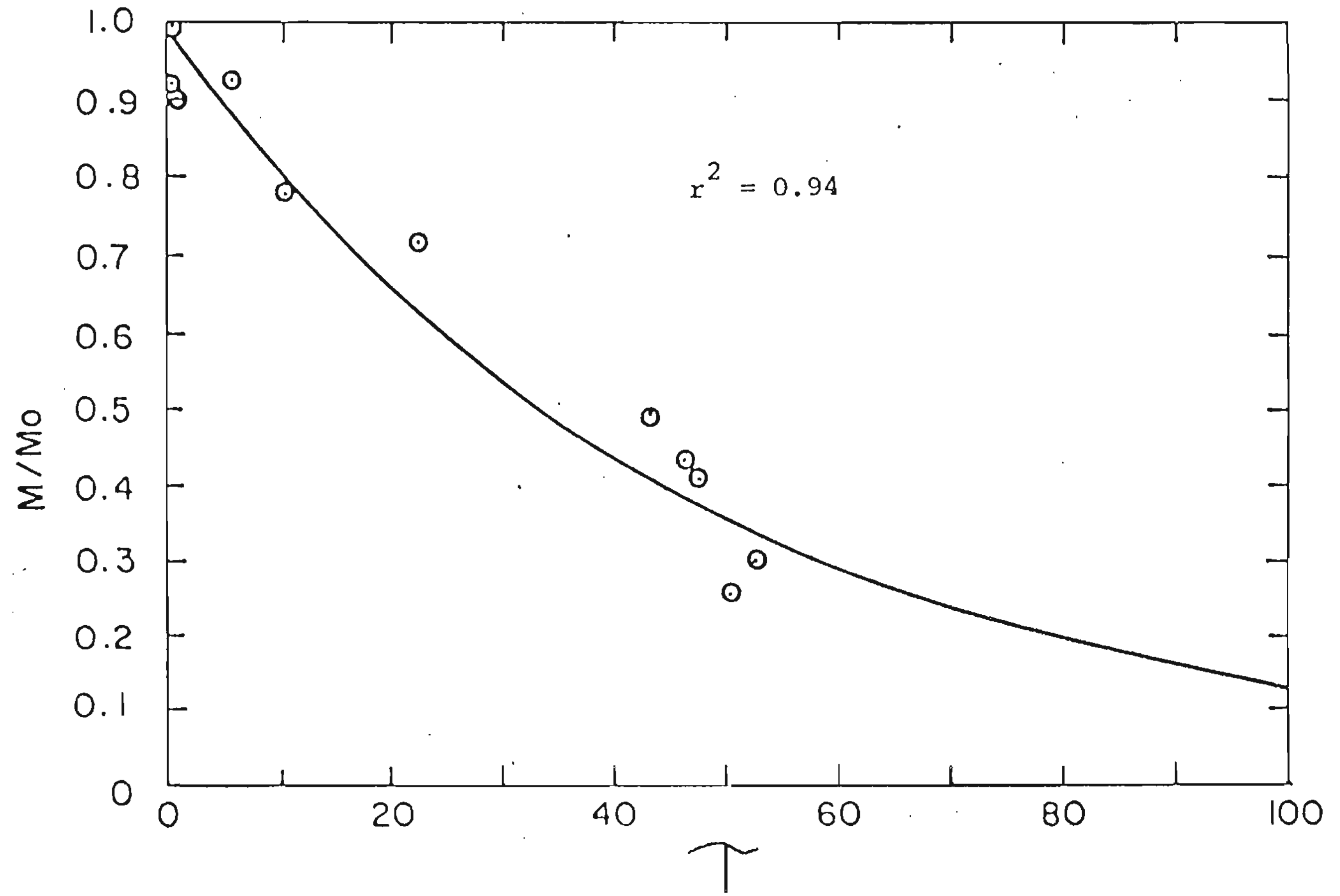

Figure 10: Curve fitted for Corn Residue.

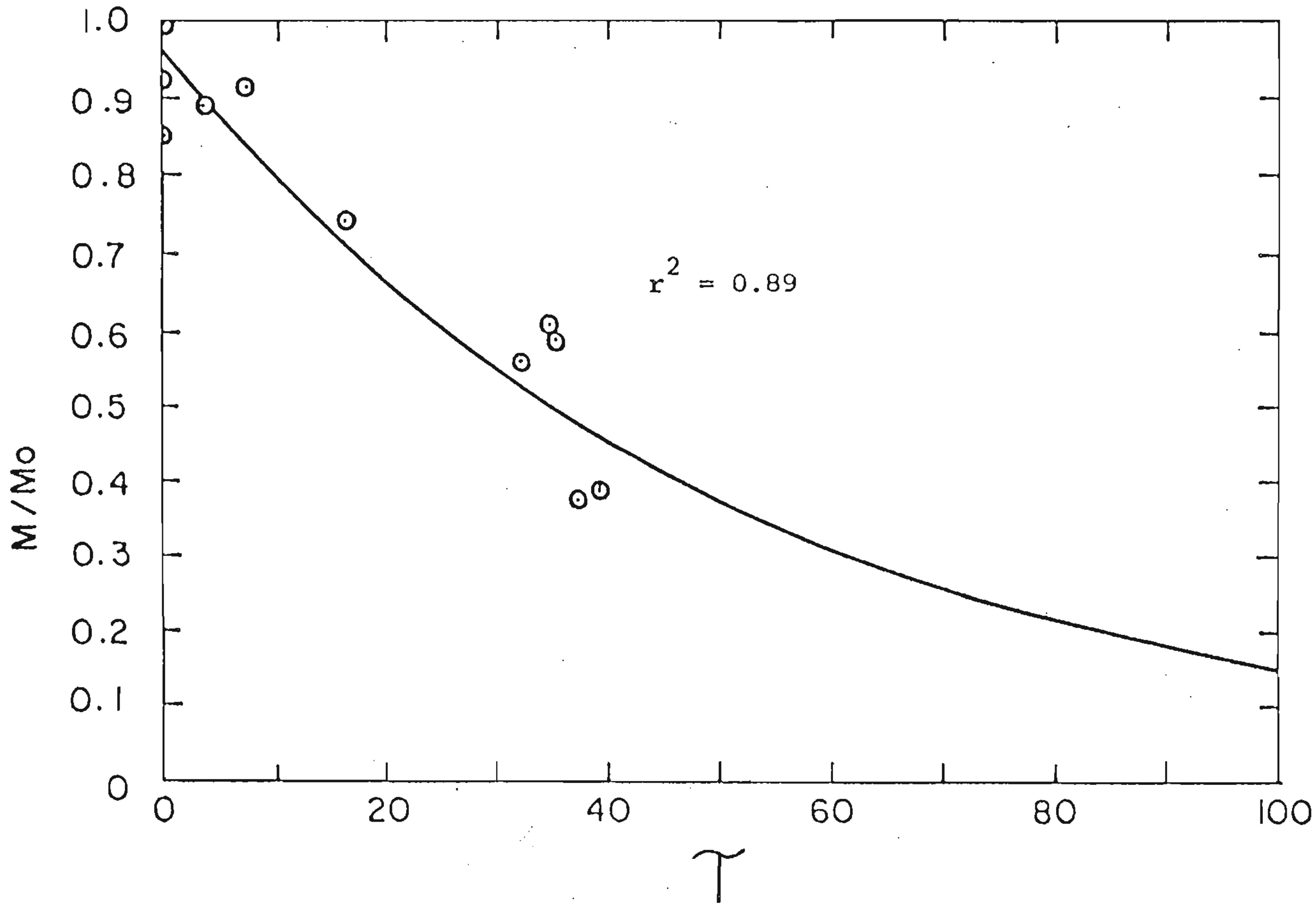

Figure 11: Curve fitted for Sunflower Residue.

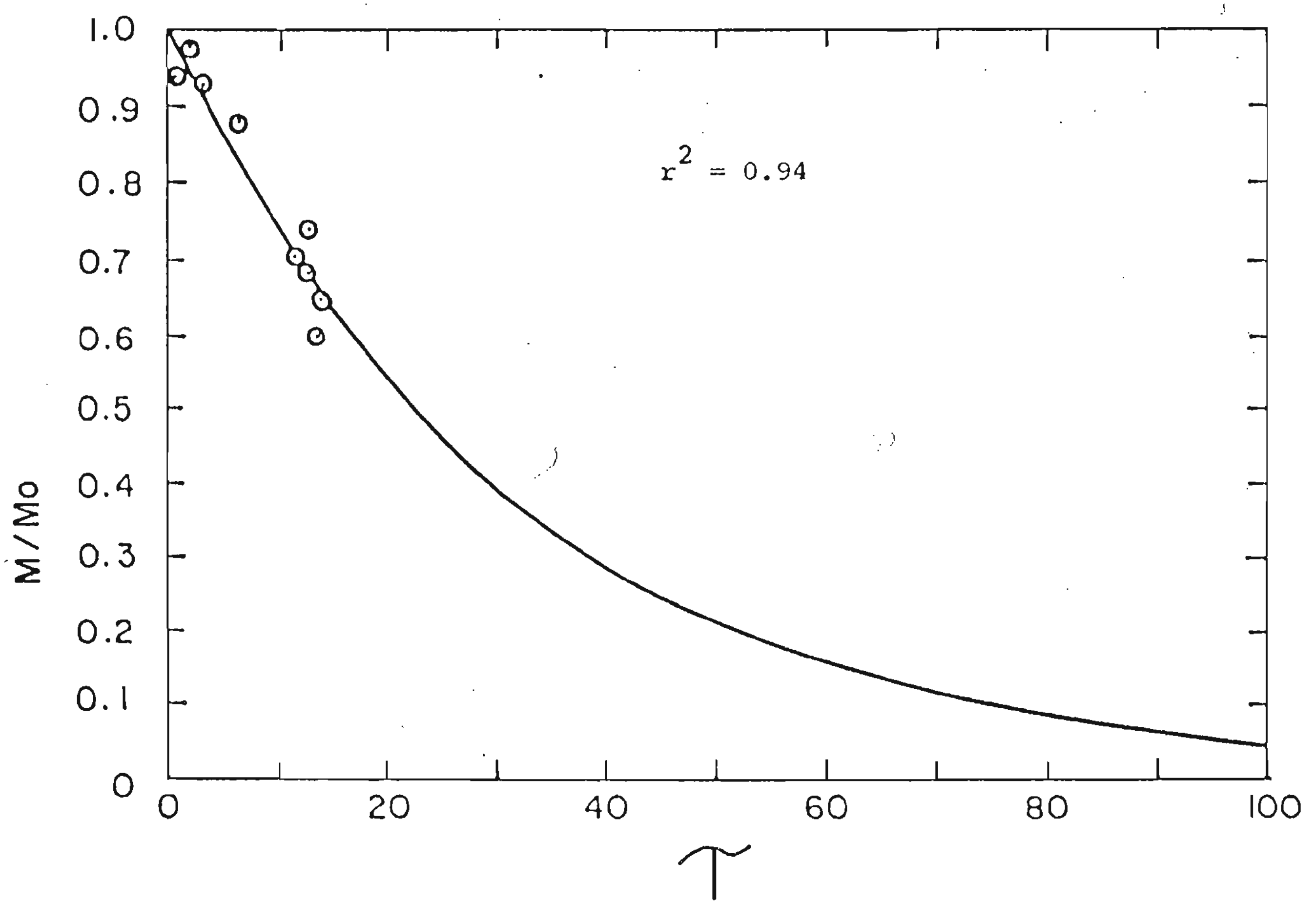

Figure 12; Curve fitted for Wheat Residue.