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Research Technical Completion Report
Project B-041-IDA

SOIL WATER INTAKE RATES AND SURFACE IRRIGATION SYSTEM CHARACTERISTICS BY SOIL SERIES IN SOUTHEASTERN IDAHO

by

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Moscow, Idaho

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SUMMARY

Seven major soil series of irrigated agricultural land of southeastern Idaho were evaluated to obtain soil water intake rates. They range in texture from silt loam to gravelly loam. Three crops (hay, grain and potatoes) were selected for this study. Soil survey maps from local Soil Conservation Service were used to locate each soil series of the area. It was difficult to select representative sampling sites in any field. Therefore, it was necessary to test several different sites to obtain average results.

The infiltrometer ring test method was used for border irrigated fields, and the inflow-outflow method for furrow fields. There were different intake rates for fields of different crops on the same soil. Generally potato fields had lower intake rates than the other crops when tested by the ring method. There were also differences between the intake rates obtained by the ring test and the inflow-outflow method for furrow irrigated potato fields. The inflow-outflow method has been known as the most dependable method of obtaining furrow intake rate. However, under some conditions, the ring test is simpler and easier than the inflow-outflow method. There were not enough test data to statistically test any relationship between the two methods in this study.

The irrigation practices on two furrow fields were evaluated using the data obtained in this study. The results showed that improved water management practices are needed to obtain higher application efficiencies on both fields. One field had excess irrigation with high runoff loss and the other field had a lack of irrigation with high runoff loss. The irrigators could increase the efficiency by using a cut back stream and/or a return flow recovery system.

CHAPTER 1

INTRODUCTION

The drought of 1977 in the Pacific Northwest caused most irrigators in Idaho to realize the limits of their life-giving irrigation water supply. As demands for water increase it is imperative that irrigation systems be designed and managed in the best possible manner. To design and operate efficient irrigation systems it is necessary to know those field parameters that influence system operation.

The major factors affecting irrigation practices include slope steepness, run length, field width, soil texture, crop, and irrigation method. These factors may be arbitrarily controlled except soil texture and slope steepness. In this study soil water intake rates of border and furrow irrigated fields and some advance time relationships of furrow fields were analyzed. The importance of these parameters for improving irrigation practices has been well documented by other researchers (Fok and Bishop, 1965; Fok and Bishop, 1969; and Katopodes and Strelkoff, 1977).

BACKGROUND

The complexity of soil characteristics affecting intake rate make it necessary to measure intake rates for soils in a given area. The different soil profiles at each sample site in the same soil type could be one reason, and sampling errors might be another. Also, without reliable field data, it is extremely difficult to estimate advance and recession time relationships even with sophisticated mathematical models. It is intended that the results of this report help those who want to develop improved surface irrigation practices in the study area or similar areas.

To manage irrigation water effectively with a surface system, it is necessary to know the intake rate for a given soil. Intake rate is dynamic and is influenced by many factors including time. Lewis (1937) and Criddle and others (1956) have shown that the intake rate decreases with time, and that it can be expressed very well by a simple geometric equation;

$$I = at^b \tag{1}$$

where

I = intake rate in inches per hour

t = intake opportunity time in minutes

a and b = empirical constants.

Another equation can be used to calculate the intake rate considering the final infiltration rate.

$$I = \alpha t^{\beta} + c \tag{2}$$

where

α and β = empirical constants

c = a constant that the intake rate will approach for infinite intake time.

This equation is used by the Soil Conservation Service of the USDA (SCS, 1974).

In this study equation (1) was used to analyze the sample data. By integrating equation (1) the cumulative intake depth at time t is obtained. It is expressed as:

$$D = \frac{a}{60(b+1)} \quad t^{b+1} \tag{3}$$

where

D = cumulative intake depth in inches at time t minutes.

Because of the characteristics of measurement, cumulative intake depth equations were obtained from the infiltrometer ring tests, and intake rate equations from the inflow-outflow tests. They were converted to intake rate and cumulative intake depth equations, respectively. The intercept of the intake rate equation explains initial intake rate of a soil and the exponent shows the characteristics of the intake rate of a soil.

DEFINITIONS OF TERMS

Soil Water Intake Rate - The purpose of irrigation is to store water into soil for later use by plants by applying water to the field surface. The entry rate of water into soil under field conditions is called intake rate. It is a function mainly of time, soil texture and surface cover.

Border Irrigation - A method of controlled surface flooding in which the field to be irrigated is divided into strips by parallel dikes or border ridges. Each strip is irrigated separately.

Furrow Irrigation - Furrow irrigation refers to water that is discharged into and runs down small sloping channels (called furrows or corrugates) which are cut or pressed into the soil.

Available Water Holding Capacity - The amount of water a soil profile will hold against drainage by gravity at a specified time after a thorough wetting.

Management Allowed Deficit (MAD) - The percent of the total available soil moisture in the root zone or the corresponding depth of water that can be extracted from the root zone between irrigations to produce the best economic balance between crop returns and costs of irrigation.

Distribution Uniformity (DU) - indicates the uniformity of infiltration throughout the field.

$$DU = \frac{\text{average depth infiltrated in the lowest one quarter of the area}}{\text{average depth of water infiltrated}} \times 100$$

Application Efficiency (AELQ or AELA) - indicates how well a system is being used.

$$\text{AELQ or AELA} = \frac{\text{average low quarter depth of water stored in root zone}}{\text{average depth of water applied}} \times 100$$

Potential Application Efficiency (PELQ or PELA) indicates a measure of system performance attainable under reasonably good management when the desired irrigation is being used.

$$\text{PELQ or PELA} = \frac{\text{average low quarter depth infiltrated when equal to MAD}}{\text{average depth of water applied when MAD just satisfied}} \times 100$$

CHAPTER 2

DESCRIPTION OF STUDY AREA

The study area is located in southeastern Idaho near Idaho Falls. It is located in the southwestern portion of Bonneville and the northeastern portion of Bingham Counties. The location of the study area is shown in Figure 1. The area includes two irrigation districts, the Idaho and Snake River Valley Irrigation Districts. Both districts started their irrigation in the late 1800's. The Idaho Irrigation District serves about 30,000 acres and around 20,000 acres are served by the Snake River Valley Irrigation District. Irrigation water used by the districts is diverted from the Snake River. Some excess water from upstream irrigation districts is dumped into this area.

There are ten major soil series in the study area. They vary in texture from silt loam to sandy loam and gravelly loam. The location of each soil series in the study area are also shown in Figure 1. Each soil is briefly described in Table 1. More detailed descriptions are given in Appendix I.

Soil survey maps obtained from the Soil Conservation Service offices in Bingham and Bonneville counties (USDA, SCS, 1973, and personal contact with Bonneville county SCS office) were used to define the soil patterns of the study area. Boundaries of each soil series in the study area were digitized and composited with area maps generated from the low level infrared aerial pictures taken in August, 1978 (Yoo and Busch, 1980).

The major crops grown in the area are small grain, potatoes, alfalfa hay, and pasture. Pastured areas were not evaluated in this study as the total area of pasture is small compared with other crop areas. The common surface irrigation methods used in the area are furrow irrigation for potato

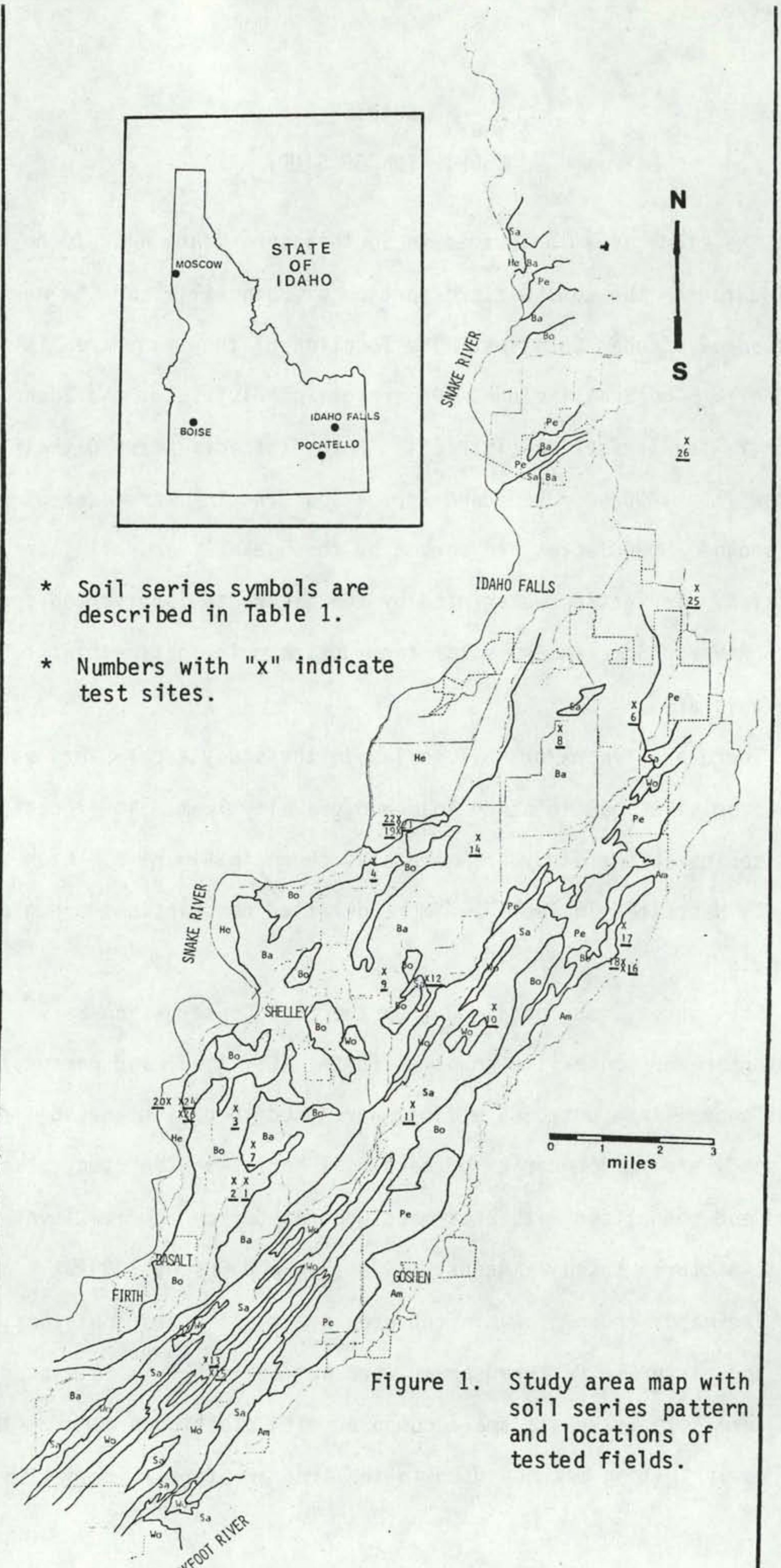


Figure 1. Study area map with soil series pattern and locations of tested fields.

Table 1. Description of Tested Soils

Symbol	Soil Series	Depth From Surface (in.)	Texture
Am	Ammon	0-60	silt loam
Ba	Bannock	0-36	loam and gravelly loam
		36-60	very gravelly coarse sand
Bo	Bock	0-45	loam
		45-60	very gravelly coarse sand
He, Ha	Hayeston	0-30	sandy loam
		30-60	very gravelly coarse sand
Hs, Ht	Heiseton	0-45	stratified sandy loam and fine sandy loam
		45-60	very gravelly coarse sand
Pd, Pe	Paesl	0-27	silt loam
		27-50	gravel and sand
Sa	Sasser	0-38	fine sandy loam
		38-60	very gravelly coarse sand
St	Stan	0-50	fine sandy loam
		50-60	very gravelly sandy loam
Wa, Sn	Wapello	0-29	fine sandy loam
		29-70	silt loam
Wo	Wolverine	0-60	sand

fields and border for other crops. The data in Tables 2 and 3 show the distribution patterns of crops, irrigation system types, and soil series of the study area in the 1978 crop year.

Several sampling sites for different soil-crop-irrigation type combinations were selected. Intake rates were determined at each site, and furrow advance-time data were obtained on a limited number of potato fields. The sampling sites are shown in Figure 1.

Table 2. Crop and Irrigation System Type Patterns for the Study Area in 1978.

		ID[a]		SRV[b]		TOTAL	
		acres	% of irrigated area	acres	% of irrigated area	acres	% of irrigated area
CROPS	Potatoes	7,815	27.0	4,573	27.0	12,388	27.0
	Grain	11,434	40.0	6,830	40.0	18,264	40.0
	Hay	5,382	19.0	4,020	23.0	9,402	21.0
	Pasture	3,946	14.0	1,754	10.0	5,700	12.0
TOTAL		28,577	100.0	17,177	100.0	45,754	100.0
IRRIGATION TYPES	Border	15,120	53.0	8,460	49.0	23,580	51.0
	Furrow	3,014	11.0	1,009	6.0	4,023	9.0
	HM[1]	7,375	26.0	5,832	31.0	12,757	28.0
	SR[2]	2,602	8.0	2,059	12.0	4,661	10.0
	CP[3]	466	2.0	267	2.0	733	2.0
TOTAL		28,577	100.0	17,177	100.0	45,754	100.0
IRRIGATED area		28,577	82.3*	17,177	78.2*	45,754	80.7*
NON-IRRIGATED area		6,145	17.7*	4,796	21.8*	10,941	19.3*
TOTAL		34,722	100.0	21,973	100.0	56,695	100.0

a/ Idaho Irrigation District

b/ Snake River Valley Irrigation District

1/ HM - Hand move sprinkler

2/ SR - Side-roll sprinkler

3/ CP - Center-pivot sprinkler

* % of total area for irrigated and non-irrigated areas

Table 3. Distribution Patterns of Soil Series of the Study Area

	IDAHO IRRIGATION DISTRICT		SNAKE RIVER VALLEY IRRIGATION DISTRICT		TOTAL	
Soils	Acres	% of Total Area	Acres	% of Total Area	Acres	% of Total Area
Am	4,894	14.1	95	0.4	4,989	8.8
Ba	11,627	33.5	6,592	30.0	18,219	32.1
Bo	3,293	9.5	4,503	20.5	7,796	13.0
He[1/]	3,649	10.5	2,074	9.5	5,723	10.1
Pe[2/]	4,675	13.5	1,193	5.4	5,868	10.4
Sa[3/]	4,659	13.4	4,423	20.1	9,082	16.0
Wo	1,925	5.5	3,093	14.1	5,018	8.8
TOTAL	34,722	100.0	21,973	100.0	56,695	100.0

1/ Includes soil series He, Ha, Hs, and Ht

2/ Includes soil series Pe and Pd

3/ Includes soil series Sa, Sn, St, and Wa

CHAPTER 3

PROCEDURES

Two methods were used to measure the water intake rate of each soil series. They are the infiltrometer ring test and the inflow-outflow method. In most cases ring tests were used for border irrigated fields and inflow-outflow tests for furrow irrigated fields. Some ring tests were made on furrow fields.

Infiltrometer rings were driven into a border field at several different sites one or two days before irrigation. The rings used ranged in size from 12 to 14 inches in diameter by 18 inches long. The major problem in the ring tests was to select a representative sample site in a field. It was also important to select a representative sample field for a particular soil. In this study four rings were used at each of four different locations within a field. At each location the rings were spaced 5 to 10 feet apart. This method is well described by Merriam and Keller (1978) and Galinato (1974). Test data were used to derive the intake rate-time relationship equation of a soil-crop combination using regression analyses.

In furrow irrigated fields, the inflow-outflow method was used. With this method, trapezoidal flumes were installed at different furrows in a field. Two to four furrows were tested for each field in this study. Two flumes were set 100 feet to 200 feet apart in each furrow depending on the inflow rate. Siphon tubes were used to divert water from the supply ditch. To obtain more accurate inflow rate data, a pump was used to deliver a constant inflow to each furrow in later tests. The intake rate of a furrow is calculated by the following equation.

$$\text{Intake rate} = \text{inflow rate} - \text{outflow rate} - \text{surface storage} \quad (4)$$

Inflow and outflow can be measured as mentioned above and surface storage is determined from flow depths at each station along the measured furrow. Measuring the flow depth at field conditions is extremely difficult. Merriam and Keller (1978) recommended to eliminate this difficulty by counting the first time interval after the water front reaches a point halfway between the measuring points.

At least one of the tested furrows in each field was a packed furrow. The packed furrow refers to that furrow in which tractor wheels travel during cultivation. It is known that packed furrows have lower intake rates than unpacked furrows. The results obtained reflect the influence of the packed furrows. Some potato fields were tested with infiltrometer rings as well as with the inflow-outflow method.

CHAPTER 4

RESULTS AND DISCUSSION

The results of this study are summarized in Tables 4 and 5. Each table gives the site number, soil, crop, field slope, coefficients of the intake rate and cumulative intake depth equations, and coefficients of determination (R^2) of the log-transformed regression equations. The R^2 values relate how well the observed data are described by the derived equations. The site numbers refer to the test locations shown in Figure 1. The field slopes were surveyed during the test period. The intake family for each test is also given according to the SCS classification (SCS, 1974).

Plots were drawn to show how the intake rate coefficients vary for different crops within a soil. They were also drawn to show how the coefficients vary between soil types for a given crop.

In Figure 2 all three soils shown have the largest intercept value for hay, intermediate for grain and lowest for potatoes except Bannock for which grain has the lowest and potato has the second largest value. For the exponent values Bock and Hayeston soils have an almost constant value while that for Bannock shows a decreasing value in the order of hay, grain and potatoes. Generally, alfalfa hay has the highest intake rate and potatoes have the lowest among the three crops. The coefficients for potato furrow fields were obtained using infiltrometer rings. This might cause some error from the true intake rate of these fields. The differences of intake rates obtained by ring tests and inflow-outflow tests are discussed later.

The graphical comparisons of coefficients of intake rate equations among tested soils are shown in Figure 3. For alfalfa hay fields, the intercept values increase from silt loam (Ammon) to gravelly loam (Bannock) and the exponent values decrease slightly. For the grain fields the exponents are nearly

Table 4. Tested Field Descriptions and Coefficients of the Intake Rate Equations Obtained by Infiltrometer Ring Tests

Site No.	Soil[1/]	Crop	Field Slope (%)		Coefficients[2/] a	b	R^2[3/]	SCS intake family
1	Bo	Alfalfa Hay	0.32	I D	8.57 0.27	-0.46 0.54	0.95	1.0-1.5
2	Bo	Grain	0.32	I D	5.95 0.20	-0.50 0.50	0.97	0.5
3	Bo	Potatoes	--	I D	2.45 0.09	-0.54 0.46	0.91	0.1
5	Ba	Alfalfa Hay	--	I D	17.30 0.44	-0.35 0.65	0.96	4.0
6	Ba	Grass Hay	--	I D	33.64 0.86	-0.35 0.65	0.76	>4.0
7	Ba	Grain	0.24	I D	2.18 0.07	-0.49 0.51	0.87	0.1
8			Missing Data					
9	Ba	Potatoes	--	I D	6.33 0.24	-0.55 0.45	0.42	0.5
10	St	Alfalfa Hay	0.26	I D	10.88 0.31	-0.41 0.59	0.98	2.0
11	Wa	Grain	--	I D	5.57 0.15	-0.38 0.62	0.96	1.0
12	St	Potatoes	--	I D	1.81 0.08	-0.60 0.40	0.85	<0.1
13	Sa	Alfalfa Hay	--	I D	15.10 0.48	-0.47 0.53	0.95	3.0
14	Sn	Alfalfa Hay	--	I D	4.79 0.18	-0.54 0.46	0.84	0.3
15	Sa	Grain	--	I D	16.39 0.49	-0.44 0.56	0.90	4.0
16	Am	Alfalfa Hay	--	I D	4.23 0.16	-0.55 0.45	0.88	0.3
18	Am	Potatoes	--	I D	2.17 0.07	-0.50 0.50	0.89	0.1
19	He	Alfalfa Hay	0.34	I D	6.02 0.23	-0.57 0.43	0.93	0.3
20	Ha	Alfalfa Hay	0.50	I D	9.87 0.33	-0.50 0.50	0.94	1.0
21	He	Grain	0.33	I D	3.49 0.12	-0.51 0.49	0.91	0.3
23	He	Potatoes	0.20	I D	2.60 0.09	-0.52 0.48	0.85	0.1
24	Ht	Alfalfa Hay	0.34	I D	4.24 0.12	-0.43 0.57	0.96	0.5
25	Pd	Alfalfa Hay	0.16	I D	4.86 0.22	-0.62 0.38	0.66	0.3

1/ Symbols are described in Table 1

2/ I = infiltration rate in in/hr
D = cumulative intake in inches

3/ R^2 = coefficients of determination of intake rate curve

Table 5. Test Field Descriptions and Coefficients of the Intake Rate Equations Obtained by the Inflow-Outflow Method.

Site No.	Soil[1/]	Crop	Field Slope (%)		Coefficients[2/] a	b	R^2[3/]	SCS Intake Family
				I	7.18	-0.59		
3	Bo	Potatoes	0.36	I36	2.39	-0.59	0.56	0.05
				D	0.10	0.41		
				I	12.92	-0.53		
4	Ba	Potatoes	--	I36	4.31	-0.53	0.83	0.20
				D	0.15	0.47		
				I	4.70	-0.54		
12	St	Potatoes	--	I36	1.57	-0.54	0.93	0.05
				D	0.06	0.46		
				I	4.16	-0.38		
17	Am	Potatoes	0.27	I36	1.39	-0.38	0.61	0.10
				D	0.04	0.62		
				I	18.32	-0.67		
22	He	Potatoes	0.33	I36	6.11	-0.67	0.96	0.25
				D	0.30	0.33		
				I	3.54	-0.35		
26	Pe	Potatoes	0.39	I36	1.18	-0.35	0.62	0.10
				D	0.03	0.65		

1/ Symbols are described in Table 1

2/ I = intake rate of 3 foot furrow spacing in in/hr or gpm/100 ft
I36 = intake rate per unit spacing in in/hr or gpm/100 ft
D = cumulative intake rate in inches

3/ R^2 = coefficients of determination of intake rate curve

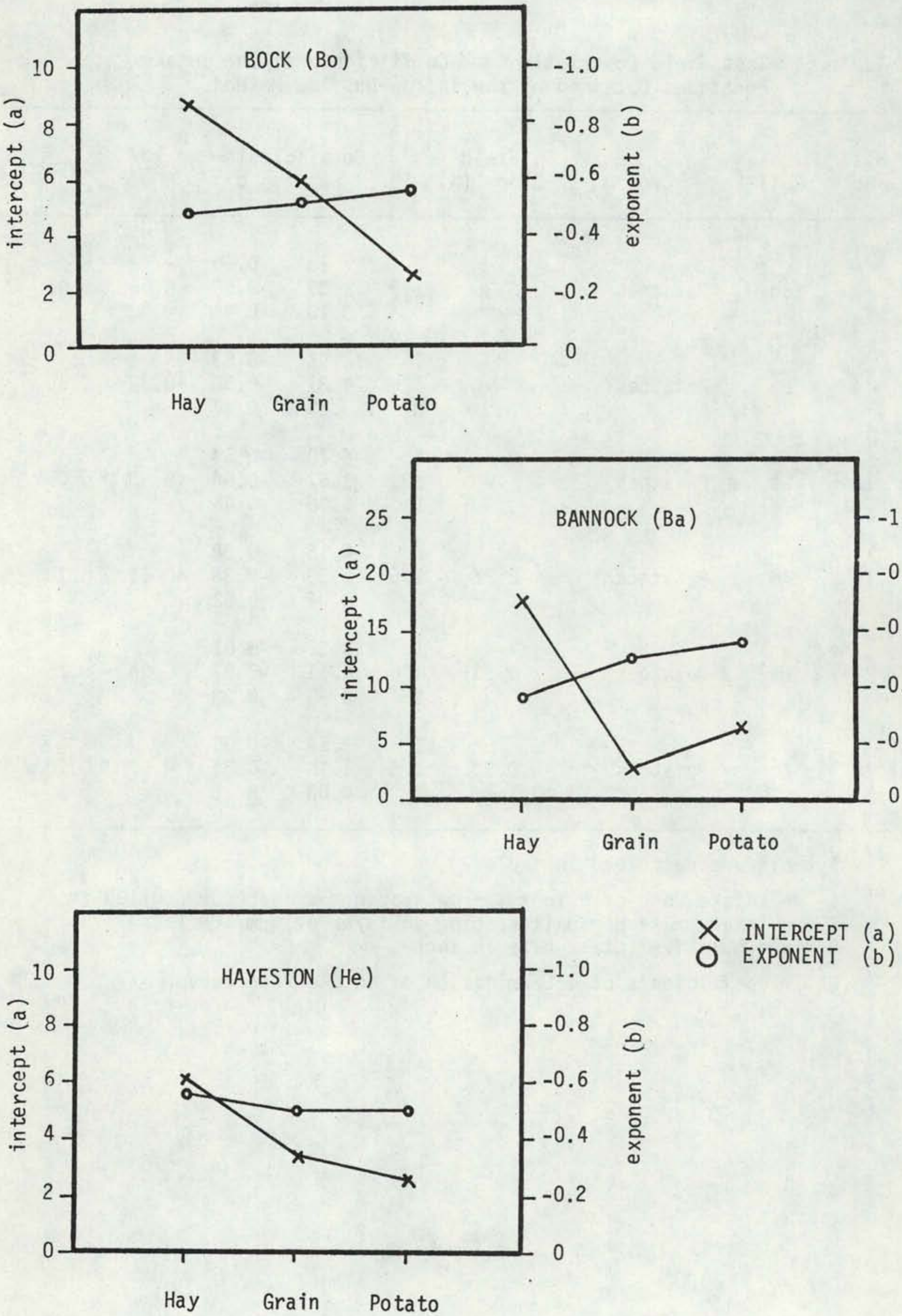


Figure 2. Graphical comparison of coefficients of intake rate equations among crops (potato fields tested by infiltrometer ring).

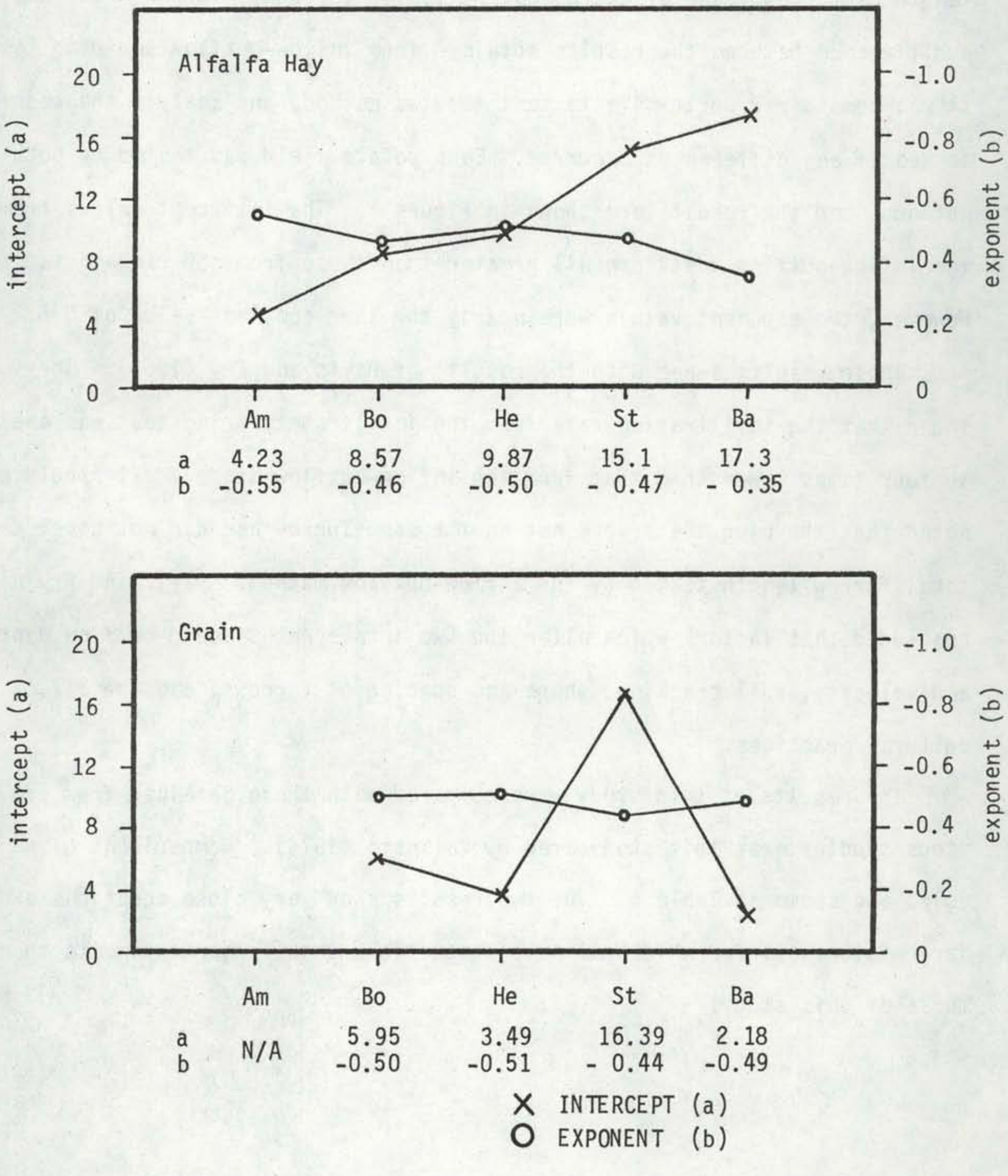


Figure 3. Graphical comparison of coefficients of intake rate equations among soils (potato fields tested by infiltrometer ring).

constant, but the wide variation in intercept values indicates possible sampling error. There were no samples for grain fields for Ammon silt loam.

Bondurant (1957) noted that the rate of infiltration was most accurately determined by inflow-outflow measurements where water is flowing in a given length of furrow. The effect of water flowing through a furrow might cause a difference between the results obtained from inflow-outflow and ring tests. It was considered worthwhile to test the two methods and analyze the results to see if any differences occurred. Each potato field was tested by both methods, and the results are shown in Figure 4. The intercept values from the inflow-outflow tests are all greater than those from the ring tests. However, the exponent values were nearly the same constant value of 0.5.

These results agree with the results of Davis and Fry (1963). They found that the infiltration rate from the infiltrometer ring test was one to four times lower than that from the inflow-outflow method. It should be noted that the ring tests were not on the same furrow and did not cover the total furrow length tested by the inflow-outflow method. Davis and Fry also concluded that factors which alter the two intake rates could be flow depth and velocity, soil cracking, shape and spacing of furrows, and the effect of cultural practices.

The results of this study were compared with those obtained from previous studies near this study area by Galinato (1974). Comparisons of results are shown in Table 6. The two results show very close equations except for Heiston soil for which Galinato's equations show larger exponents than those of this study.

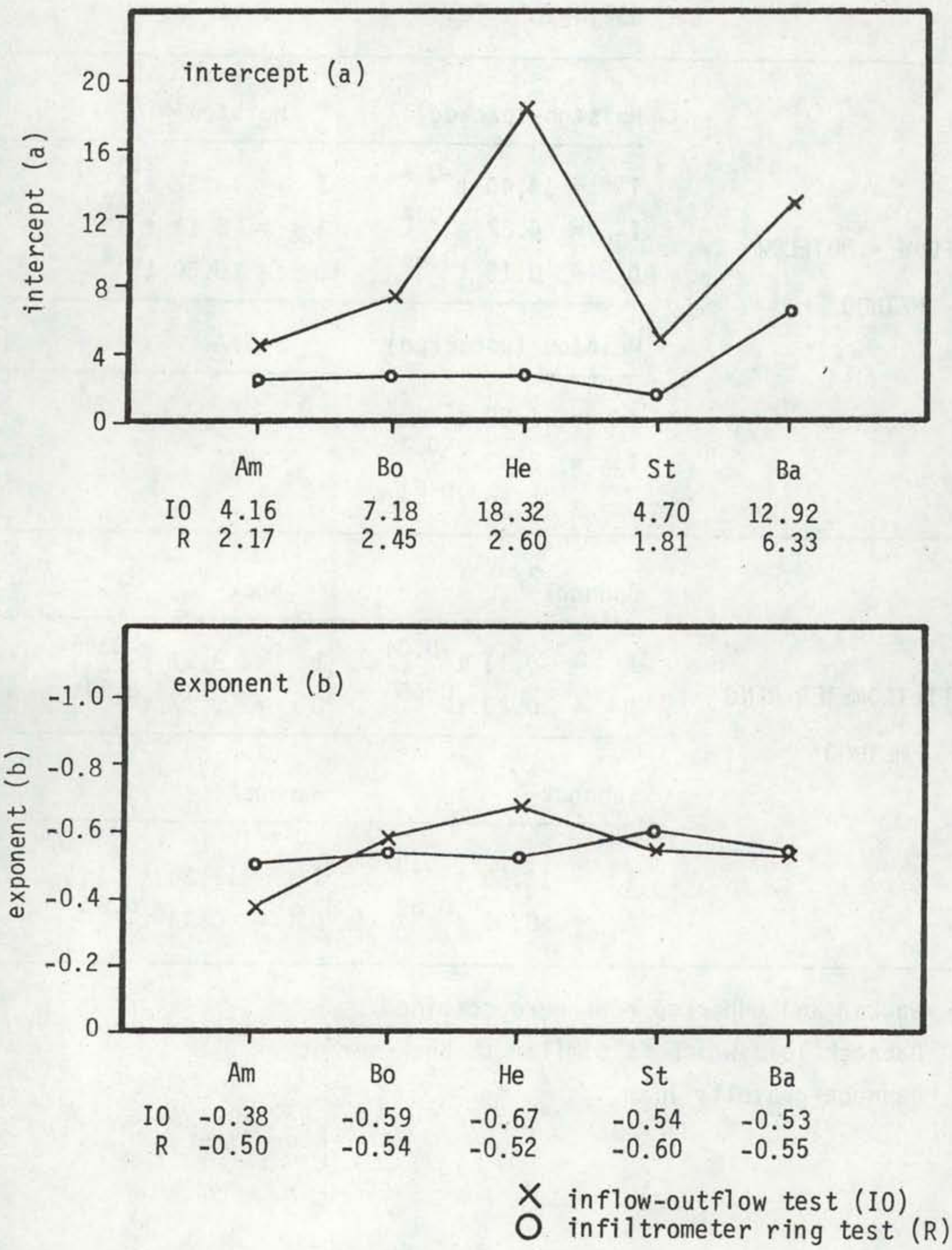


Figure 4. Graphical comparison of the intake rate equations by inflow-outflow test and infiltrometer ring test on furrow irrigated potato fields.

Table 6. Comparison of Test Results With Previous Study Near the Study Area (Galinato, 1974)

	Galinato's Test	This Test
INFLOW - OUTFLOW METHOD	Heiston (packed)	Heiston[1/]
	$I = 14.40\ t^{-0.4}$ $I_{36} = 4.62\ t^{-0.4}$ $D = 0.13\ t^{0.6}$	$I = 18.32\ t^{-0.67}$ $I_{36} = 6.11\ t^{-0.67}$ $D = 0.30\ t^{0.33}$
	Heiston (unpacked)	N/A
	$I = 26.90\ t^{-0.49}$ $I_{36} = 8.63\ t^{-0.49}$ $D = 0.28\ t^{0.51}$	N/A
INFILTROMETER RING METHOD	Bannock[2/]	Bock
	$I = 9.11\ t^{-0.34}$ $D = 0.23\ t^{0.66}$	$I = 8.57\ t^{-0.46}$ $D = 0.27\ t^{0.54}$
	Bannock[3/]	Bannock[3/]
	$I = 13.60\ t^{-0.37}$ $D = 0.36\ t^{0.63}$	$I = 17.30\ t^{-0.35}$ $D = 0.44\ t^{0.65}$

1/ Packed and unpacked rows were combined

2/ Bannock loam which is similar to Bock series

3/ Bannock gravelly loam

CHAPTER 5

FURROW SYSTEM EVALUATION

Two potato furrow fields were evaluated to measure advance time relationships. The inflow rates were controlled and found to be close to inflow rates used in irrigation. The relationships were expressed as geometric functions, as:

$$\ell = ct^d \qquad (5)$$

where

ℓ = advance of water front in feet,

t = elapsed time in minutes, and

c and d = experimental coefficients.

The coefficients are unique for a certain inflow rate. Coefficients for different furrows and inflow rates are given in Table 7. These data and the intake rate equations of the same soils and crops were used to evaluate the irrigation practices on two furrow fields. The procedure follows that recommended by Merriam and Keller (1978).

A. Field 1

Soil -- Paesl silt loam

Available Water Holding Capacity (AWC) -- 2.52 in/ft.

Root zone depth -- 3 feet

Depleted Readily Available Moisture (DRAM) between irrigations -- 40%

Management Allowed Deficit (MAD) -- 3.0 inches

Slope -- 0.39%

Furrow spacing -- 36 inches

$$\ell = 20.20\ t^{0.75}$$

Table 7. Coefficients of Advance-time Relation Equations for Different Soils and Inflow Rates ($\ell = ct^d$).

Soil	Crop	Field Slope (%)	Flow Rate (gpm)	Coefficients c	Coefficients d
Ammon	Potatoes	0.27	7.00	10.95	0.77
			5.40	13.44	0.76
			5.63	11.31	0.75
			5.61	10.84	0.75
Paesl	Potatoes	0.39	5.45	19.80	0.74
			5.45	20.45	0.71
			5.45	20.20	0.75
			5.71	19.06	0.78

$$I = 3.54\ t^{-0.35}$$

$$I_{36} = 1.18\ t^{0.65}$$

$$D = 0.03\ t^{0.65}$$

Time of application (Ta) -- 24 hours

Field length -- 650 feet

Inflow rate -- 5.45 gpm

a. Distribution Uniformity (DUa)

Opportunity time at the upper end, To(U);

$$To(u) = Ta = 24 \text{ hours} = 1440 \text{ minutes}$$

The infiltration depth at the upper end, D(u);

$$D(u) = 0.03 \times 1440^{0.65} = 3.4 \text{ inches}$$

The opportunity time at the lower end, To(ℓ), is obtained as

$$To(\ell) = To(u) - Tadv$$

where

Tadv = advance time of water front when water reaches at the lower end of a field.

$$Tadv = (\ell/c)^{1/d}$$

$$= (650/20.20)^{1/0.75} = 102 \text{ minutes}$$

Therefore,

$$To(\ell) = 1440 - 102 = 1338 \text{ minutes, and}$$

The infiltration depth at the lower end;

$$D(\ell) = 0.03 \times 1338^{0.65} = 3.23 \text{ inches.}$$

Assuming a uniform change in depth infiltrated along the furrow, the distribution uniformity is:

$$DUa = \frac{3.23}{(3.4 + 3.23)/2} \times 100 = 97.5\%$$

The water losses are to runoff and deep percolation. The amount of runoff (RO) is the average depth applied minus the average depth infiltrated. The deep percolation (DP) is the infiltrated depth minus the stored depth. The approximate average depth of water applied to this system is:

$$D = 96.3 \times \frac{5.45 \text{ gpm} \times 24 \text{ hours}}{3.0 \text{ feet} \times 650 \text{ feet}} = 6.46 \text{ inches}$$

therefore,

$$RO = 6.46 - (3.4 + 3.23)/2 = 3.15 \text{ inches or } 49\% \text{ of the total.}$$

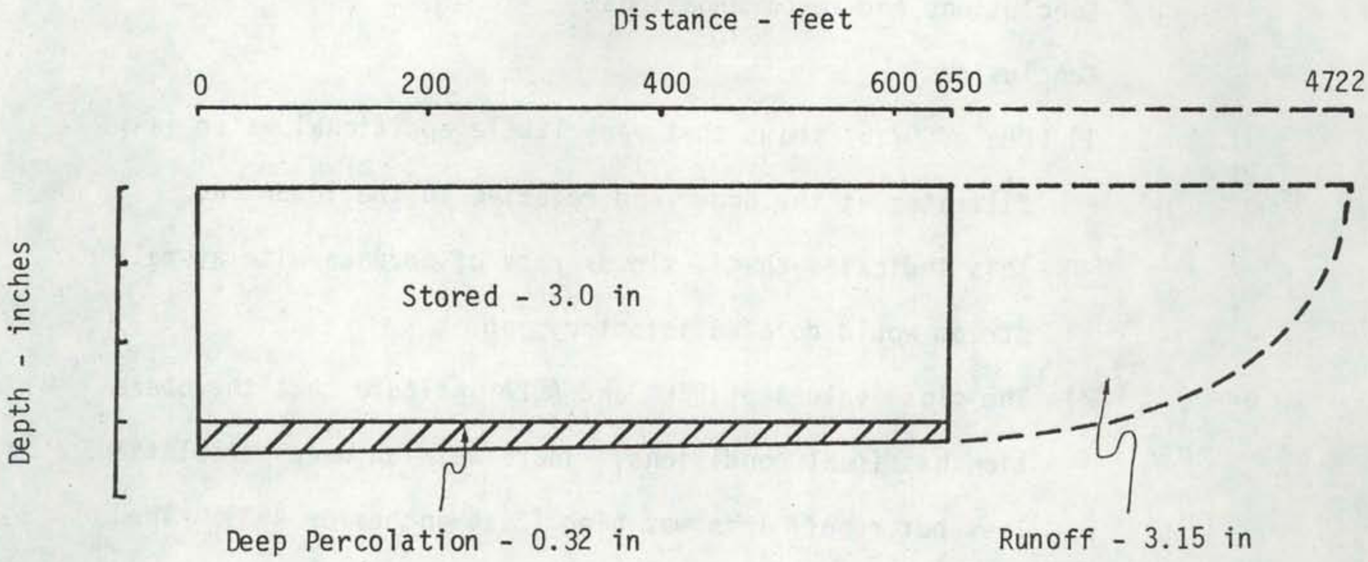
$$DP = 3.32 - 3.0 = 0.32 \text{ inches or } 3\% \text{ of the total water applied.}$$

These values are drawn to scale below.

b. Potential Application Efficiency (PELA)

The PELA is found when the "absolute" minimum depth of water infiltrated just satisfies the MAD. The time of irrigation (Ti) to apply MAD, 3.0 inches, at the lower end is;

$$Ti = (3.0/0.03)^{1/0.65} = 1193 \text{ minutes}$$



therefore,

$$To(u) = 1193 + 102 = 1295 \text{ minutes}$$

The average depth of water applied is:

$$D = 96.3 \times \frac{5.45 \times 21.5}{3.0 \times 650} = 5.79 \text{ inches}$$

$$PELA = \frac{3.0}{5.79} \times 100 = 52\%$$

c. Application Efficiency (AELA)

The application efficiency (AELA) describes how much of the water applied is retained in the soil and is available for consumptive use at the point of "absolute" minimum application. The average water applied in 24 hour application time is:

$$D = 96.3 \times \frac{5.45 \times 24}{3.0 \times 650} = 6.46 \text{ inches}$$

$$AELA = \frac{3.23}{6.45} \times 100 = 50\%$$

d. Conclusions and recommendations

Conclusions

1) DUa of 97.5% shows that very little additional water infiltrates at the upper end relative to the lower end. This indicates that a slower rate of advance with a smaller stream would do a satisfactory job.

2) The close values of PELA and AELA indicate that the operation has ideal conditions. There was low deep percolation loss but runoff loss was high (3.15 inches or 49%). The runoff loss can be reduced by decreasing the application time to just satisfy the MAD at the lower end.

Recommendations

1) Run water for a shroter time to satisfy;

$$Ti + Tadv = 1193 + 102 = 1295 \text{ minutes or } 21.5 \text{ hours.}$$

To further reduce the runoff loss, cut back the stream or use a return flow recovery system which makes the runoff available for further use.

2) Increase the furrow length if practical since it may be inferred that a much longer furrow could be used with the 5.45 gpm stream.

B. Field 2

The evaluation of this field will be more abstracted. This field has similar soil to Field 1 but the farmer practices farm irrigation differently.

Soil -- Ammon silt loam

AWC -- 2.4 in/ft

AWC -- 2.4 in/ft

Root zone depth -- 3 feet

DRAM -- 40%

MAD -- 2.9 inches

Slope -- 0.27%

Furrow width -- 36 inches

$$\ell = 11.31\ t^{0.75}$$

$$I = 4.16\ t^{-0.38}$$

$$I_{36} = 1.39\ t^{-0.38}$$

$$D = 0.04\ t^{0.62}$$

Ta -- 12 hours

Field length -- 650

Inflow rate -- 5.63 gpm

a. Distribution uniformity (DUa)

$$To(u) = Ta = 720 \text{ minutes}$$

$$D(u) = 0.04 \times 720^{0.62} = 2.36 \text{ inches}$$

$$To(\ell) = To(u) - Tadv$$

$$Tadv = (650/11.31)^{1/0.75} = 222 \text{ minutes}$$

$$To(\ell) = 720 - 222 = 498 \text{ minutes}$$

$$D(\ell) = 0.04 \times 498^{0.62} = 1.89 \text{ inches}$$

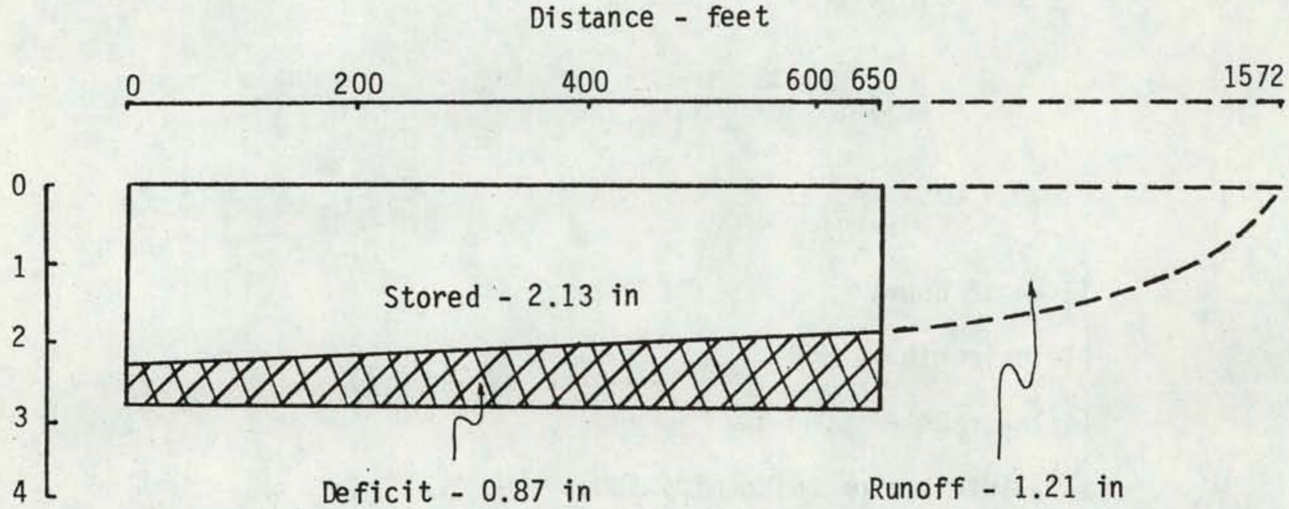
$$DUa = \frac{1.89}{(2.36 + 1.89)/2} \times 100 = 89\%$$

$$D = 96.3 \times \frac{5.63 \times 12}{3.0 \times 650} = 3.34 \text{ inches}$$

$$RO = 3.34 - (2.36 + 1.89)/2 = 1.21 \text{ inches or } 36\% \text{ of the total applied}$$

There is no deep percolation loss as the infiltrated depth is less than MAD.

These values are drawn to scale below.



b. Potential Application Efficiency (PELA)

$$Ti = (2.9/0.04)^{1/0.62} = 1001 \text{ minutes}$$

$$To(u) = 1001 + 222 = 1223 \text{ minutes}$$

$$D = 96.3 \times \frac{5.63 \times 20.3}{3.0 \times 650} = 5.64 \text{ inches}$$

$$PELA = \frac{2.9}{5.64} \times 100 = 51\%$$

c. Application Efficiency (AELA)

T_a = 12 hours

$$D = 96.3 \times \frac{5.63 \times 12}{3.0 \times 650} = 3.34 \text{ inches}$$

$$AELA = \frac{1.89}{3.34} \times 100 = 57\%$$

d. Conclusions and recommendations

Conclusions

1) DUa of 89% shows a greater amount of water infiltrated at the upper end relative to the lower end.

2) Since no water was lost to deep percolation, there must have been a large amount of runoff loss. For the system as used, there was 1.22 inches or 36% of the total water applied lost as runoff. If a longer application time required for a full irrigation of 2.9 inches at the lower end were used, runoff loss would have been even greater.

Recommendations

1) Run water longer to satisfy;

$$T_i + T_{adv} = 1001 + 212 = 1223 \text{ minutes or } 20.4 \text{ hours.}$$

To reduce runoff, cut back the stream or use return flow recovery system.

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APPENDIX I

Description of major soil series
of irrigated agricultural land
in the study area

AMMON SERIES[1/]

The Ammon series consists of well drained, nearly level to gently sloping soils that are more than 60 inches deep. These soils formed under bunchgrass and big sagebrush on alluvial fans that consist of outwash from loessal uplands. They are associated with Newdale and Paesl soils.

Elevations range from 4400 to 4800 feet. The annual precipitation is about 11 to 13 inches. The mean annual air temperature is 43° to 45° F, and the frost-free period is 110 to 126 days.

In a representative profile the surface layer is grayish-brown silt loam 10 inches thick. The underlying layers are light brownish-gray silt loam that extends to a depth of more than 60 inches. The soils are limy throughout. The permeability is 0.63 to 2.0 inches per hour. The available water holding capactiy is 0.19 to 0.21 inches per inch over this soil layer.

Ammon soils are used mainly for irrigated crops.

1/ These descriptions were obtained from "Soil Survey of Bingham Area, Idaho" by the Soil Conservation Service, USDA and the Agricultural Experiment Station, University of Idaho, Moscow, 1973.

BANNOCK SERIES

The Bannock series consists of well drained, nearly level to moderately sloping soils that are 20 to 40 inches deep to very gravelly sands. These soils formed under big sagebrush and bunchgrass in alluvium on high river terraces. These soils are associated with Bock, Polatis, Hayeston, and Packham soils.

Elevations range from 4200 to 4600 feet. The annual precipitation is 11 to 13 inches. The mean annual air temperature is 42^{o} to 45^{o} F, and the frost-free period is 110 to 126 days.

In a representative profile the surface layer is grayish-brown loam that is slightly gravelly and 6 inches thick. The subsoil is grayish-brown and light brownish-gray loam that is slightly gravelly and extends to a depth of 16 inches. The substratum, in the upper part, is pale brown and light brownish-gray, strongly calcareous stratified loam, gravelly loam, and very gravelly sandy loam. This is underlain by very gravelly coarse sand at a depth of 36 inches. The profile is limy throughout. The permeability is 0.63 to 2.0 inches per hour. The available water holding capacity is 0.14 to 0.16 inches per inch of top soil and 0.04 to 0.06 inches per inch for subsoil layer.

Bannock soils are used for irrigated hay, pasture, small grains, beets, and potatoes.

BOCK SERIES

The Bock series consists of deep, well drained, loamy soils more than 60 inches deep that formed on nearly level to very gently sloping high terraces. The vegetation is mainly big sagebrush and bunchgrass. These soils are associated with Bannock, Packham, Hayeston, and Stan soils.

Elevations range from 4200 to 4500 feet. The annual precipitation is 11 to 13 inches. The mean annual air temperature is 42^{o} to 45^{o} F, and the frost-free period is 110 to 126 days.

In a representative profile the surface layer is grayish brown loam about 10 inches thick. The subsoil is brown loam that extends to a depth of 15 inches. The substratum is light brownish-gray and light-gray, stratified alluvium that is mainly loam and fine sandy loam to a depth of 47 inches. Below 47 inches is very gravelly coarse sand. These soils have a limy substratum.

The permeability is 0.63 to 2.0 inches per hour. Available water holding capacity is 0.16 to 0.18 inches per inch of top soil depth and very low (0.03 to 0.06 inches per inch of soil) for subsoil (0.03 to 0.05 inches per inch).

Bock soils are used mainly for irrigated hay, small grains, pasture, potatoes, and sugarbeets.

HAYESTON SERIES

The Hayeston series consists of well drained, nearly level to very gently sloping soils that are less than 40 inches thick over sand and gravel. These soils formed under big sagebrush and bunchgrass in alluvium. They are on river terraces. Hayeston soils are associated with soils of the Heiseton, Bannock, Blackfoot, and Wardboro series.

Elevations range from 4200 to 4600 feet. The annual precipitation is 11 to 13 inches. The mean annual air temperature is 42^{o} to 45^{o} F, and the frost-free period is 110 to 126 days.

In a representative profile the surface layer is grayish-brown sandy loam that contains a little gravel and is 9 inches thick. The underlying material is light brownish-gray, calcareous sandy loam that extends to a depth of 30 inches. Below this is light brownish-gray very gravelly coarse sand. These soils are limy throughout.

The permeability is 2.0 to 6.3 inches per hour. The available water holding capacity is 0.11 to 0.13 inches per inch of top soil and 0.03 to 0.05 inches per inch of subsoil layer.

Hayeston soils are used primarily for irrigated hay, pasture, small grains, and potatoes.

HEISETON SERIES

The Heiseton series consists of moderately well drained, level to very gently sloping soils that are more than 40 inches deep to sand and gravel. These soils formed under big sagebrush and bunchgrass in alluvium. They are on river terraces. The texture is stratified sandy loam and fine sandy loam. Heiseton soils are associated with soils of the Hayeston, Bannock, Blackfoot, and Wardboro series.

Elevations range from 4200 to 4600 feet. The annual precipitation is 11 to 13 inches. The mean annual air temperature is 42^{0} to 45^{0} F and the frost-free period is 110 to 126 days.

In a representative profile the surface layer is grayish-brown sandy loam 8 inches thick. The underlying material is light brownish gray, dominantly fine sandy loam that extends to a depth of 45 inches. This is underlain by light brownish-gray very gravelly coarse sand. These soils are limy throughout.

The permeability is 2.0 to 6.3 inches per hour. The available water holding capacity is 0.12 to 0.14 inches per inch of top soil and 0.03 to 0.05 inches per inch of subsoil.

Heiseton soils are used primarily for irrigated hay, pasture, small grains, sugarbeets, and potatoes.

PAESL SERIES

The Paesl series consists of well drained, nearly level soils overlying sand and gravel at depths ranging from 20 to 40 inches. These soils formed in mixed alluvium. They are on flood plains and terraces. Nearly all the areas are cultivated. In uncultivated areas the vegetation is big sagebrush, three-tip sagebrush, and bunchgrass. These soils are associated with Ammon, Stan, and Wapello soils.

Elevations range from 4600 to 4800 feet. The mean annual precipitation ranges from 11 to 13 inches. The mean annual air temperature ranges from 42^{o} to 45^{o} F, and the frost-free season is 110 to 130 days.

In a representative profile the surface layer is grayish-brown silt loam 9 inches thick. The subsoil is brown and light-brown silt loam. The substratum is pinkish-gray loam to a depth of 27 inches. It is underlain by light brownish-gray very gravelly loamy coarse sand that extends to a depth of more than 50 inches. The soil is limy throughout, but is more limy in the lower part of the subsoil and substratum than in the surface layer.

The permeability is 0.63 to 2.0 inches per hour. The available water holding capacity is 0.19 to 0.21 inches per inch of top soil and 0.04 to 0.06 inches per inch of subsoil.

Paesl soils are used for irrigated potatoes, sugarbeets, small grains, alfalfa, and pasture.

SASSER SERIES

The Sasser series consists of well-drained, nearly level to gently sloping soils that are about 38 inches deep to sand and gravel. These soils formed under grasses and shrubs in fine sandy alluvium. They are on river terraces. Sasser soils are associated with soils of the Bannock, Bock, and Stan series.

Elevations range from 4200 to 4600 feet. The mean annual precipitation is 11 to 13 inches. The mean annual air temperature is 39^{0} to 45^{0} F, and the frost-free period is 110 to 130 days.

In a representative profile the surface layer is grayish-brown sandy loam 6 inches thick. The subsoil is light brownish-gray and pale-brown fine sandy loam 8 inches thick. The substratum is light-gray fine sandy loam that contains as much as 15 percent gravel. It extends to a depth of 38 inches. It is underlain by sand and waterworn gravel. These soils are limy throughout but have lime accumulations in the substratum.

The permeability is 2.0 to 6.3 inches per hour. The available water holding capacity is 0.11 to 0.13 inches per inch of top soil and 0.04 to 0.06 inches per inch of subsoil layer.

Sasser soils are used mainly for irrigated hay, pasture, and small grain.

STAN SERIES

The Stan series consists of well drained soils that formed in sandy alluvium on river terraces. The slope is 0-4 percent. These soils are fine sandy loam in texture. The vegetation is mainly big sagebrush and bunchgrass. Stan soils are associated with soils of the Sasser, Bannock, and Paesl series.

Elevations range from 4200 to 5500 feet. The mean annual precipitation is 11 to 13 inches. The mean annual air temperature is 39^{0} to 45^{0} F, and the frost-free period is 110 to 125 days.

In a representative profile, the surface layer is grayish-brown and brown fine sandy loam 16 inches thick. The subsoil is pale-brown fine sandy loam 13 inches thick. The substratum is light gray fine sandy loam to a depth of 50 inches. It is underlain by light-gray, very gravelly light-sandy loam. These soils are limy throughout but are mostly limy in the substratum.

The permeability is 2.0 to 6.3 inches per hour. The available water holding capacity is 0.13 to 0.15 inches per inch of top soil and low in subsoil layer (0.07 to 0.09 inches per inch).

Stan soils are used for irrigated hay, pasture, small grains, and potatoes.

WAPELLO SERIES

The Wapello series consists of well-drained, nearly level and very gently sloping soils that are 20 to 30 inches deep over silt loam or loam. These soils are fine sandy loam in texture. They formed on stream terraces under big sagebrush and bunchgrass. Wapello soils are associated with Wolverine, Preston, and Firth soils.

Elevations range from 4200 to 4600 feet. The annual precipitation is 11 to 13 inches. The mean annual air temperature is 42^{o} to 45^{o} F, and the frost-free season is 110 to 125 days.

In a representative profile the surface layer is grayish-brown fine sandy loam 8 inches thick. The underlying material is light brownish-gray and light-gray fine sandy loam. It is underlain at a depth of 29 inches by stratified layers of light-gray silt loam and loamy alluvium. These soils are limy throughout.

This soil has high permeability for top soil (over 20 inches per hour) and decreased to 2.0 to 6.3 inches per hour of subsoil. Top soil has very low available water holding capacity (0.02 to 0.04 inches per inch) and moderate in subsoil (2.0 to 6.3 inches per inch).

Wapello soils are used mainly for irrigated hay, small grain, and for pasture.

WOLVERINE SERIES

The Wolverine series consists of excessively drained, nearly level to moderately steep, sandy soils that formed in colian sands. These soils are on terraces. Roots can penetrate to a depth of 60 inches or more. The vegetation consists mainly of bunchgrass and big sagebrush. Wolverine soils are associated with Weeding, Wapello, Firth, and Presto soils.

Elevations range from 4400 to 4600 feet. The annual precipitation is 11 to 13 inches. The mean annual air temperature is 40^{0} to 45^{0} F, and the frost-free period is 110 to 126 days.

In a representative profile, the soil is limy, light brownish-gray sand to a depth of 60 inches or more.

This soil has very high permeability (over 20 inches per hour) and low available water holding capacity (0.06 to 0.08 inches per inch of soil).

Wolverine soils are used for range.

APPENDIX II

Intake rate curves of the tested soils

by the infiltrometer ring method

Figure No.	Soil	Crop
II-1	Bock	Alfalfa hay
II-2	Bock	Grain
II-3	Bock	Potatoes
II-4	Bannock	Alfalfa hay
II-5	Bannock	Grass hay
II-6	Bannock	Grain
II-7	Bannock	Potatoes
II-8	Wapello	Grain
II-9	Stan	Potatoes
II-10	Sasser	Alfalfa hay
II-11	Sasser	Alfalfa hay
II-12	Sasser	Grain
II-13	Ammon	Alfalfa hay
II-14	Ammon	Potatoes
II-15	Hayeston	Alfalfa hay
II-16	Hayeston	Grain
II-17	Hayeston	potatoes
II-18	Heiseton	Alfalfa hay
II-19	Paesl	Alfalfa hay

I = intake rate in inches per hour

D = cumulative intake in inches

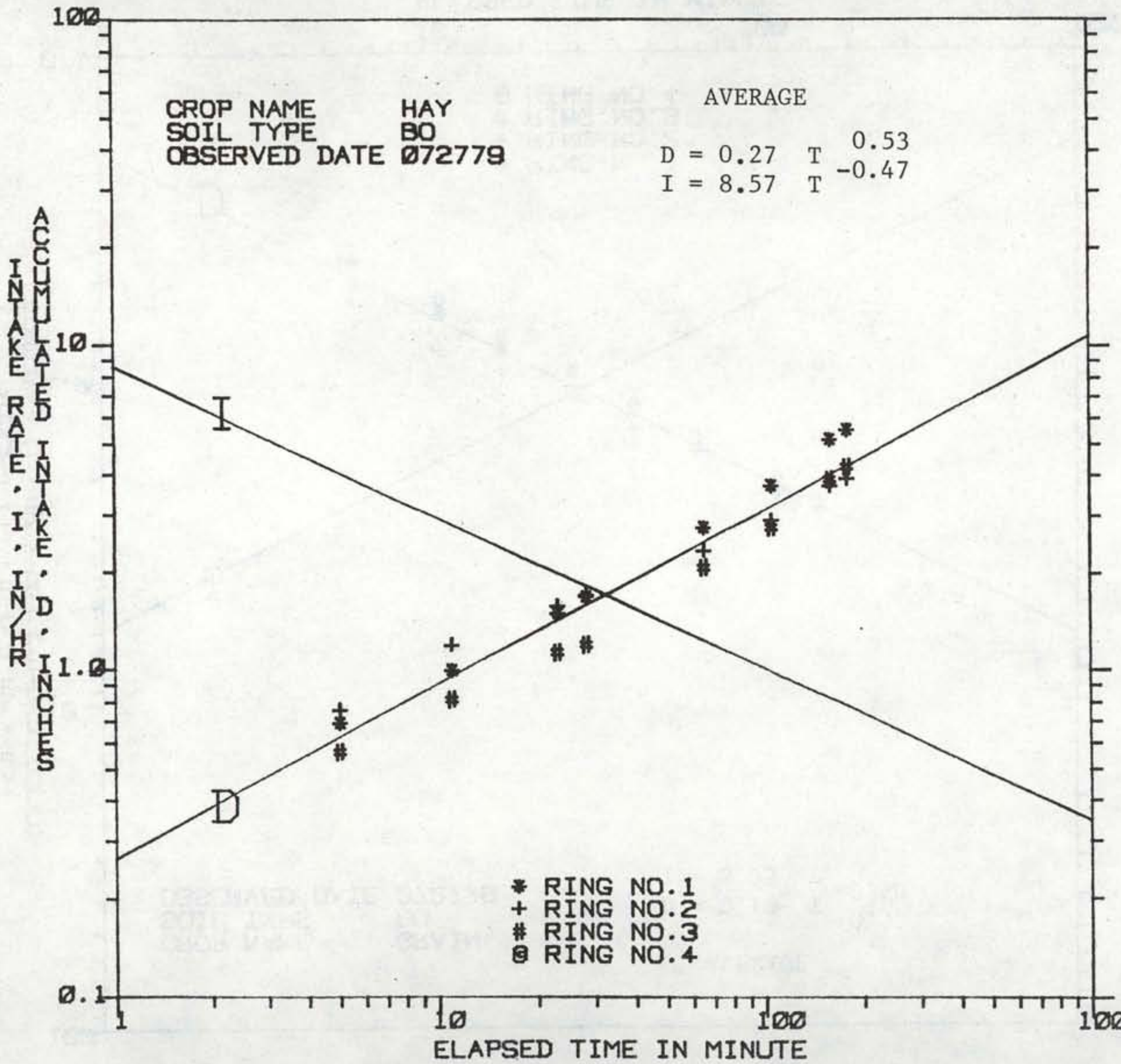

Figure II-1. Intake characteristics for alfalfa hay on Bock soil.

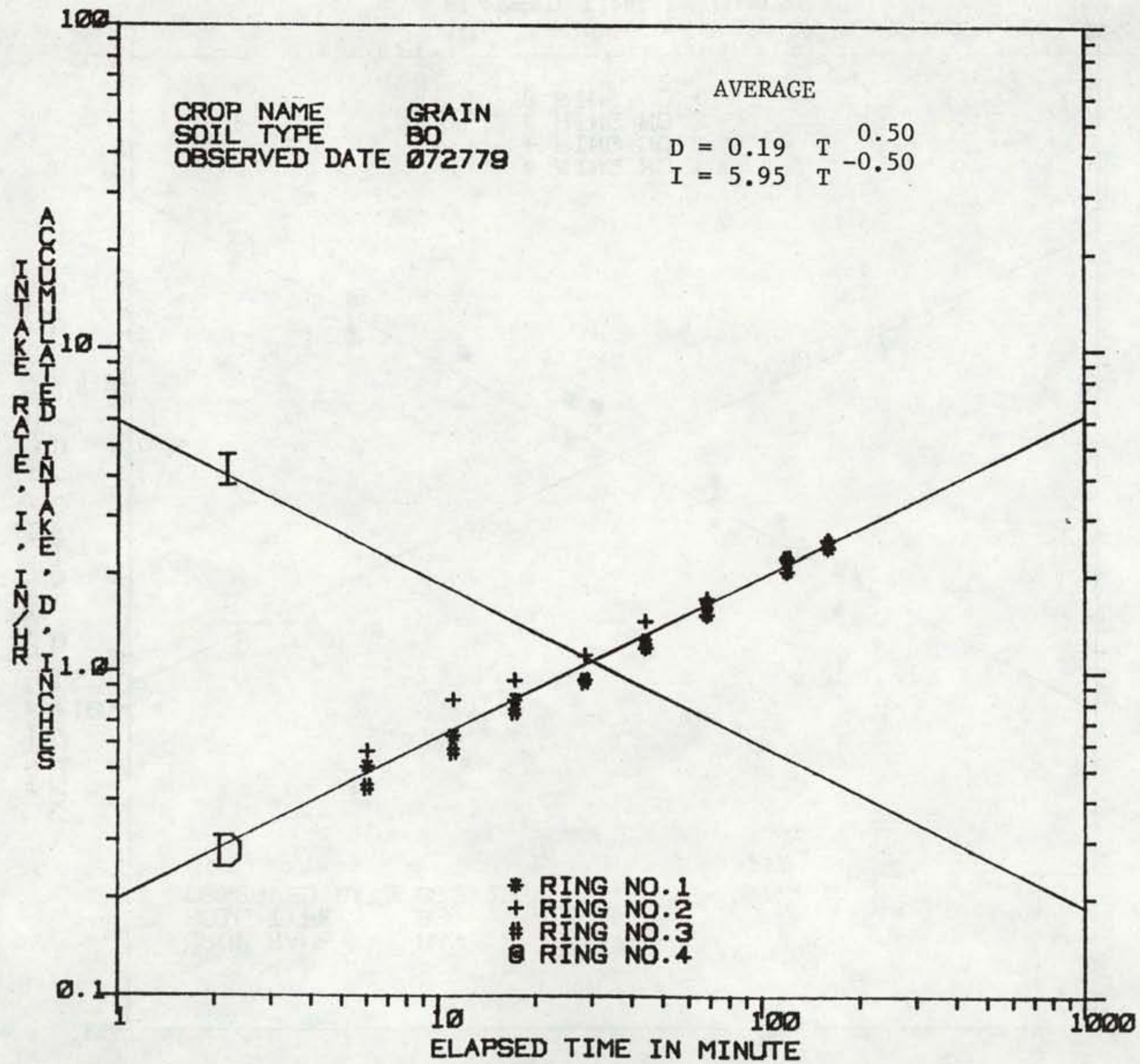

Figure II-2. Intake characteristics for grain on Bock soil.

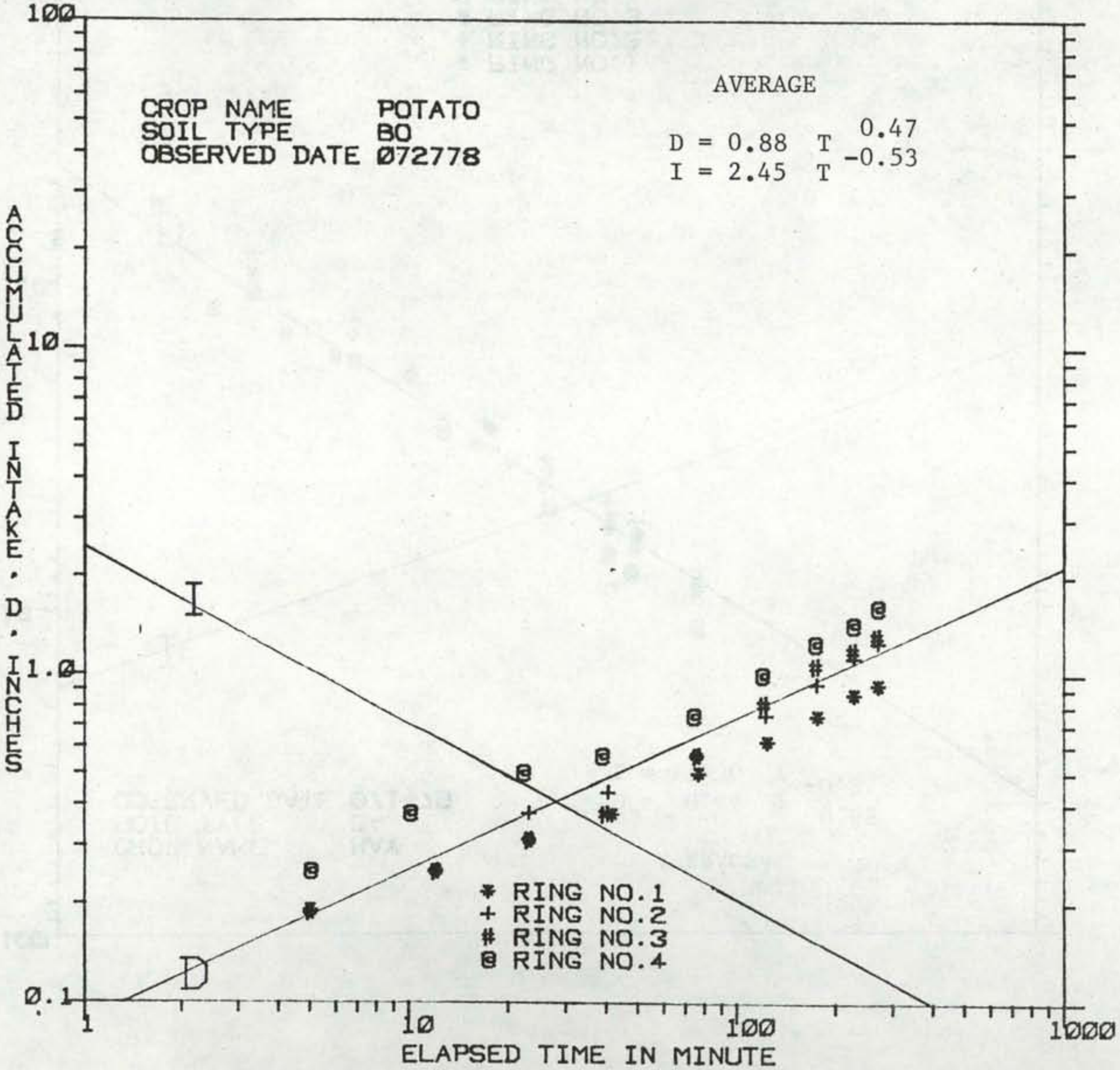

Figure II-3. Intake characteristics for potatoes on Bock soil.

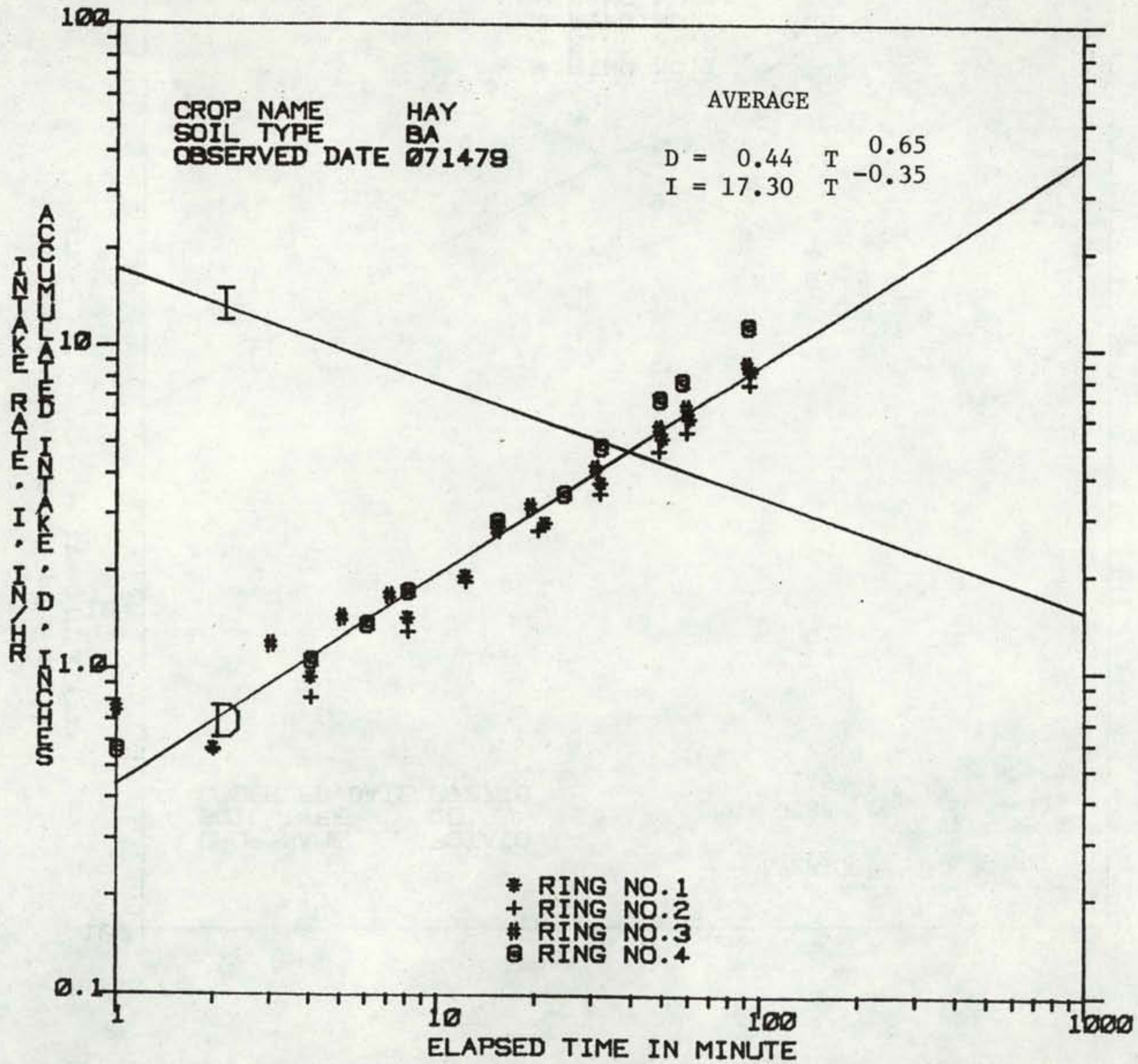

Figure II-4. Intake characteristics for alfalfa hay on Bannock soil.

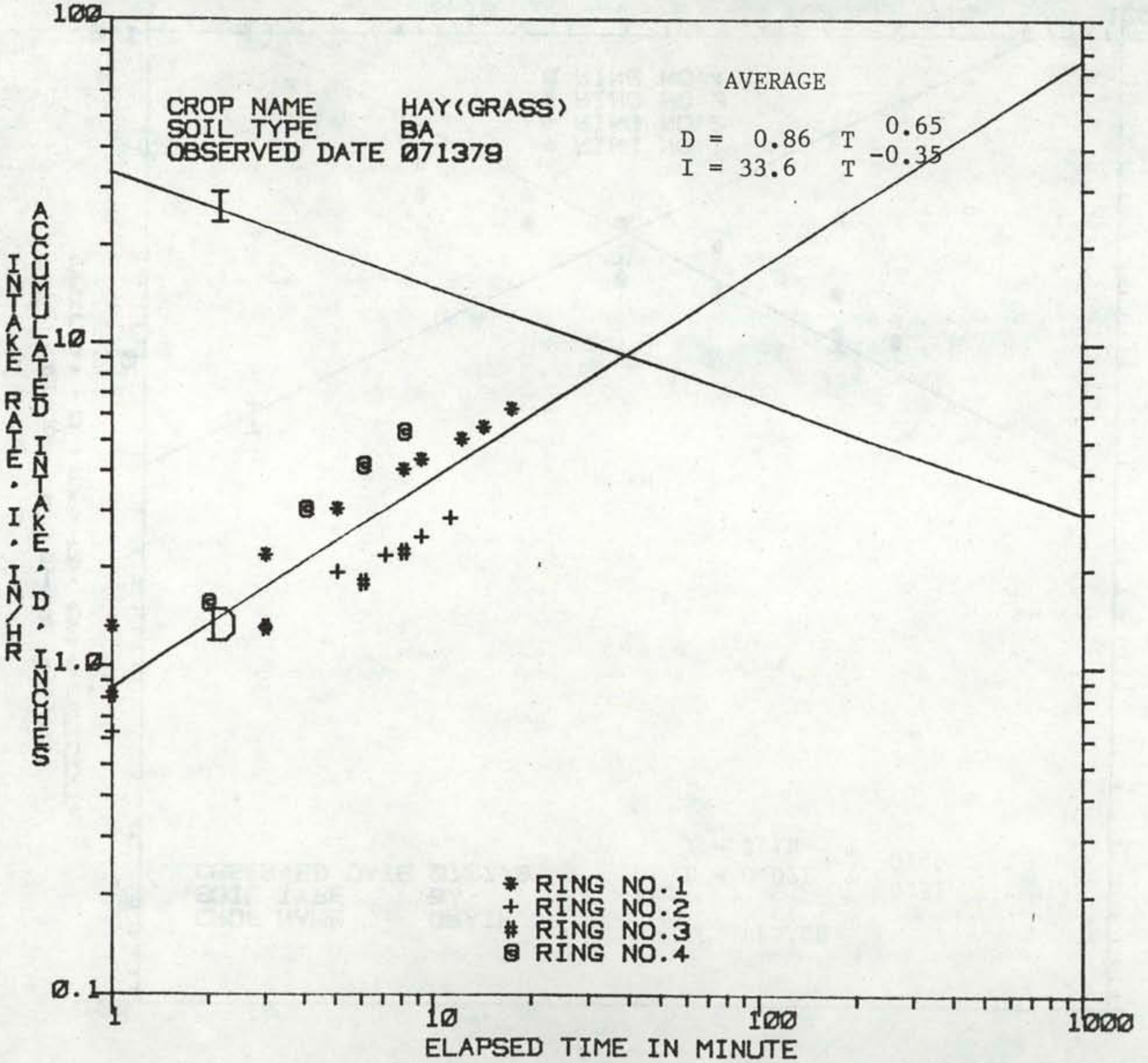

Figure II-5. Intake characteristics for grass hay on Bannock soil.

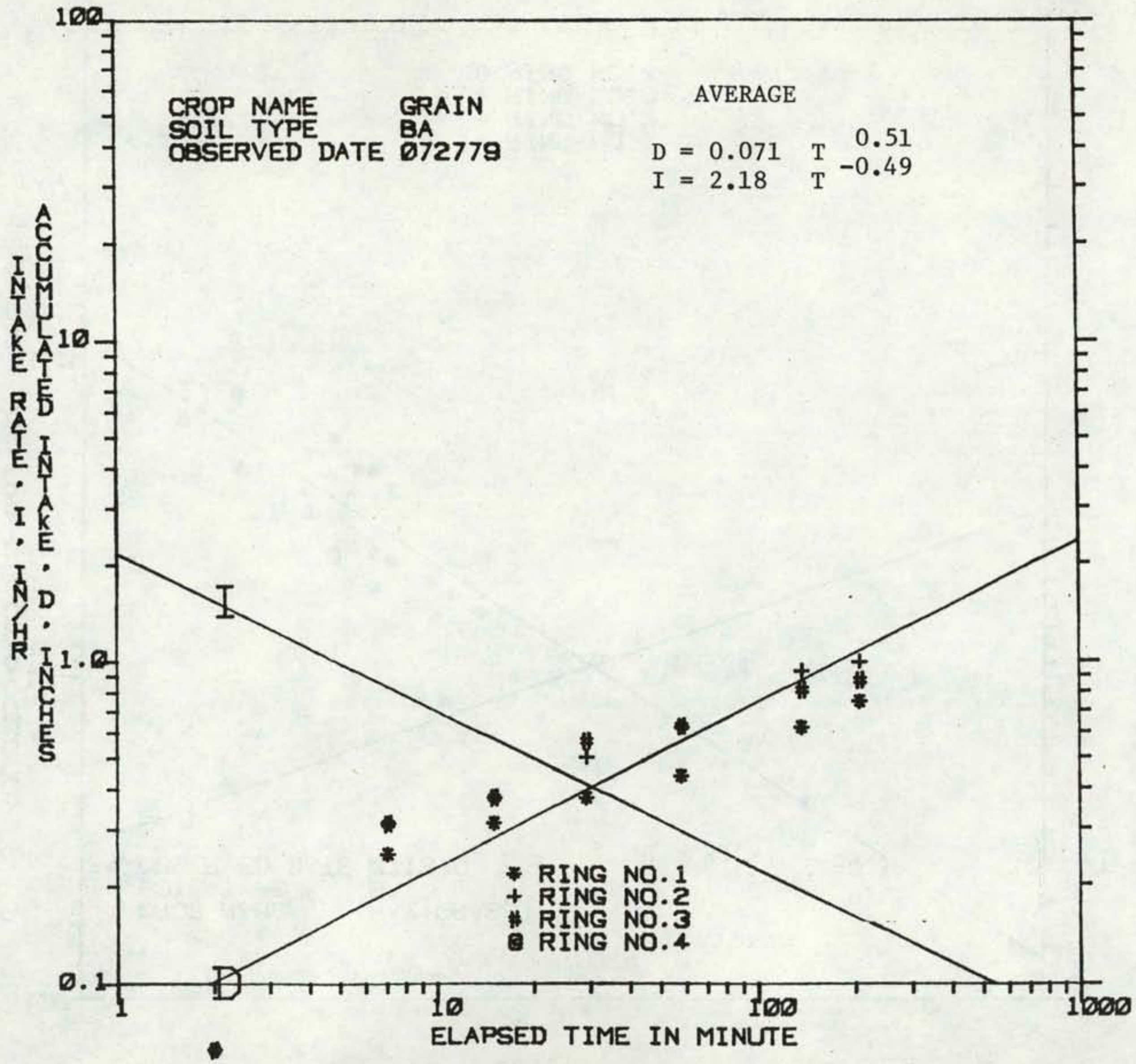

Figure II-6. Intake characteristics for grain on Bannock soil.

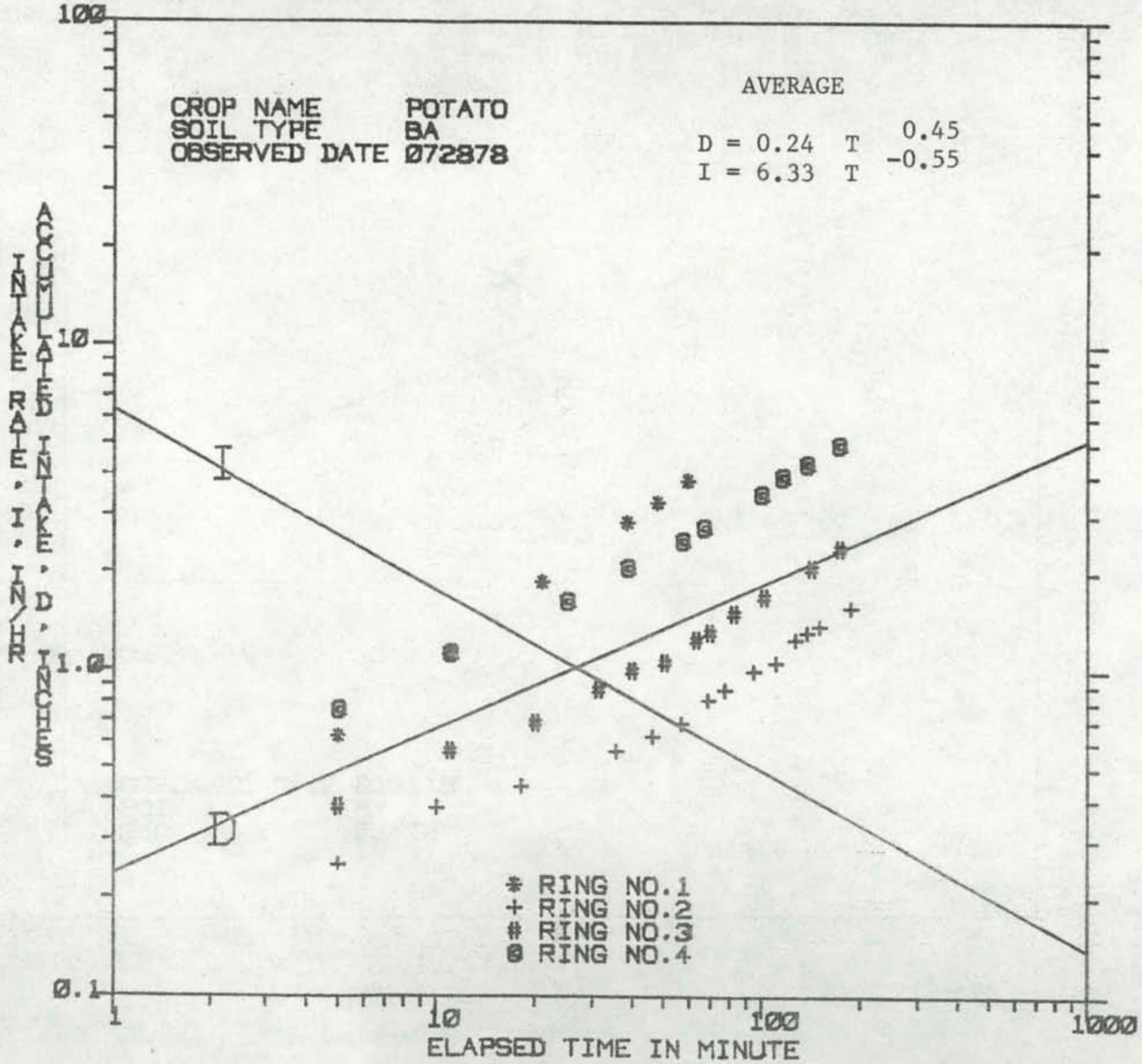

Figure II-7. Intake characteristics for potatoes on Bannock soil.

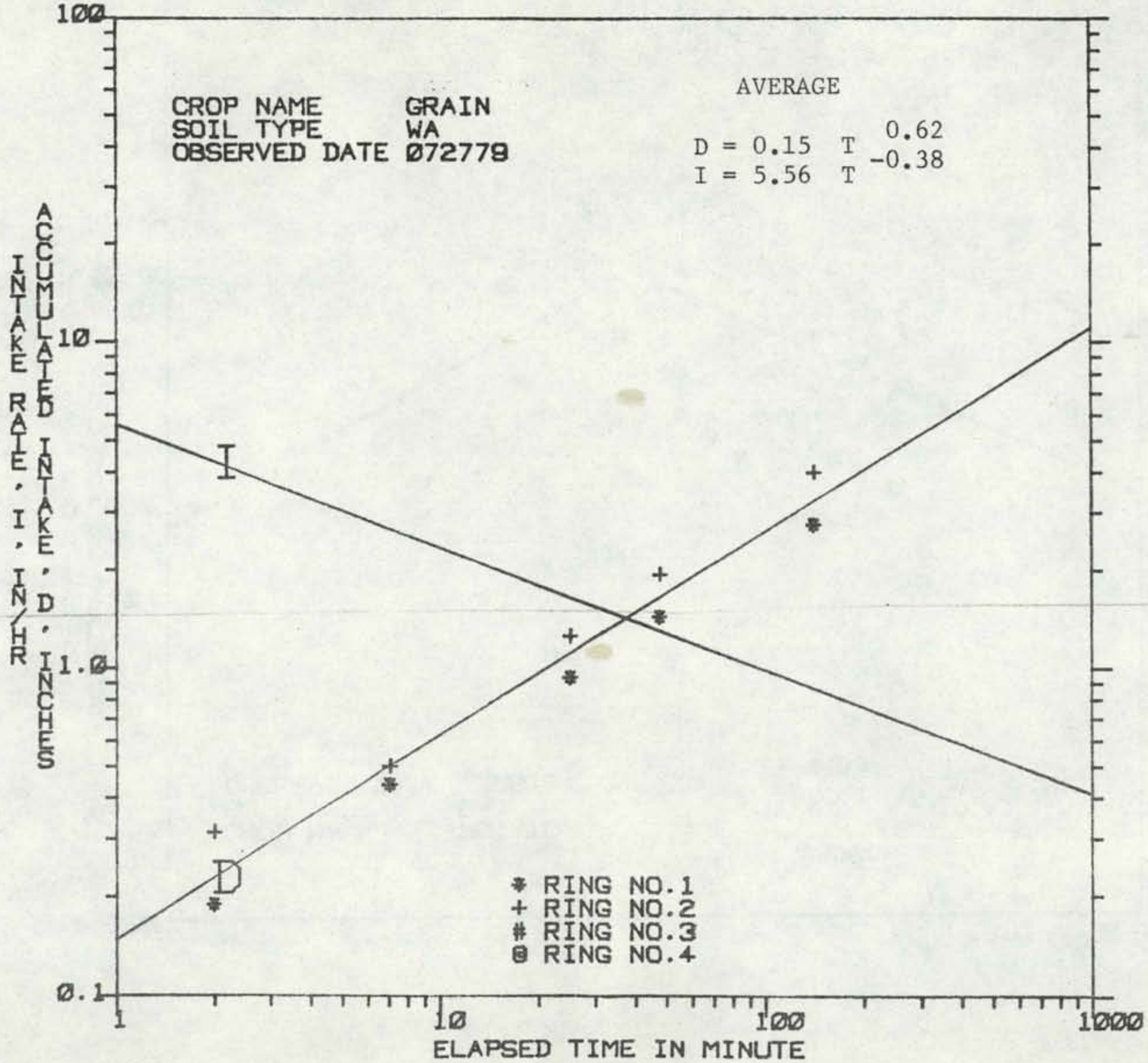

Figure II-8. Intake characteristics for grain on Wapello soil.

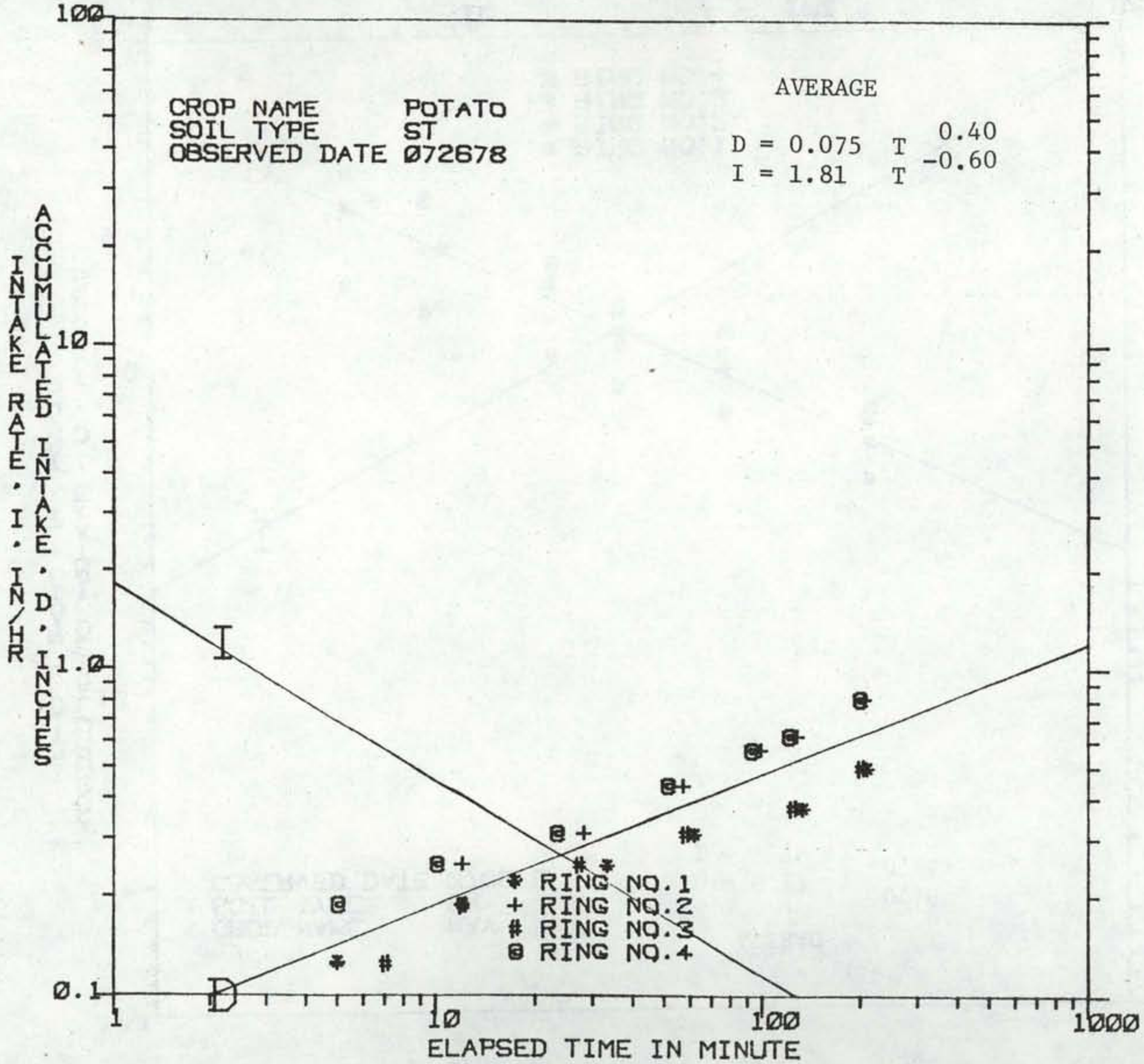

Figure II-9. Intake characteristics for potatoes on Stan soil.

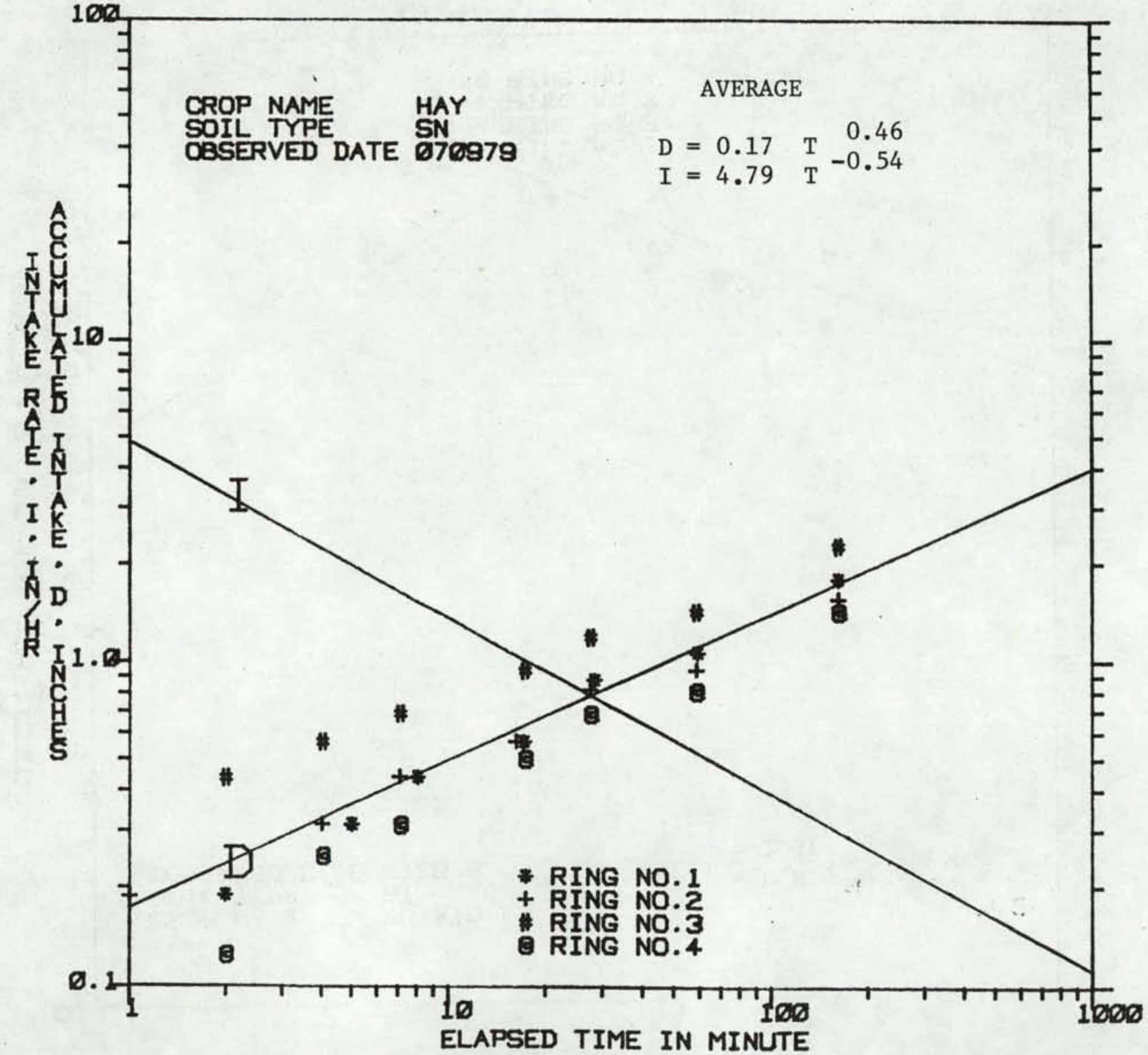

Figure II-10. Intake characteristics for alfalfa hay on Sasser soil.

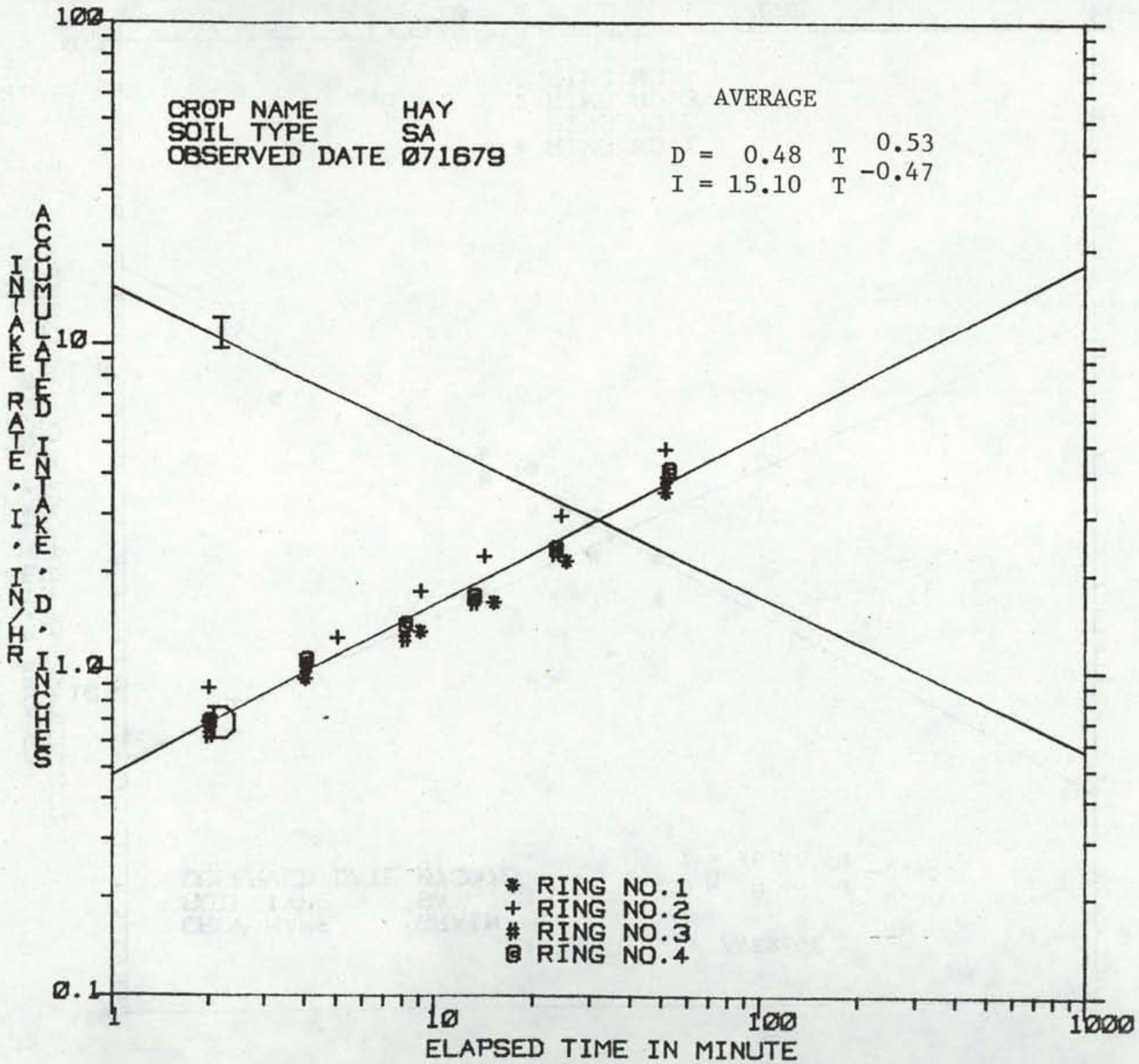

Figure II-11. Intake characteristics for alfalfa hay on Sasser soil.

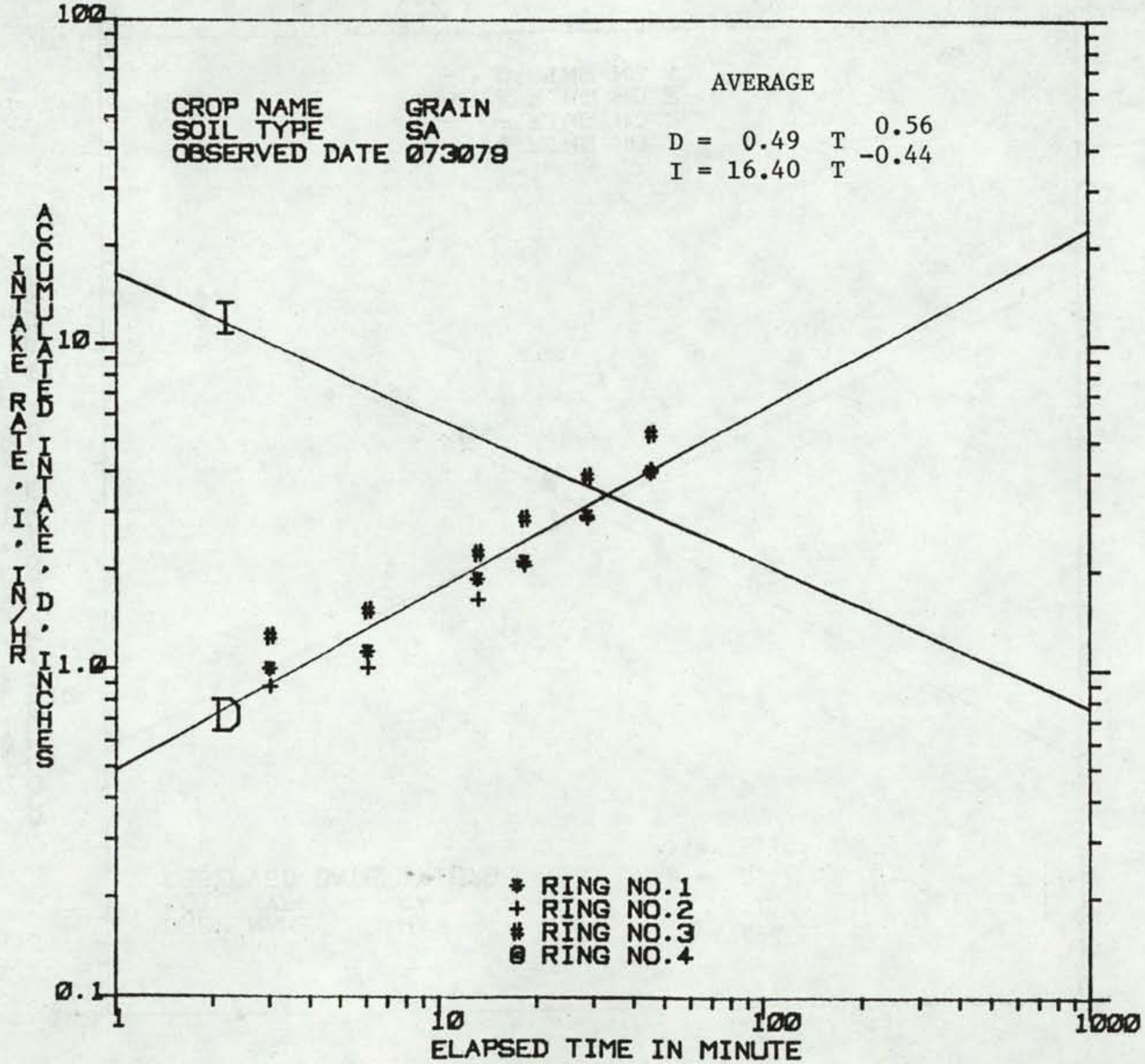

Figure II-12. Intake characteristics for grain on Sasser soil.

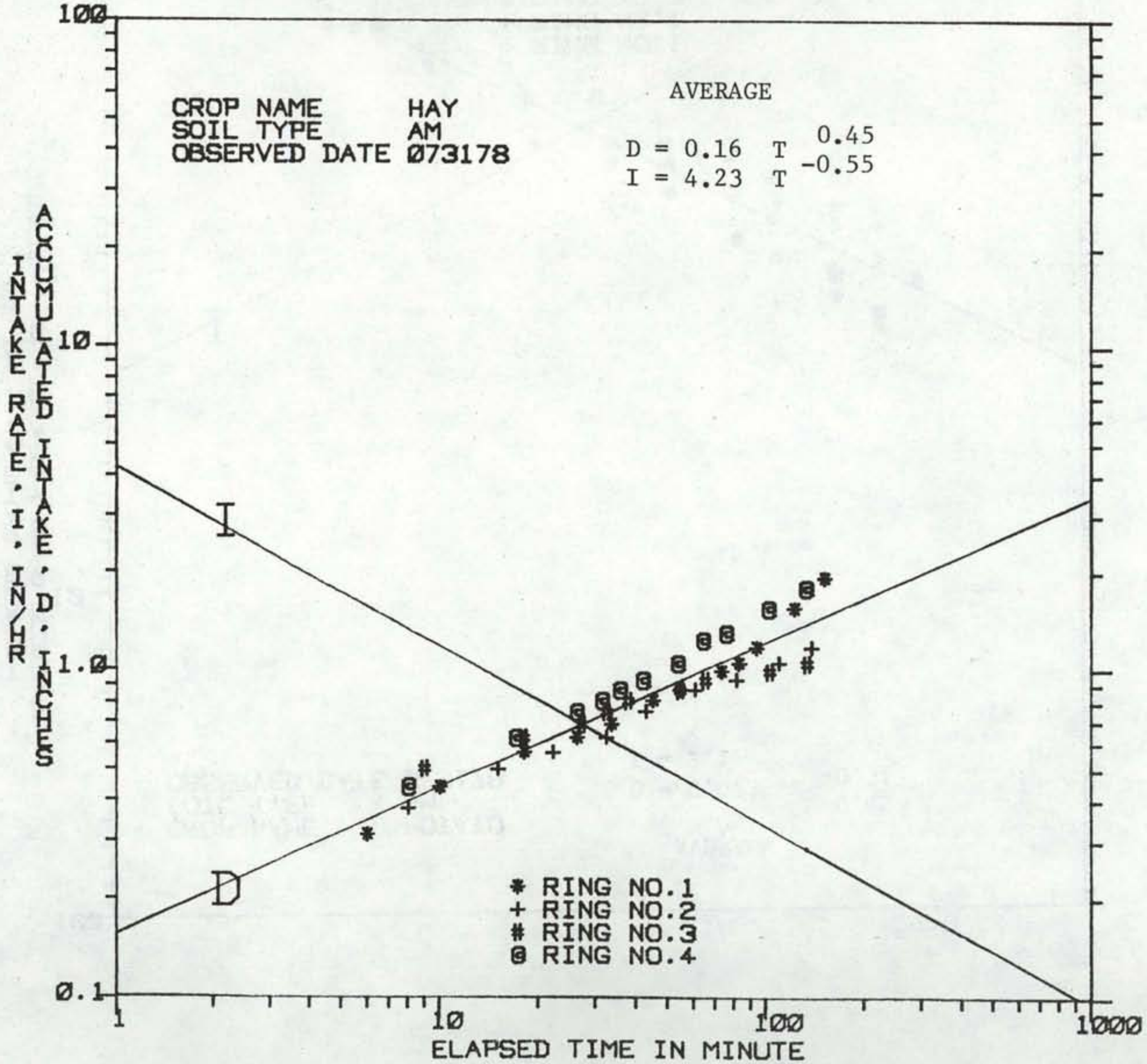

Figure II-13. Intake characteristics for alfalfa hay on Ammon soil.

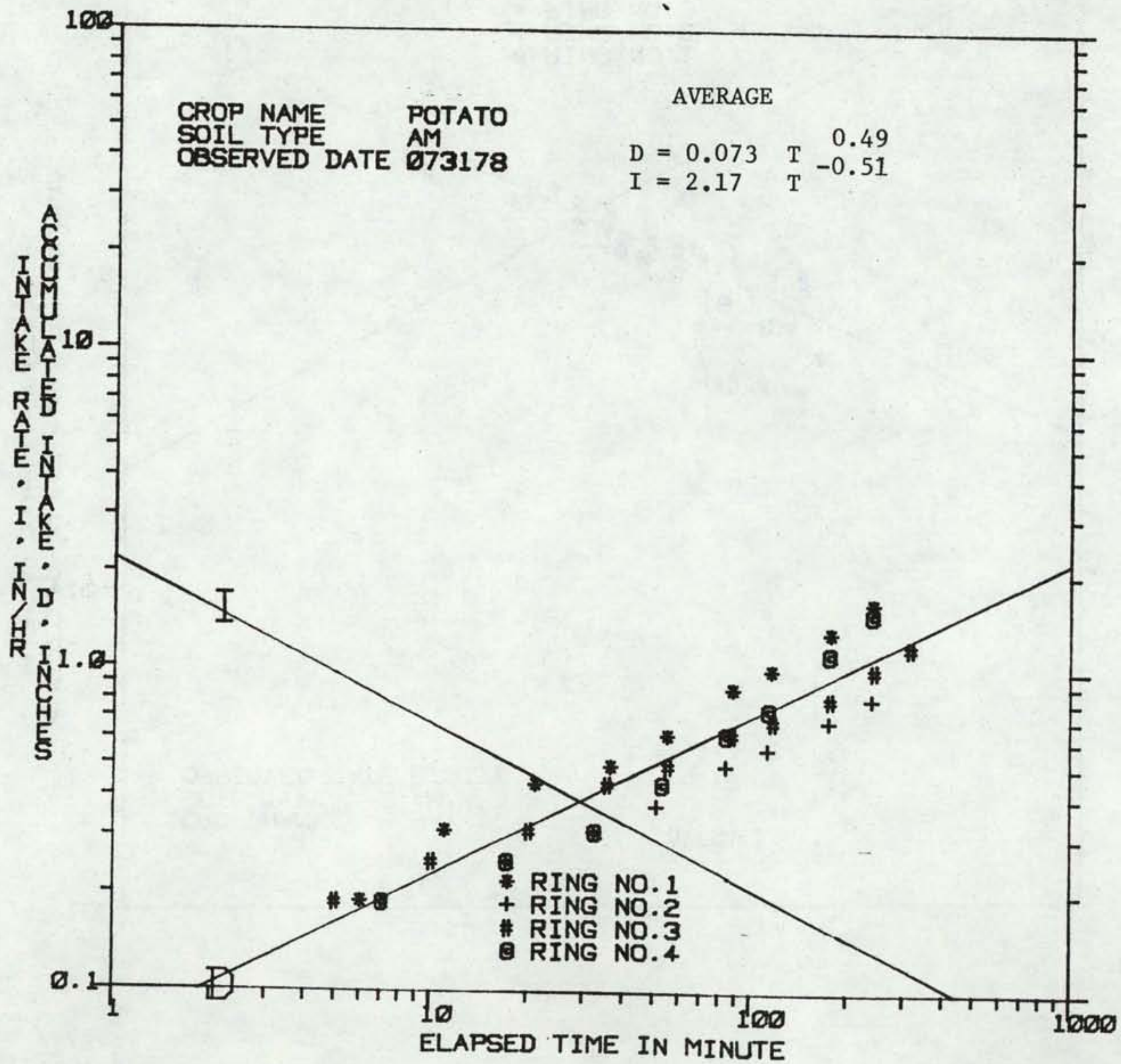

Figure II-14. Intake characteristics for potatoes on Ammon soil.

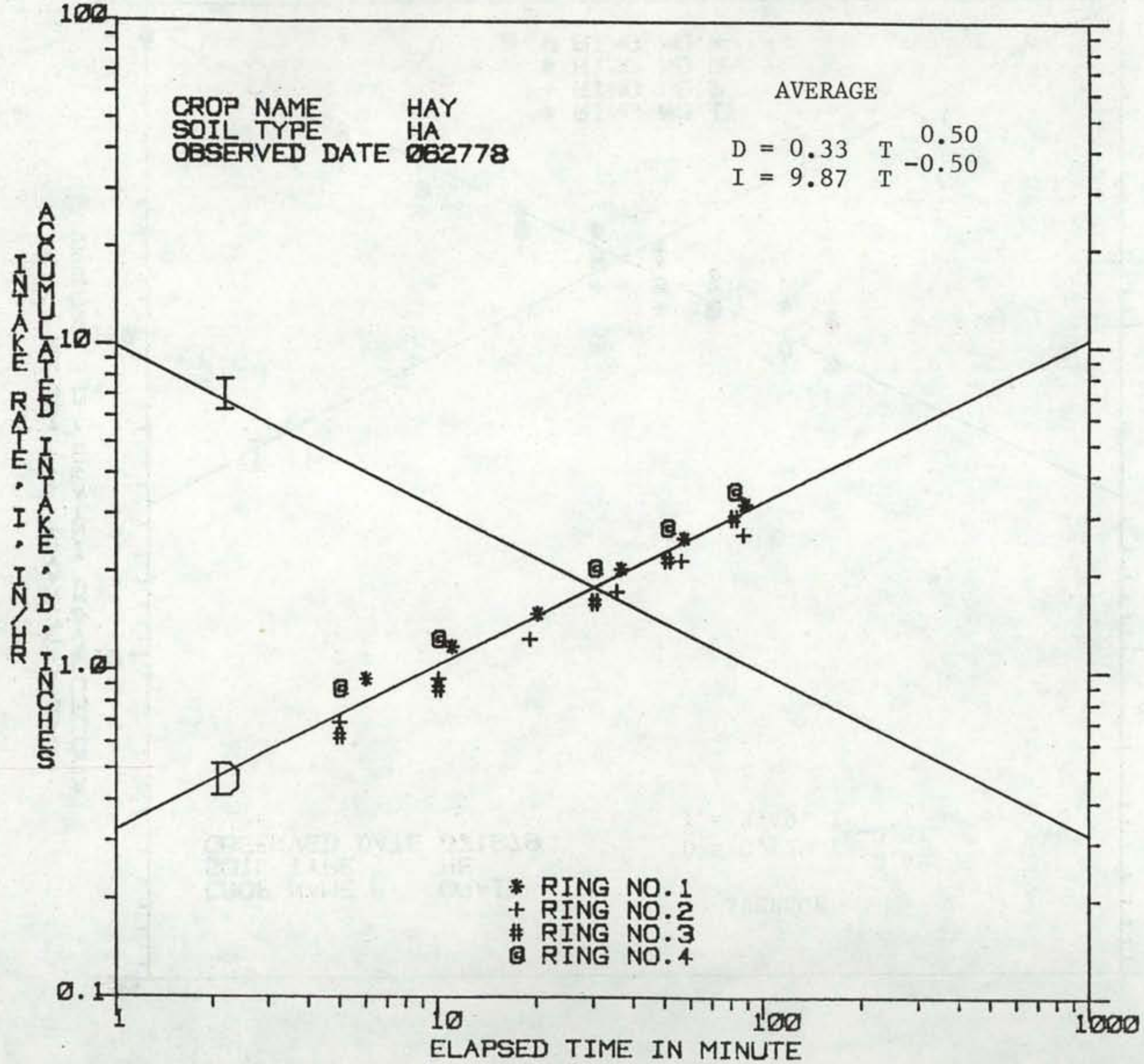

Figure II-15. Intake characteristics for alfalfa hay on Hayeston soil.

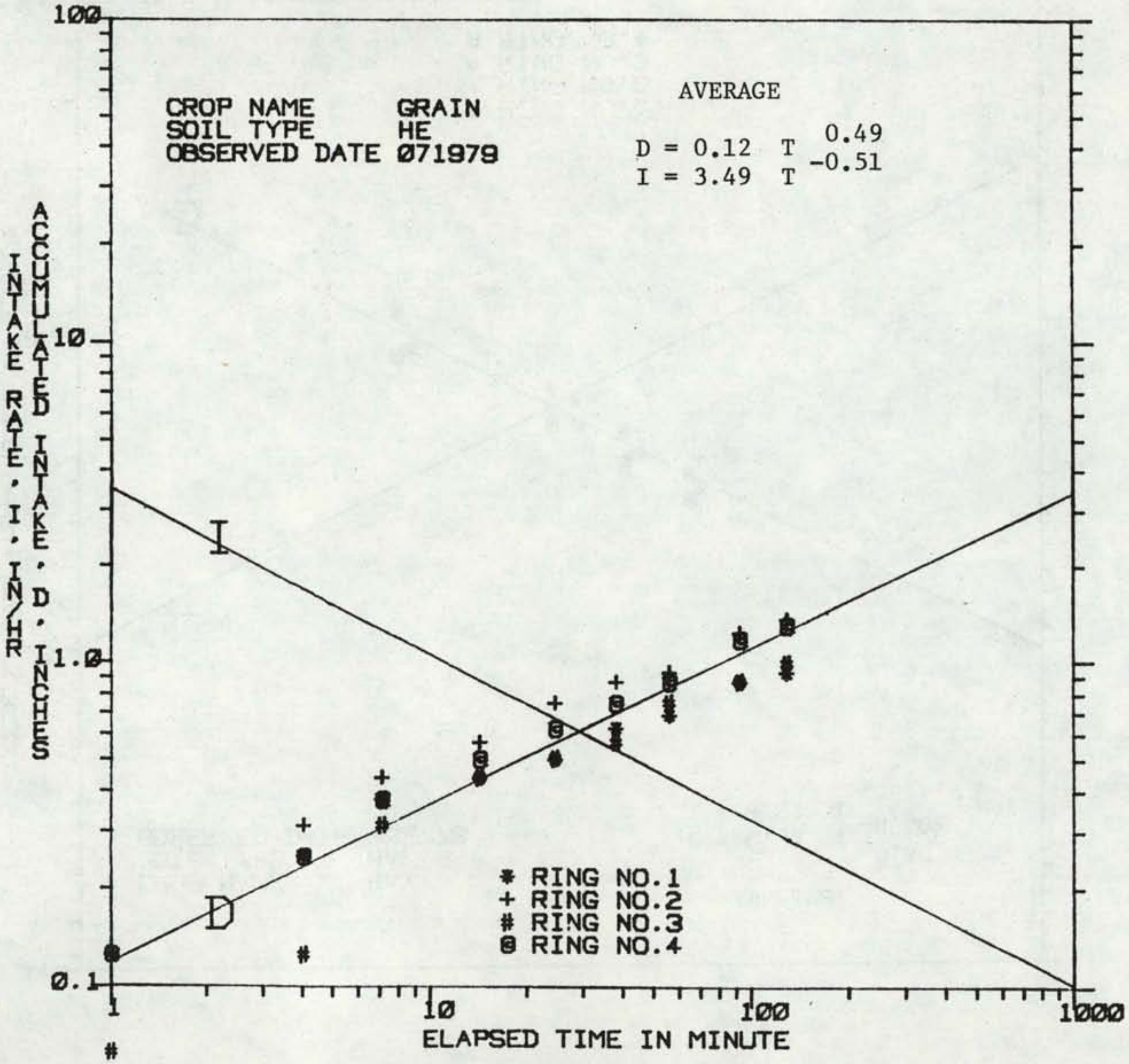

Figure II-16. Intake characteristics for grain on Hayeston soil.

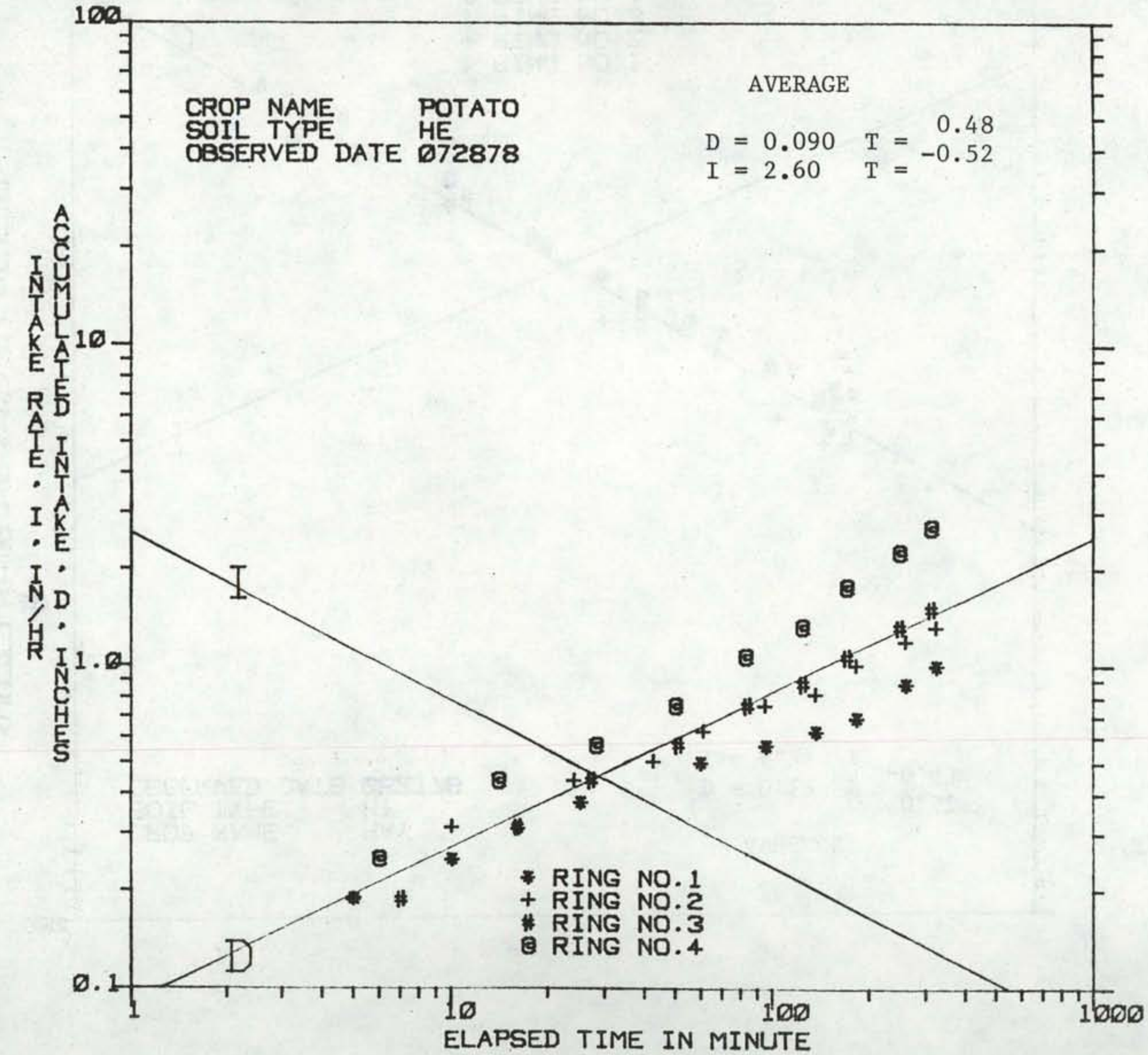

Figure II-17. Intake characteristics for potatoes on Hayeston soil.

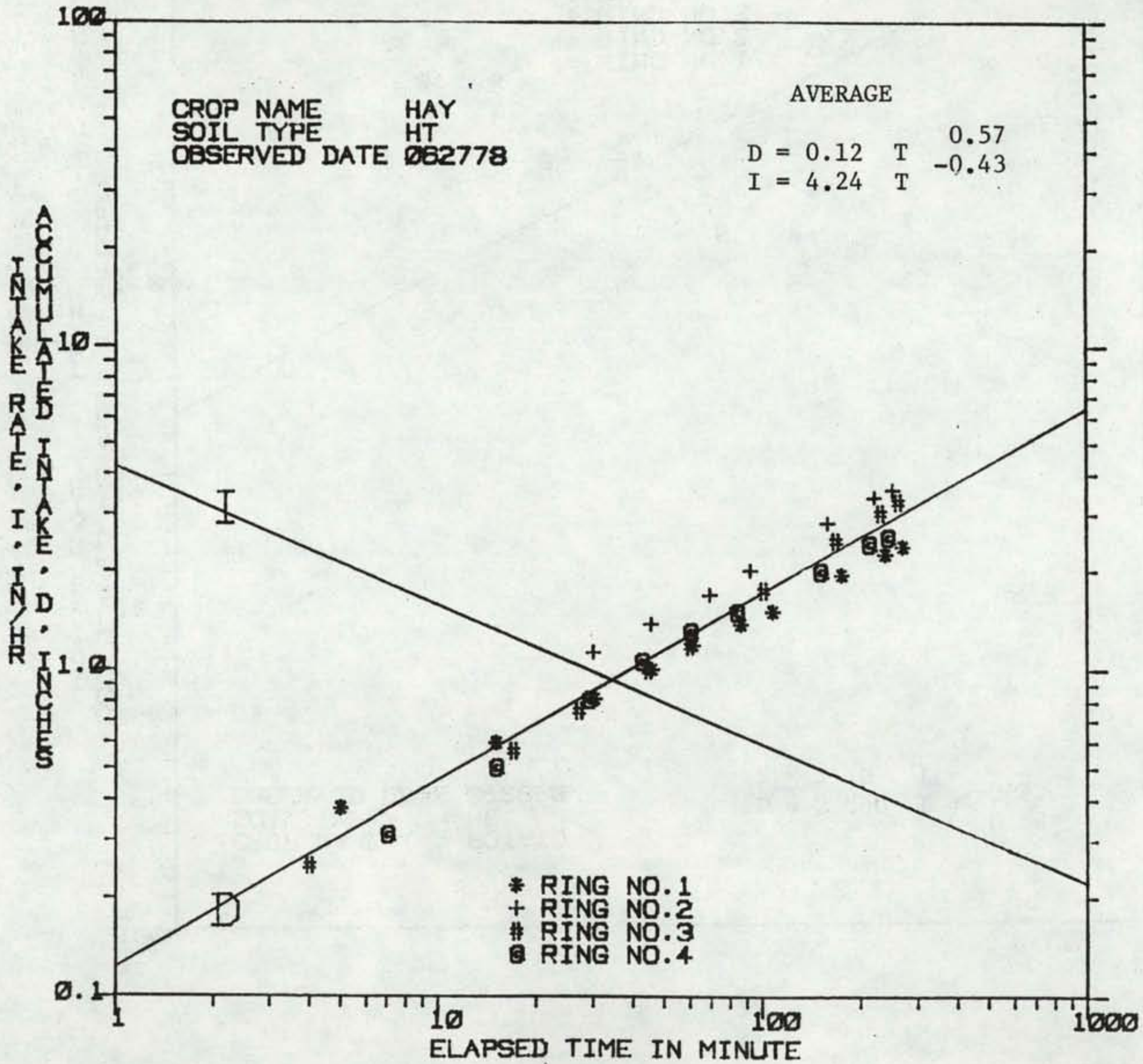

Figure II-18. Intake characteristics for alfalfa hay on Heiseton soil.

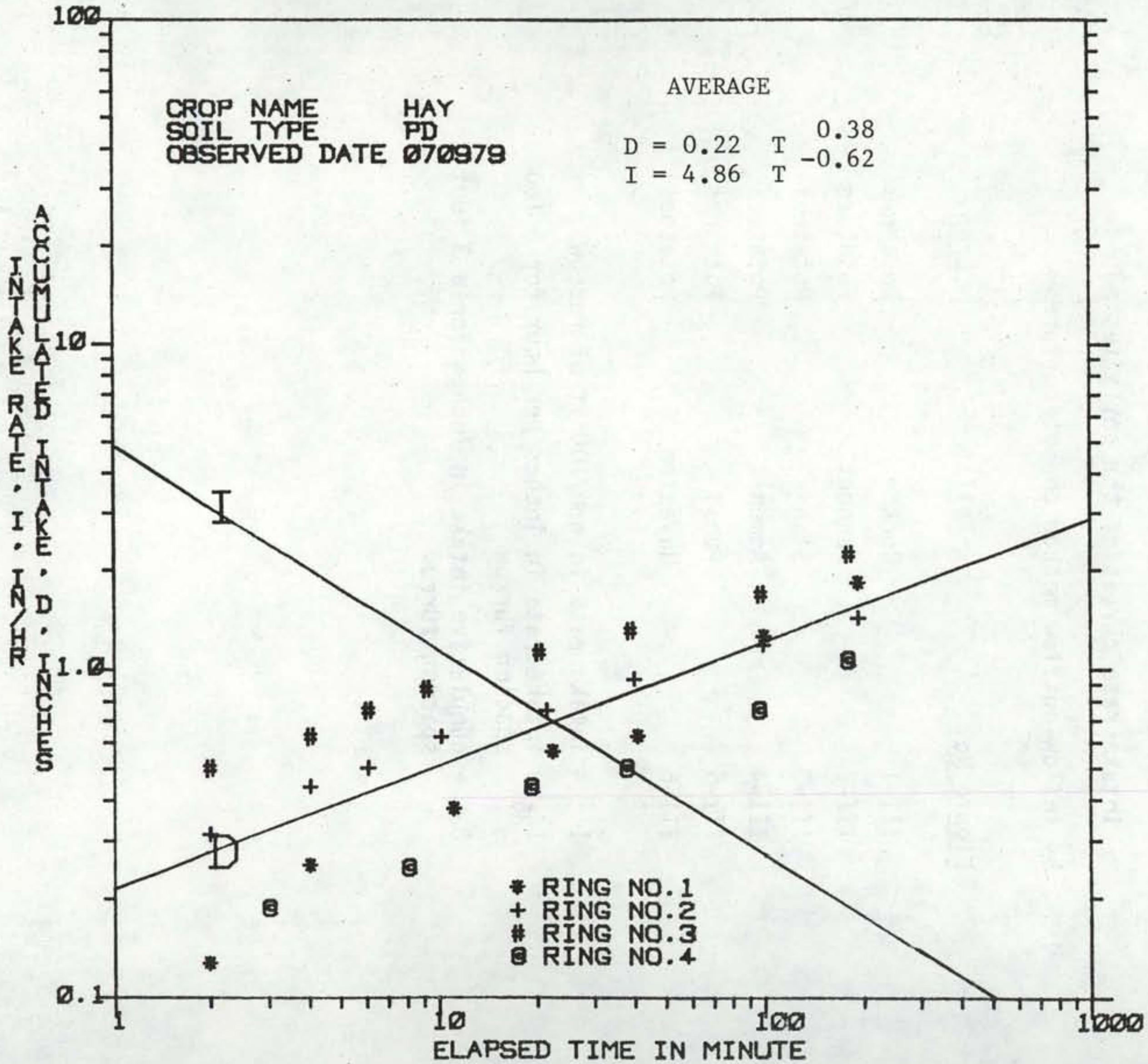

Figure II-19. Intake characteristics for alfalfa hay on Paesl soil.

APPENDIX III

Intake rate curves of the soils tested

by inflow-outflow method on potato furrow

Figure No.	Soil	Crop
III-1	Bock	Potatoes
III-2	Bannock	Potatoes
III-3	Stan	Potatoes
III-4	Ammon	Potatoes
III-5	Paesl	Potatoes
III-6	Hayeston	Potatoes

I = intake rate in gpm/100 ft of furrow

I_{36} = intake rate in inches per hour for 3 foot spacing furrow

D = cumulative intake in inches for a 3 foot spacing furrow

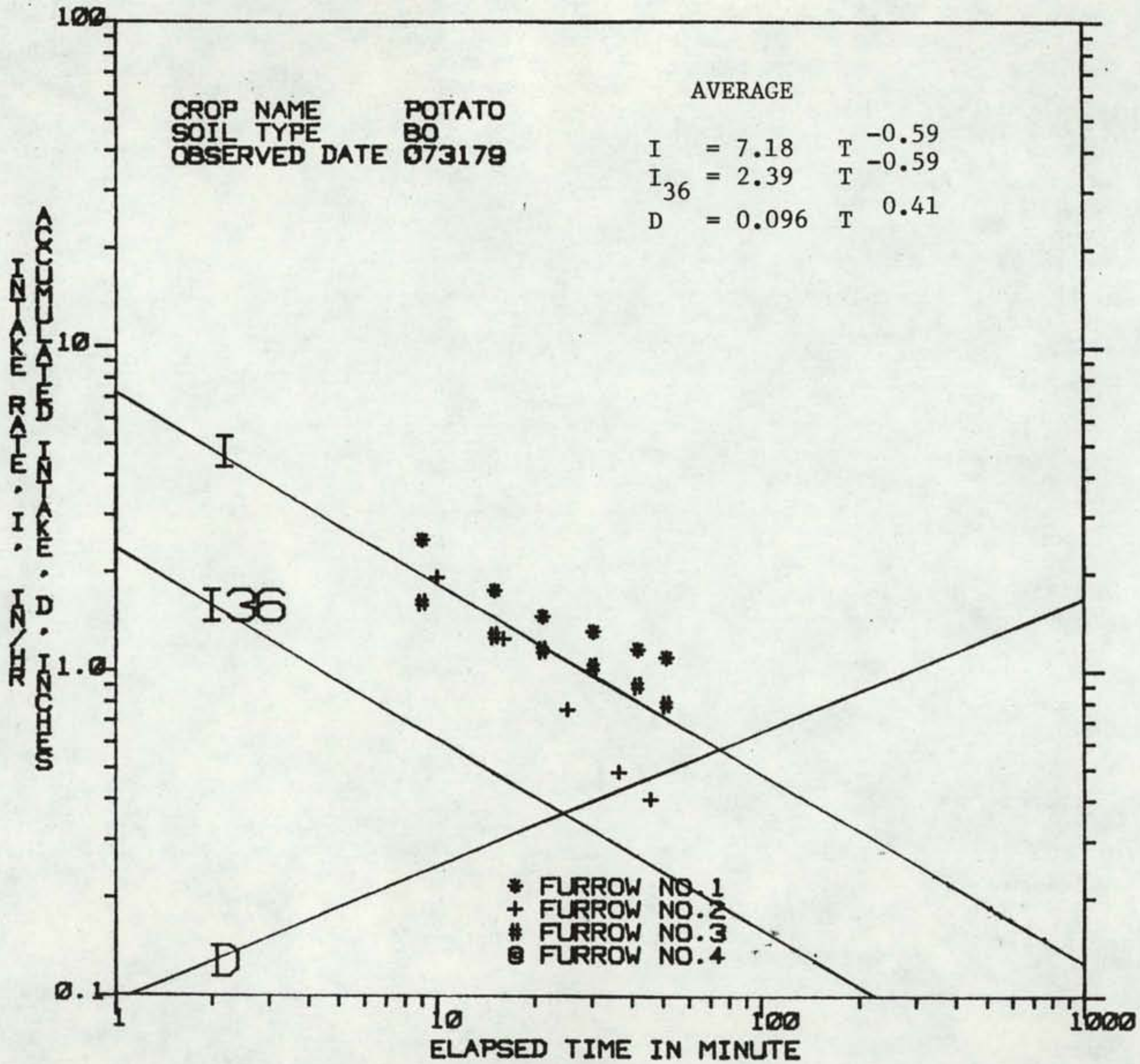

Figure III-1. Intake characteristics for potatoes on Bock soil.

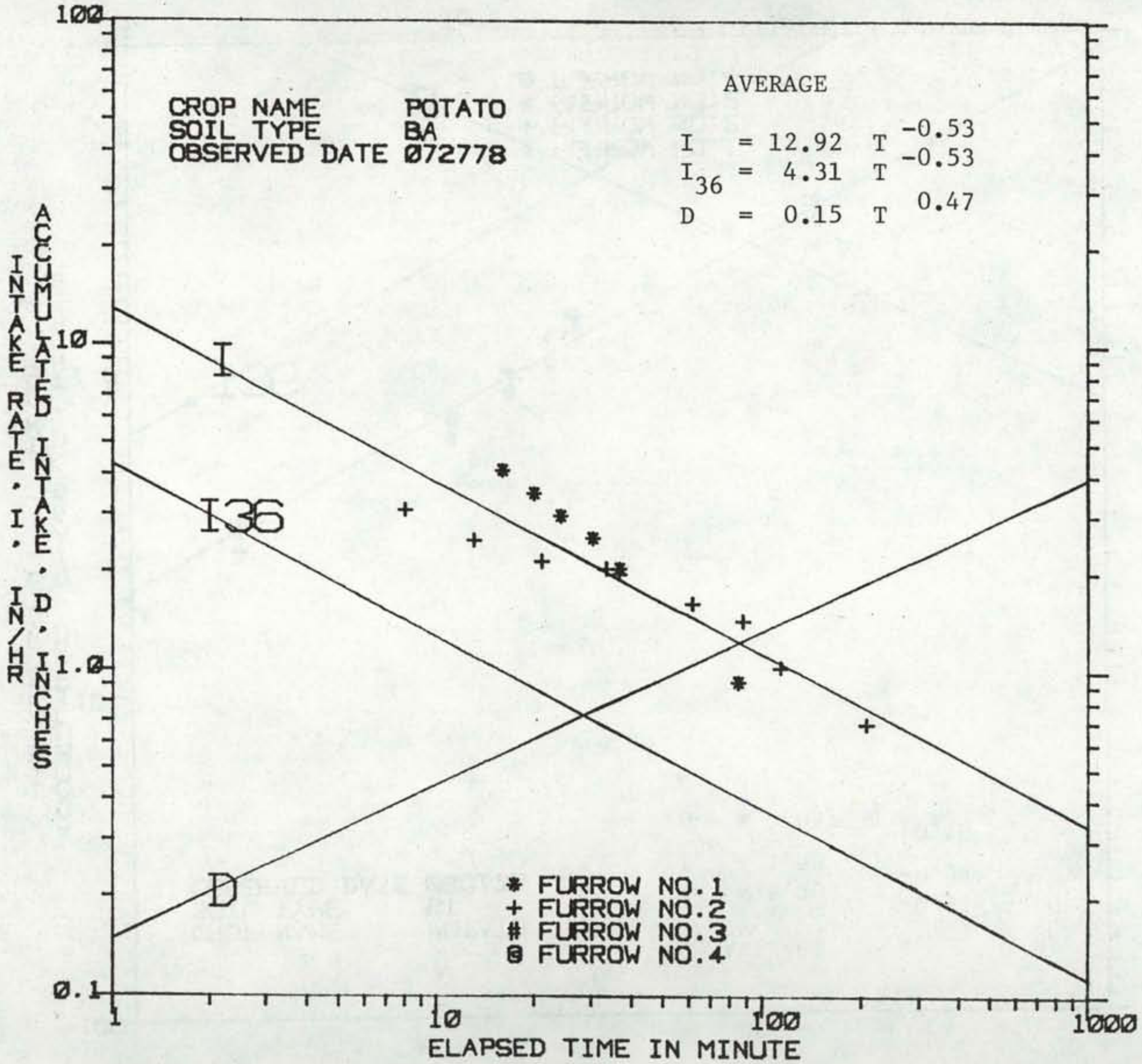

Figure III-2. Intake characteristics for potatoes on Bannock soil.

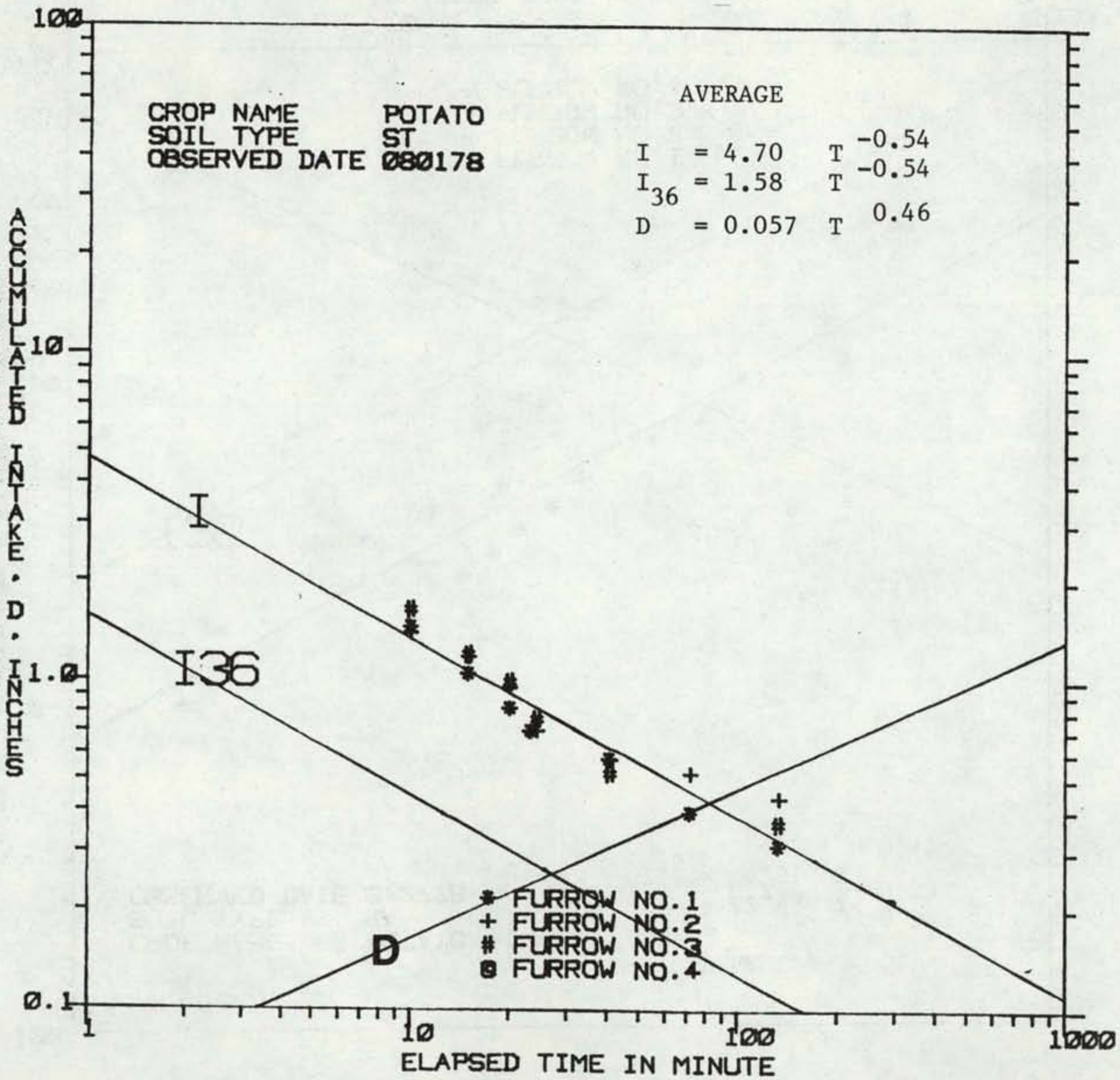

Figure III-3. Intake characteristics for potatoes on Stan soil.

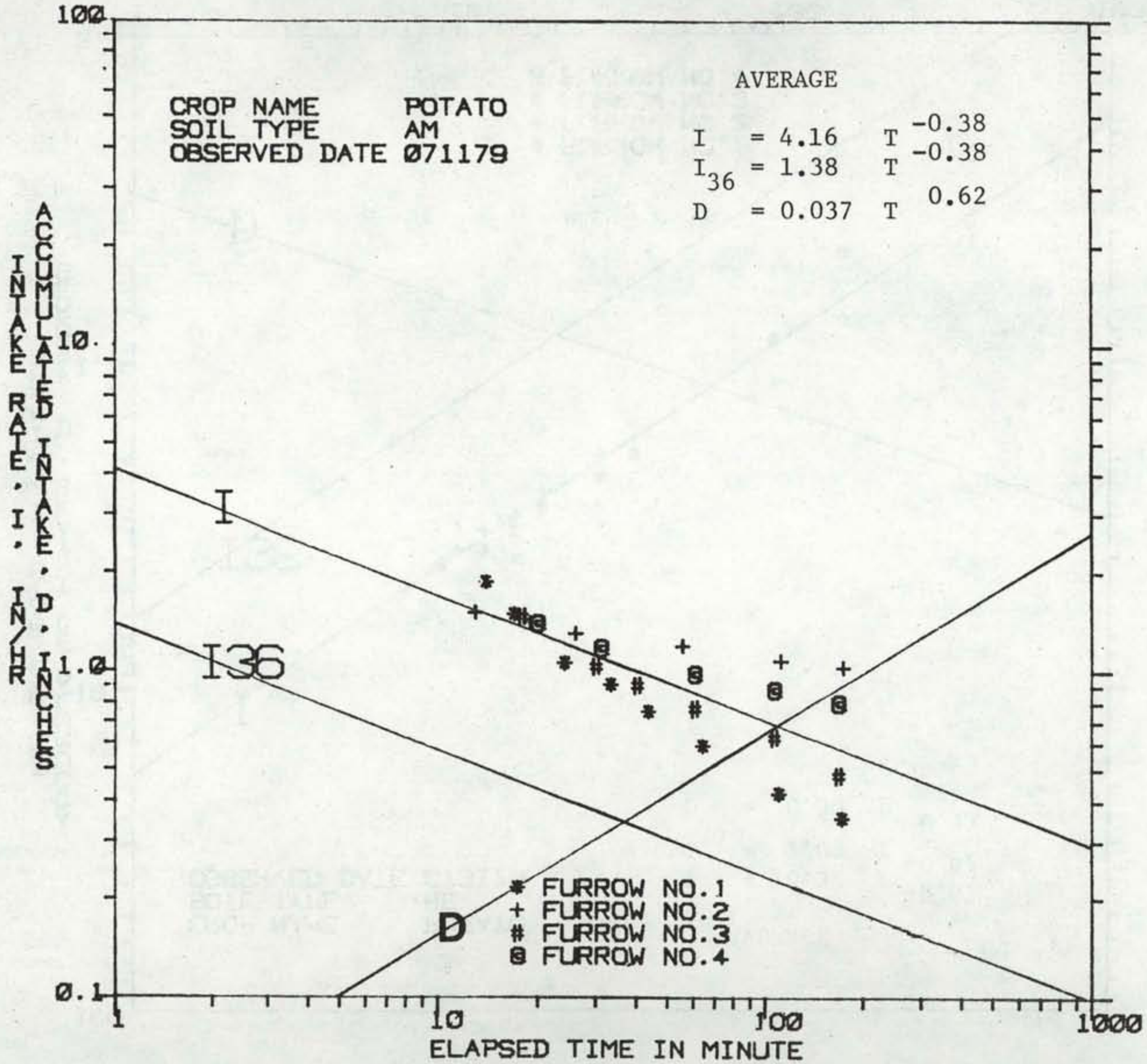

Figure III-4. Intake characteristics for potatoes on Ammon soil.

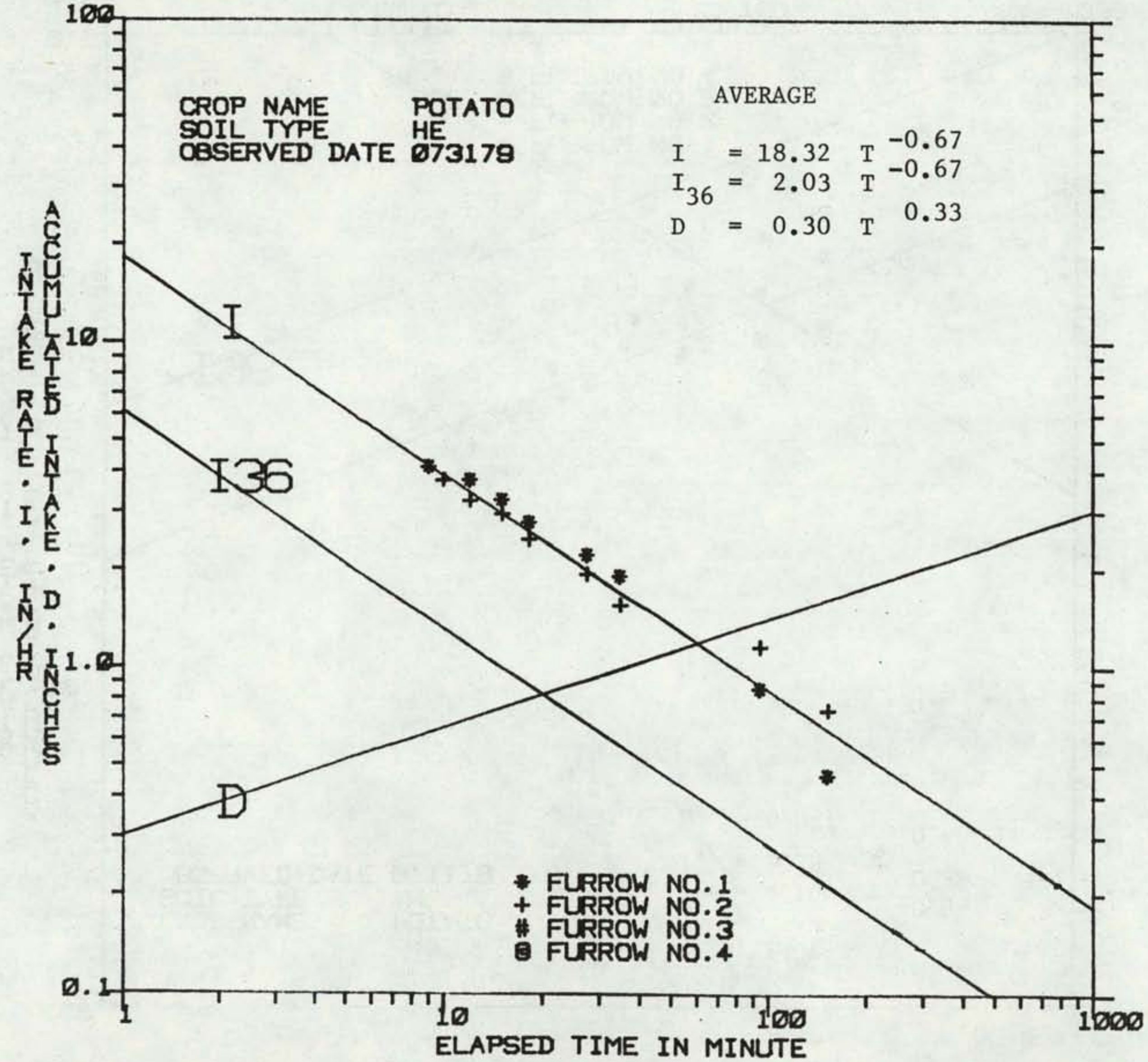

Figure III-5. Intake characteristics for potatoes on Paesl soil.

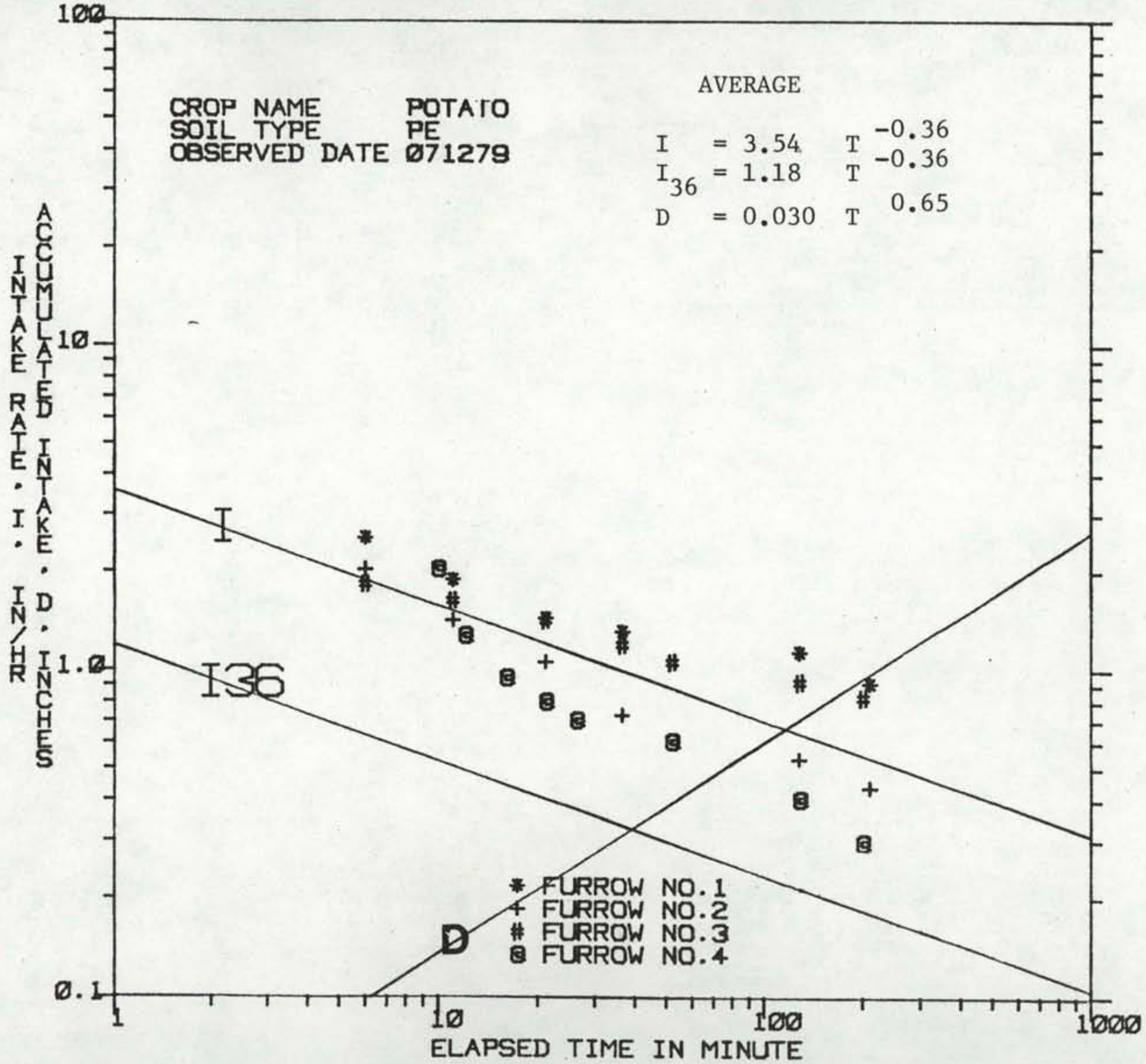

Figure III-6. Intake characteristics for potatoes on Hayeston soil.

APPENDIX IV

Advance time relationship curves of tested soils for furrow irrigated potato fields

Figure No.	Soil	Crop
IV-1	Ammon	Potatoes
IV-2	Paesl	Potatoes

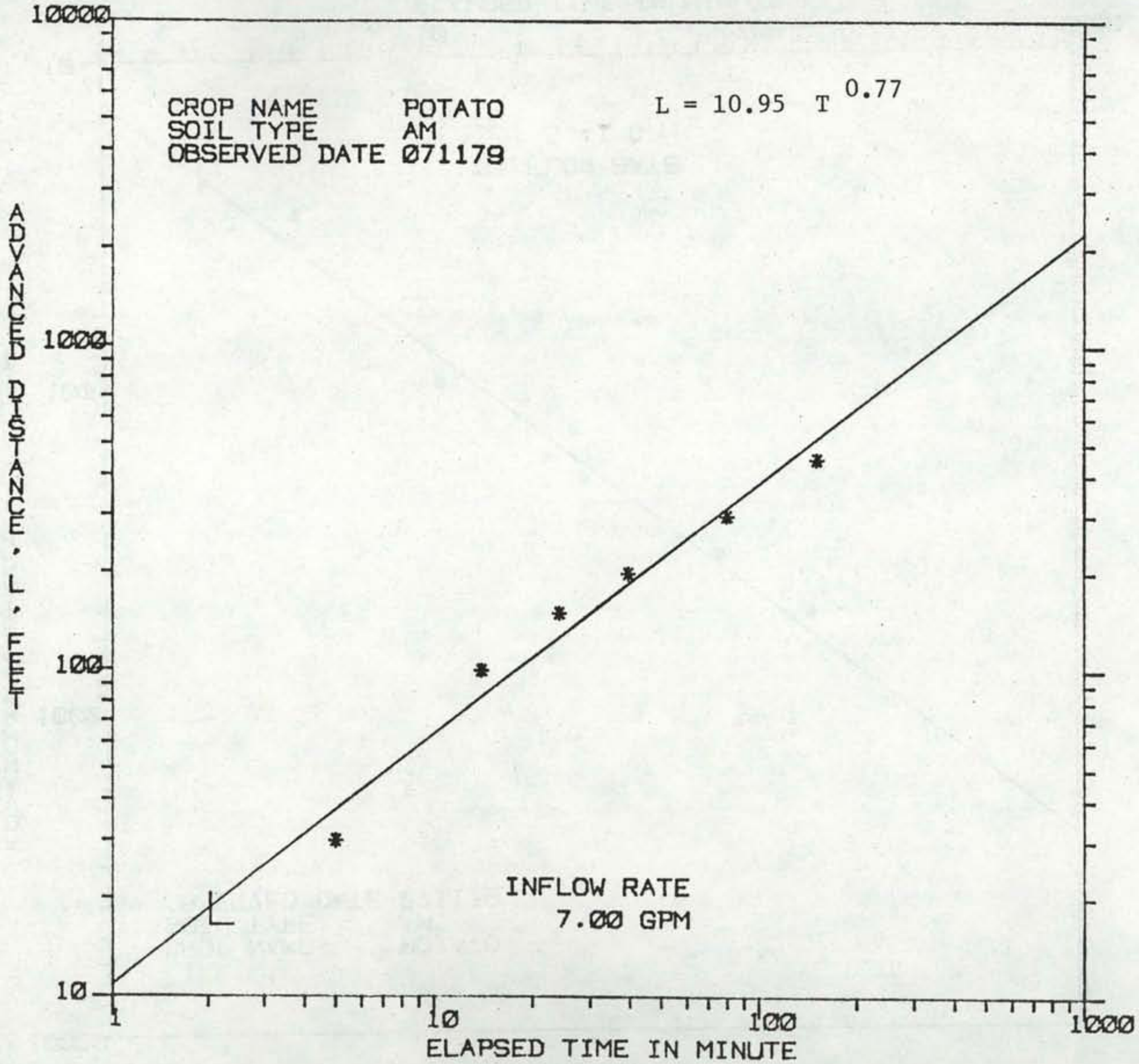

Figure IV-1 (a). Furrow advance relationship for potatoes on Ammon soil.

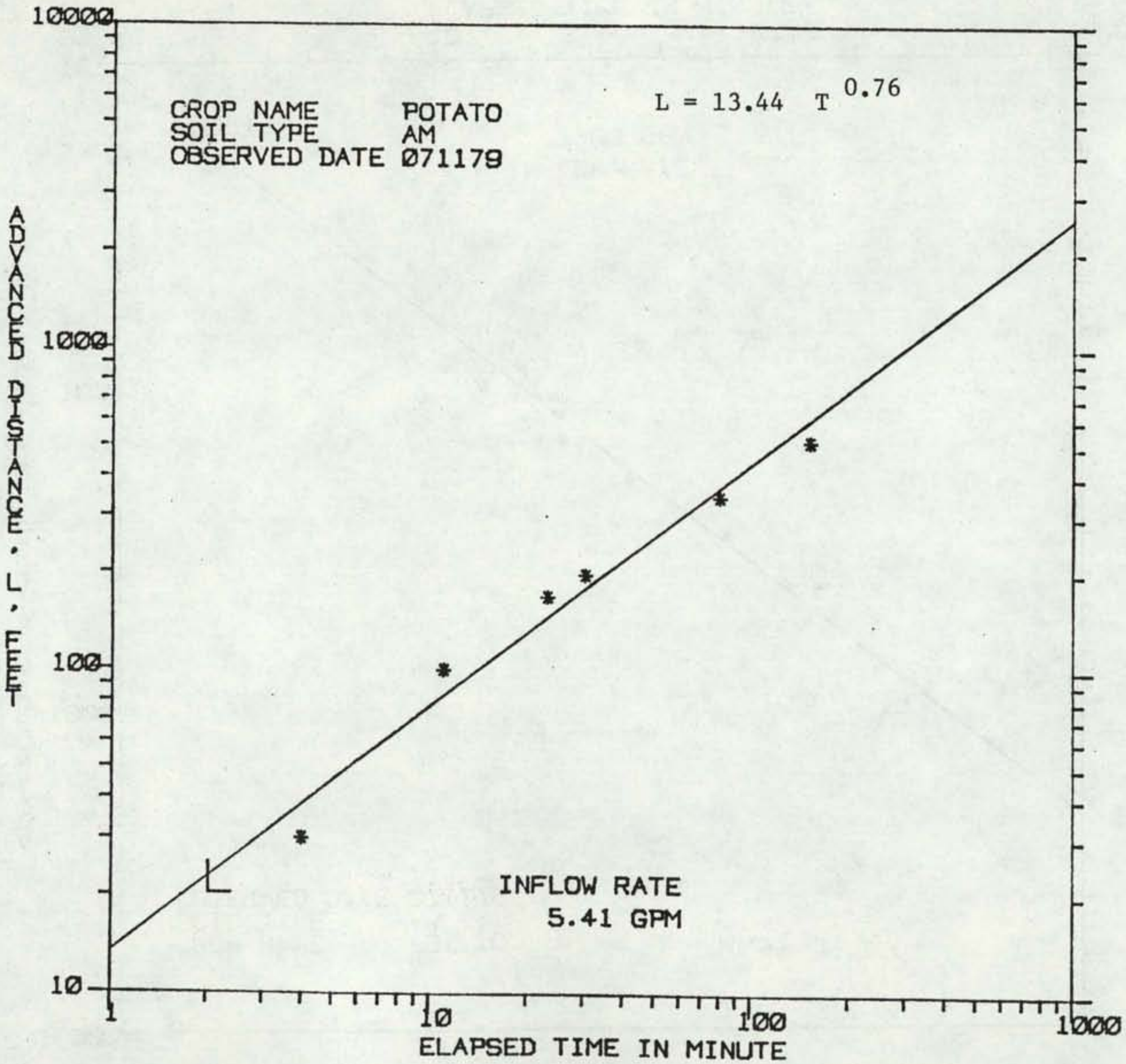

Figure IV-1 (b). Furrow advançe relationship for potatoes on Ammon soil.

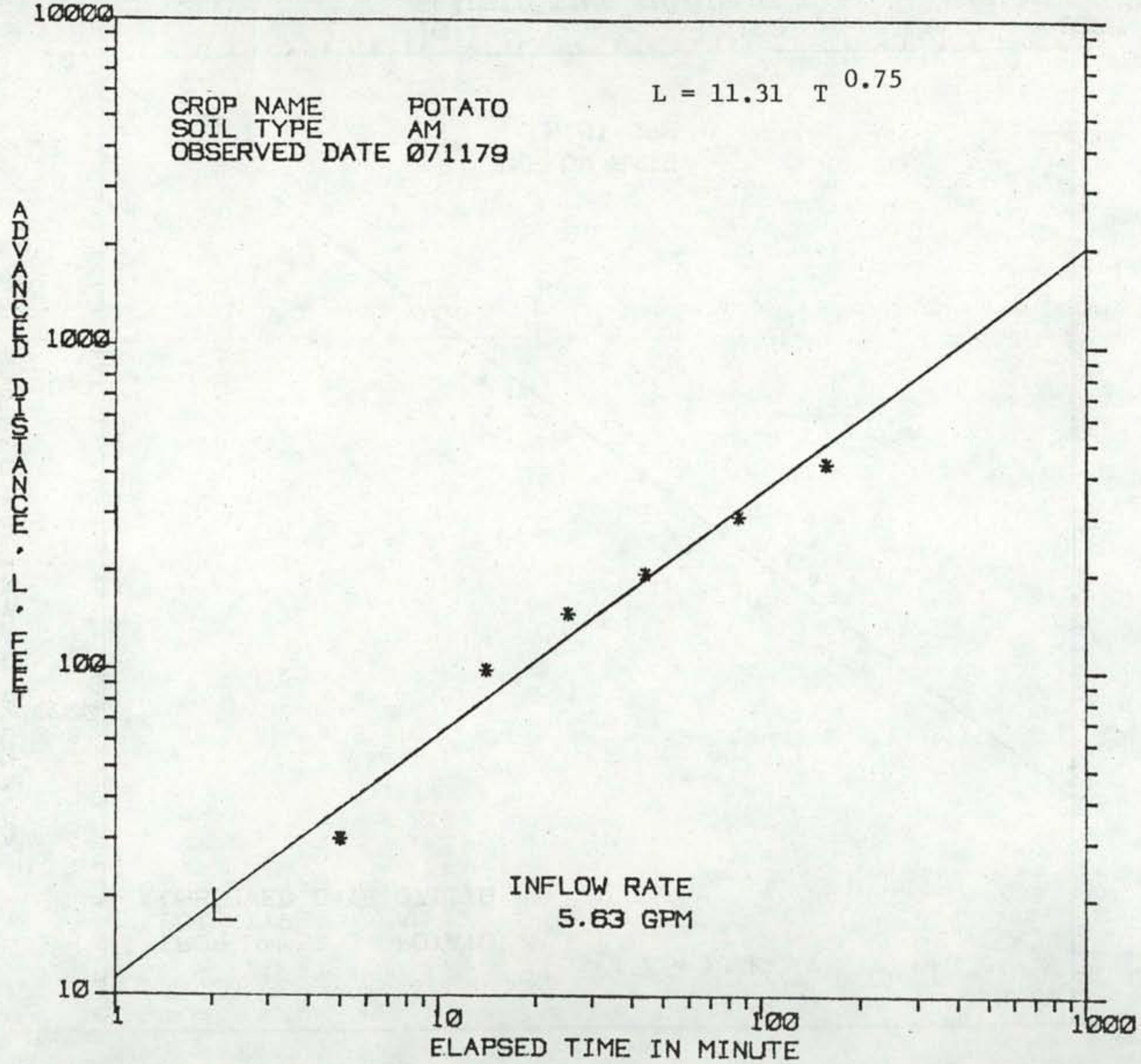

Figure IV-1 (c). Furrow advance relationship for potatoes on Ammon soil.

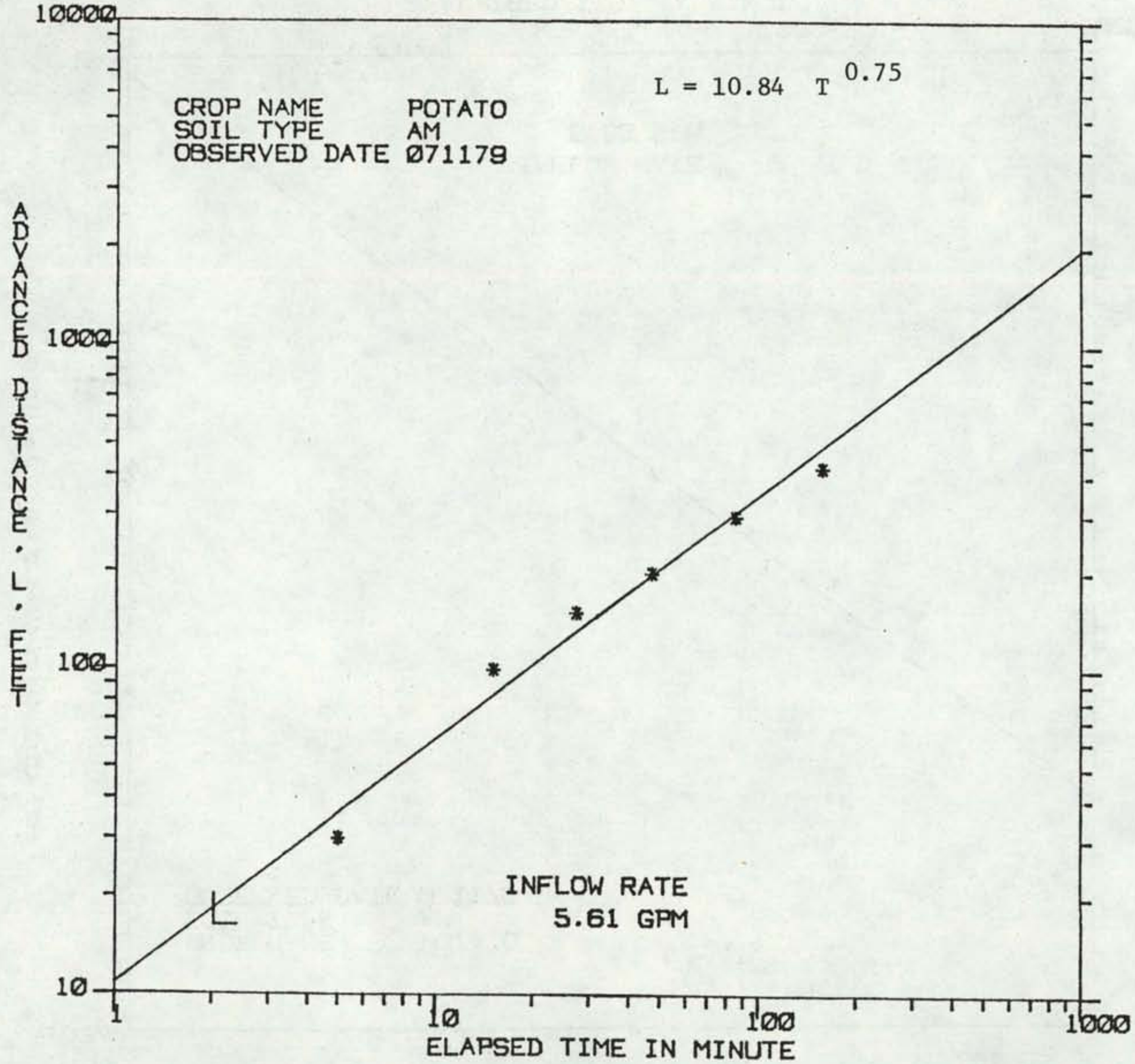

Figure IV-1 (d). Furrow advance relationship for potatoes on Ammon soil.

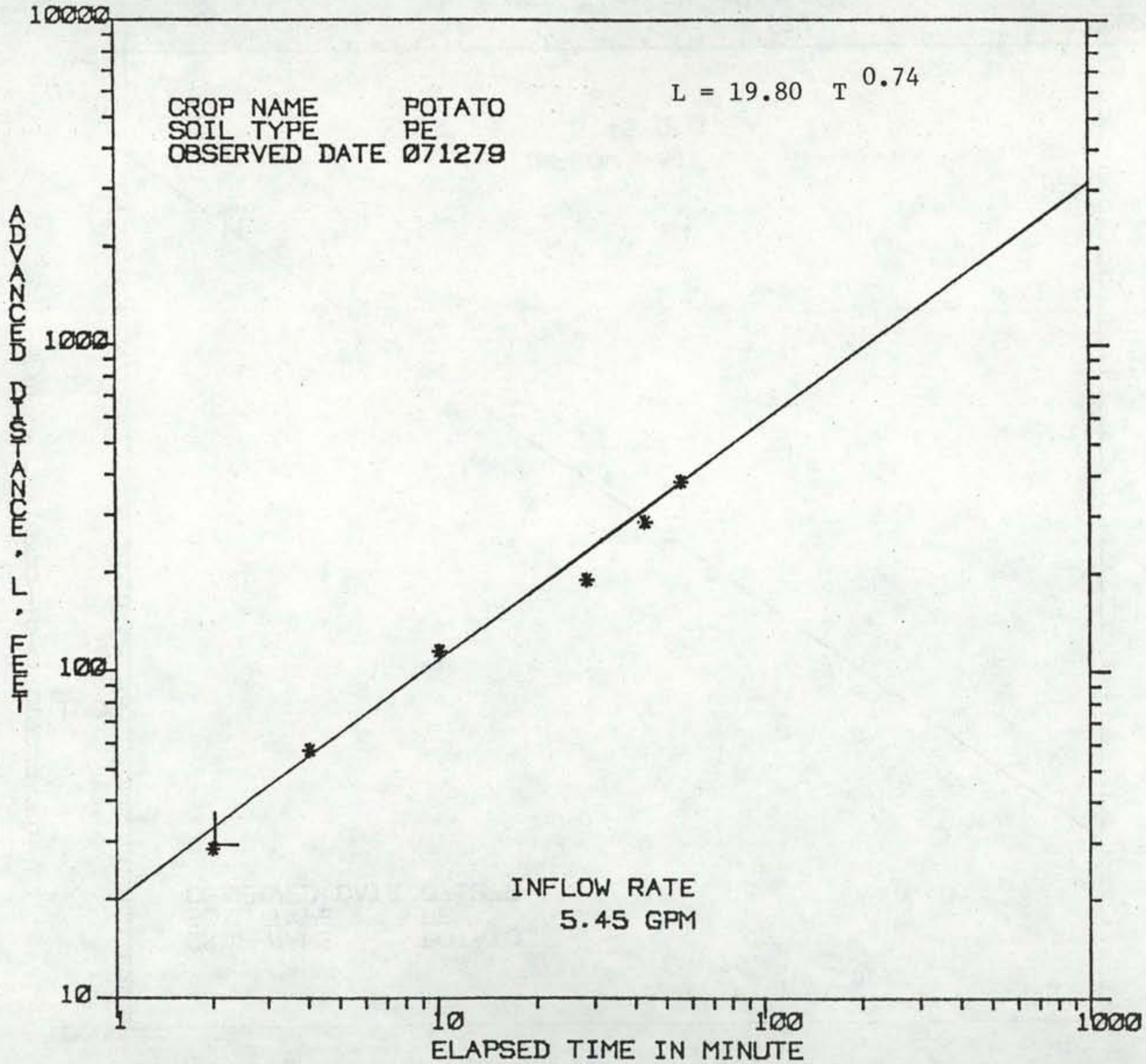

Figure IV-2 (a). Furrow advance relationship for potatoes on Paesl soil.

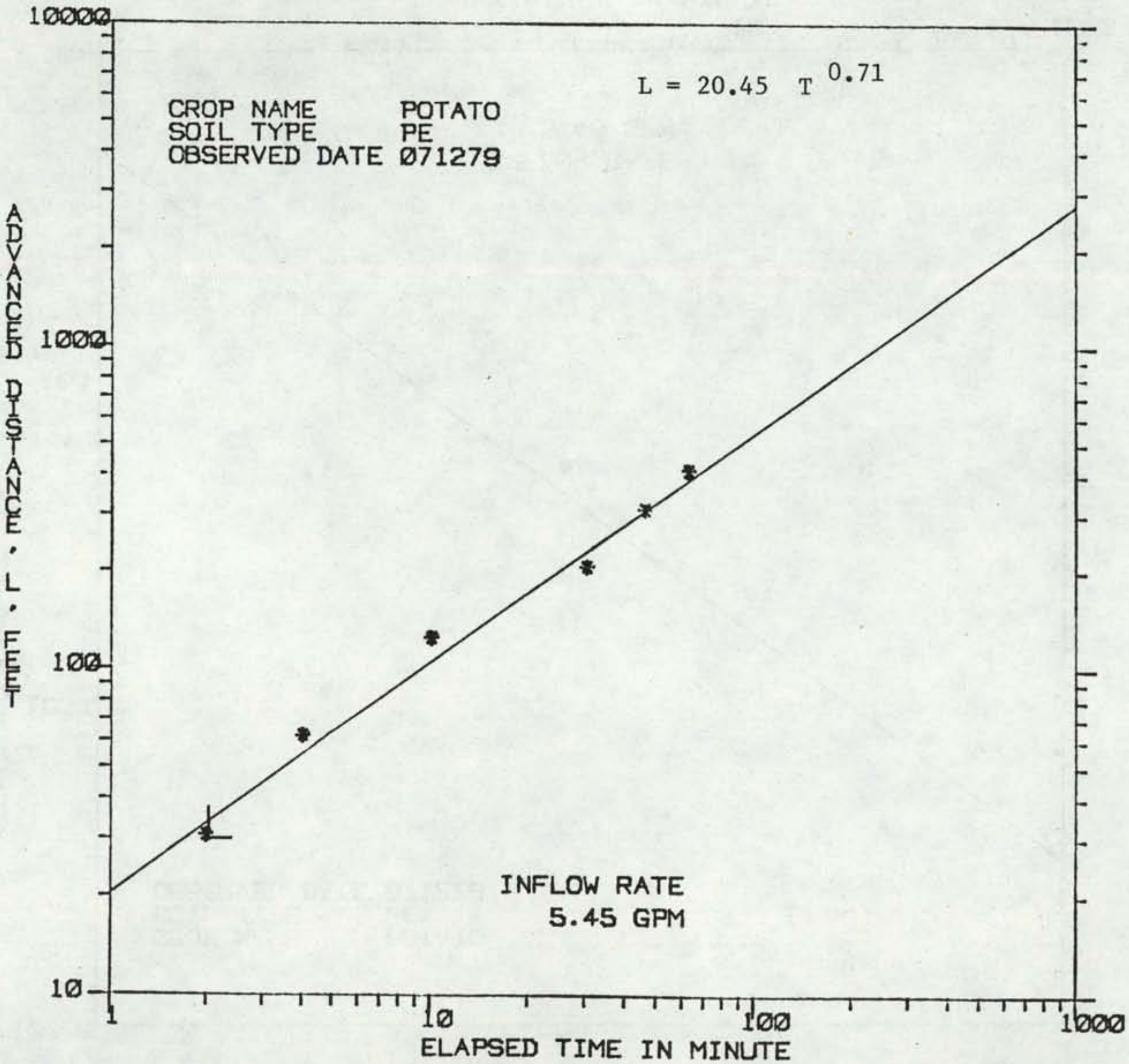

Figure IV-2 (b). Furrow advance relationship for potatoes on Paesl soil.

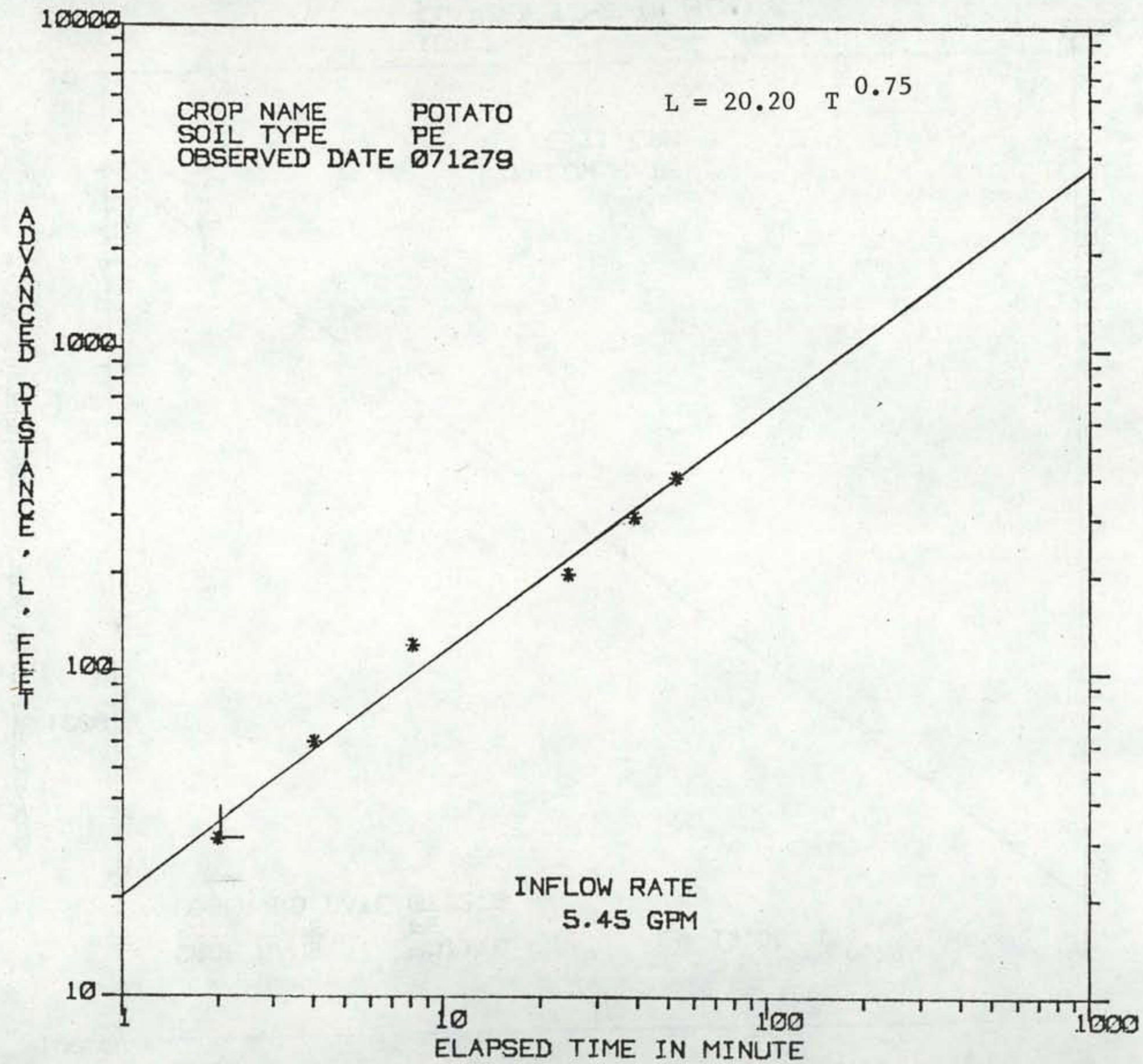

Figure IV-2 (c). Furrow advance relationship for potatoes on Paesl soil.

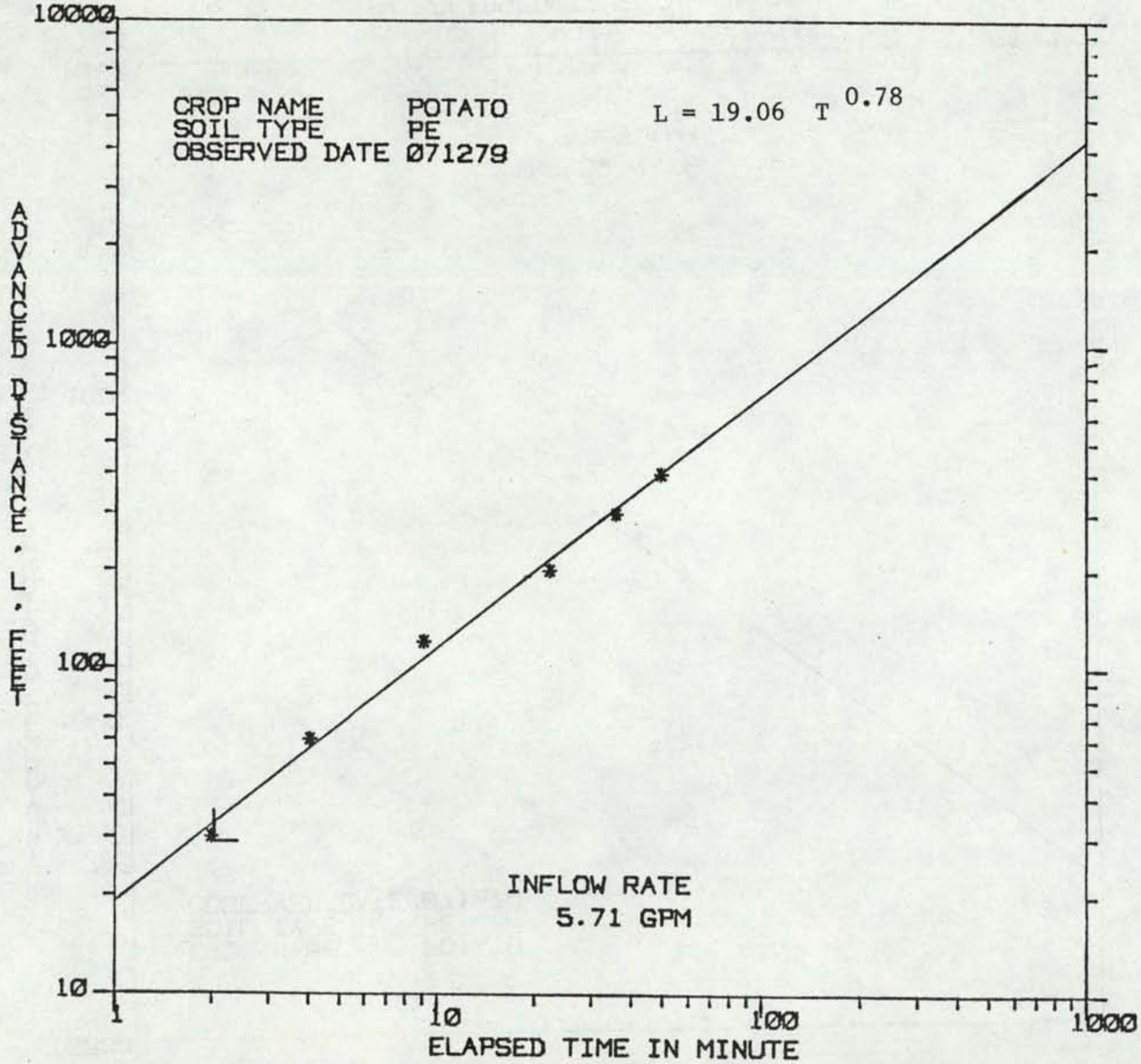

Figure IV-2 (d). Furrow advance relationship for potatoes on Paesl soil.

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16. *Abstract*

Seven major soil series of irrigated agricultural land of southeastern Idaho were evaluated to obtain soil water intake rates. They range in texture from silt loam to gravelly loam. Three crops (hay, grain and potatoes) were selected for this study. Soil survey maps from local Soil Conservation Service were used to locate each soil series of the area. It was difficult to select representative sampling sites in any field. Therefore, it was necessary to test several different sites to obtain average results.

The irrigation practices on two furrow fields were evaluated using the data obtained in this study. The results showed that improved water management practices are needed to obtain higher application efficiencies on both fields. One field had excess irrigation with high runoff loss and the other field had a lack of irrigation with high runoff loss. The irrigators could increase the efficiency by using a cut back stream and/or a return flow recovery system.

17a. *Descriptors*
Soil water intake, water management, runoff loss, return flow recovery

17c. *COWRR Field & Group*
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