ANALYSIS OF DATA FROM A NATURAL ENZOOTIC OF TRICHOSTRONGYLIDOSIS III WEIGHT DATA*

BU-119-M B. M. Rao June, 1960

The purpose of this study is to ascertain the sources of variation in weight data from lambs during the course of a naturally controlled enzootic of Trichostrongylidosis. These data from the 1958 experiment have not yet been published, but the essential conditions were the same as those previously reported [1].

The original data and the linear regression analysis have been presented in the BU-109-M [3]. It was desired to ascertain the size of the quadratic regression of weight on age for the data in BU-109-M.

The tables and graphs pertaining to the quadratic regression are presented and the explanation is given below. For details of the experiment not presented here, reference may be made to the report BU-109-M.

Tables IA to XIIIA contain the data used to find out the sum of squares due to quadratic regression. In all these tables the first column is the number of dates on which the weight of a lamb has been recorded, the second column is the total accumulated days old (X_1), the third column is the square of X_1 (X_2) and the fourth column is the total weight in pounds (Y). The totals are taken over the number of lambs given at the top of the table.

Tables IB to XIIIB are the analysis of variance for the data. The sum of squares due to dates has been divided into three parts, namely, linear regression (ignoring quadratic), quadratic (eliminating linear), and deviations from quadratic regression. The interaction dates x lambs has been divided into dates linear x lambs and residual.

In Table XIV, the range in weight for different dates, the residual mean squares, mean squares for deviations from quadratic regression, and the number of lambs are given to help study the relation between mean deviations from regression and the residual mean squares.

The graph attached shows the relation of the average age to the average weight of the lambs for the six rams [57-22 (Table I), 57-55 (Table III), 603 (Table V), 615 (Table VI), 626 (Table VII), 690 (Table XII)] whose deviations from quadratic are greater by twice or more than the residual.

The procedure adopted to calculate the sums of squares due to quadratic

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is the same as mentioned by Snedecor in his Statistical Methods [2]. First the values of $b_{y_{1\cdot2}}$ and $b_{y_{2\cdot1}}$, the partial regression coefficients, have been found from the two simultaneous equations:

$$\Sigma x_1^2 b_{y_{1\cdot2}} + \Sigma x_1 x_2 b_{y_{2\cdot1}} = \Sigma x_1 y$$

$$\Sigma x_1 x_2 b_{y_{1\cdot2}} + \Sigma x_2^2 b_{y_{2\cdot1}} = \Sigma x_2 y$$

where the small letters x_1, x_2 and y have their usual meaning, namely, the deviations of X_1, X_2 and Y from their respective means. The b's can be got as below:

$$b_{y_{1\cdot2}} = \frac{(\Sigma x_2^2)(\Sigma x_1 y)-(\Sigma x_1 x_2)(\Sigma x_2 y)}{D}$$

$$b_{y_{2\cdot1}} = \frac{(\Sigma x_1^2)(\Sigma x_2 y)-(\Sigma x_1 y)(\Sigma x_1 x_2)}{D}$$

$$\text{where } D = \begin{vmatrix} \Sigma x_1^2 & \Sigma x_1 x_2 \\ \Sigma x_1 x_2 & \Sigma x_2^2 \end{vmatrix} = (\Sigma x_1^2)(\Sigma x_2^2)-(\Sigma x_1 x_2)^2$$

After finding out the b's, the sums of squares due to regression (i.e., due to linear + quadratic) have been calculated from the formula:

$$\Sigma \hat{y}_{12}^2 = b_{y_{1\cdot2}} \Sigma x_1 y + b_{y_{2\cdot1}} \Sigma x_2 y$$

From this combined sums of squares, the sums of squares due to linear [3] has been subtracted to obtain the sums of squares due to quadratic. The sum of squares due to dates minus the sum of squares due to linear regression (ignoring quadratic) and minus the sum of squares due to quadratic (eliminating linear) equals the sum of squares for deviations from quadratic regression.

The quadratic regression looks nice except for 6 rams where the deviations are twice or more to the residual. The six rams are 57-22 (Table I), 57-55 (Table III), 603 (Table V), 615 (Table VI), 626 (Table VII) and 690 (Table XII).* The quadratic also contributes a considerable amount of the sums of squares, though not of the magnitude of linear; a small amount of sums of squares to the

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*The designation, Table I, III, etc., without the suffixes A or B, refers to the two types of tables.

deviations is left. An explanation can be given for the greater deviations in the case of the above six rams as follows. There is a sudden fall in the weight of the lambs of rams 57-55, 603 and 615 on July 25, which is related to physiological and genetical effects. If we observe the table of ranges more information can be had. As the fluctuations in the ranges are more, the deviation mean square is increased. Irregular growth of lambs has contributed to the increase in the deviation mean square. The deviation mean square increases with the irregularity of the growth patterns of the lambs. The weight of the lambs of all the above rams except 615 dropped on June 17. From the graph it is clear that these depressions in the growth of the lambs accounts for the increase in the deviations. A physiological and genetical explanation would suffice for these irregularities in growths. On the average, the quadratic regression does account for a sizeable portion of the dates sum of squares.

Missing values were computed and inserted where necessary. In another analysis five kinds of transformations are being studied. Then some of the present difficulties in interpreting the results may be overcome. An effect of the logarithmic transformation has been reported in [3].

References

[1] J. H. Whitlock. The inheritance of resistance to Trichostrongylidosis in sheep I. The Cornell Veterinarian 47:127-133, 1958.

[2] G. W. Snedecor. Statistical Methods, 5th edition, Iowa State College Press, Ames, Iowa, 1956.

[3] A. W. Douglas, W. T. Federer, and J. H. Whitlock. Analysis of data from a natural enzootic of Trichostrongylidosis I weight data. BU-109-M (July, 1959).

Table IA; Ram: 57-22
Number of Lambs = 25

	Total accumulated days old=X_1	$X_2=X_1^2$	Total weight pounds Y
1	25	625	311.2
2	387	149769	497.9
3	1337	1787569	934.5
4	1362	1855044	933.5
5	1737	3017169	1086.5
6	1937	3751969	1126.5
7	2137	4566769	1175.5
8	2312	5345344	1197.1
9	2337	5461569	1209.6
10	2512	6310144	1250.5
11	2637	6953769	1293.6
12	2762	7628644	1319.6
Total	21482	46828384	12336.0

Table IIA; Ram: 57-26
Number of Lambs = 7

	X_1	X_2	Y
1	7	49	82.9
2	92	8464	125.7
3	358	128164	235.0
4	365	133225	238.0
5	470	220900	275.5
6	526	276676	291.5
7	582	338724	296.5
8	631	398161	301.5
9	638	407044	303.5
10	687	471969	312.0
11			
12			
Total	4356	2383376	2462.1

Table IIIA; Ram: 57-55
Number of Lambs = 8

	X_1	X_2	Y
1	8	64	102.3
2	125	15625	161.8
3	429	184041	284.5
4	437	190969	281.5
5	557	310249	331.5
6	621	385641	343.0
7	685	469225	351.5
8	741	549081	340.0
9	749	561001	344.5
10	805	648025	347.0
11	845	714025	355.0
12	885	783225	364.2
Total	6887	4811171	3606.8

Table IVA; Ram: 57-58
Number of Lambs = 4

	X_1	X_2	Y
1	4	16	49.7
2	51	2601	70.3
3	203	41209	137.5
4	207	42849	137.0
5	267	71289	161.5
6	299	89401	168.0
7	331	109561	171.0
8	359	128881	173.5
9	363	131769	173.0
10	391	152881	180.0
11	411	168921	180.5
12	431	185761	178.0
Total	3317	1125139	1780.0

Table VA; Ram: 603
Number of Lambs = 9

	X_1	X_2	Y
1	9	81	124.5
2	135	18225	192.8
3	477	227529	372.0
4	486	236196	370.0
5	621	385641	426.5
6	693	480249	433.0
7	765	585225	441.5
8	828	685584	421.5
9	837	700569	426.5
10	900	810000	455.9
Total	5751	4129299	3664.2

Table VIA; Ram: 615
Number of Lambs = 5

	X_1	X_2	Y
1	5	25	51.7
2	66	4356	72.5
3	256	65536	160.5
4	261	68121	160.5
5	336	112896	181.0
6	376	141376	179.0
7	416	173056	190.5
8	451	203401	187.5
9	456	207936	194.0
10	491	241081	199.0
Total	3114	1217784	1576.2

Table VIIA; Ram: 626
Number of Lambs = 16

	X_1	X_2	Y
1	16	256	207.8
2	237	56169	328.5
3	845	714025	599.0
4	861	741321	597.0
5	1101	1212201	725.5
6	1229	1510441	748.0
7	1357	1841449	780.0
8	1469	2157961	789.5
9	1485	2205225	798.0
10	1597	2550409	814.5
11	1677	2812329	819.2
12	1757	3087049	837.5
Total	13631	18888835	8044.5

Table VIIIA; Ram: 668
Number of Lambs = 4

	X_1	X_2	Y
	4	16	64.9
	64	4096	102.2
	216	46656	155.5
	220	48400	156.0
	280	78400	185.5
	312	97344	201.0
	344	118336	209.5
	372	138384	216.0
	376	141376	215.5
	404	163216	220.5
	424	179776	224.5
	444	197136	226.5
	3460	1213136	2177.6

Table IXA; Ram: 671
Number of Lambs = 8

	X_1	X_2	Y
	8	64	104.3
	149	22201	176.7
	453	205209	307.5
	461	212521	305.5
	581	337561	351.0
	645	416025	356.0
	709	502681	373.0
	765	585225	385.5
	773	597529	386.5
	829	687241	395.0
	869	755161	407.5
	909	826281	413.8
	7151	5147699	3962.3

Table XA; Ram: 675
Number of Lambs = 5

	X_1	X_2	Y
1	5	25	63.3
2	88	7744	108.2
3	278	77284	193.5
4	283	80089	194.0
5	358	128164	232.5
6	393	158404	240.0
7	438	191844	248.5
8	473	223729	242.5
9	478	228484	244.0
10	513	263169	255.5
11	538	289444	273.9
12	563	316969	265.3
Total	4413	1965349	2561.2

Table XIA; Ram: 676
Number of Lambs = 3

	X_1	X_2	Y
1	3	9	39.2
2	44	1936	58.0
3	158	24964	109.5
4	161	25921	108.5
5	206	42436	126.0
6	230	52900	133.0
7	254	64516	133.0
8	275	75625	139.5
9	278	77284	137.5
10	299	89401	141.0
11	314	98596	137.4
12	329	108241	153.0
Total	2551	661829	1415.6

Table XIIA; Ram: 690
Number of Lambs = 8

	X_1	X_2	Y
1	8	64	95.9
2	131	17161	155.7
3	435	189225	282.0
4	443	196249	279.0
5	563	316969	333.0
6	627	393129	347.0
7	691	477481	360.5
8	747	558009	366.5
9	755	570025	373.5
10	811	657721	386.0
11	851	724201	403.5
12	891	793881	406.5
Total	6953	4894115	3789.1

Table XIIIA; Ram: 743
Number of Lambs = 8

	X_1	X_2	Y
1	8	64	106.6
2	154	23716	187.6
3	458	209764	339.5
4	466	217156	337.0
5	586	343396	384.5
6	650	422500	403.5
7	714	509796	424.0
8	770	592900	430.0
9	778	605284	435.0
10	834	695556	450.5
11	874	763876	466.2
12	914	835396	466.2
Total	7206	5219404	4430.6

Table IB
Ram: 57-22

Analysis of variance of weights (pounds)

Source of variation	df	SS	MS
Dates	11	44560.60	4050.96
D_L=Dates Linear	1	43313.22	43313.22
D_2=Dates Quadratic	1	1178.78	1178.78
Deviations	9	68.60	7.62
Lambs	24	14174.44	590.60
Dates x Lambs	259	2248.36	8.68
D_L x Lambs	24	1839.18	76.63
Residual	235	409.18	1.74
C.F.M.	1	507256.32	
Total (Uncor.)	295	568239.72	

Table IIB
Ram: 57-26

Analysis of variance of weights (pounds)

df	SS	MS
9	8213.07	912.56
1	7932.08	7932.08
1	267.34	267.34
7	13.65	1.95
6	6722.39	1120.40
54	854.34	15.82
6	762.72	127.12
48	91.62	1.91
1	86599.09	
70	102388.89	

Table IIIB
Ram: 57-55

Analysis of variance of weights (pounds)

Dates	11	9649.07	877.19
D_L=Dates Linear	1	8819.53	8819.53
D_2=Dates Quadratic	1	748.16	748.16
Deviations	9	81.38	9.04
Lambs	7	3738.20	534.03
Dates x Lambs	73	756.75	10.37
D_L x Lambs	7	503.20	71.89
Residual	66	253.55	3.84
C.F.M.	1	135510.48	
Total (Uncor.)	92	149654.50	

Table IVB
Ram: 57-58

Analysis of variance of weights (pounds)

11	5324.21	484.02
1	4971.73	4971.73
1	313.53	313.53
9	38.95	4.33
3	331.02	110.34
33	155.24	4.70
3	50.88	16.96
30	104.36	3.48
1	66008.33	
48	71818.80	

Table VB
Ram: 603

Analysis of variance of weights (pounds)

Source of variation	df	SS	MS
Dates	9	13004.75	1444.97
D_L	1	11852.39	11852.39
D_2	1	1014.73	1014.73
Deviation	7	137.63	19.66
Lambs	8	4924.47	615.56
Dates x Lambs	71	1072.57	15.11
D_L x Lambs	8	742.59	92.82
Residual	63	329.98	5.24
G.F.M.	1	149181.80	
Total (Uncor.)	89	168183.58	

Table VIB
Ram: 615

Analysis of variance of weights (pounds)

df	SS	MS
9	4898.90	544.32
1	4570.71	4570.71
1	288.05	288.05
7	40.14	5.73
4	618.58	154.64
36	318.30	8.84
4	228.30	57.08
32	90.00	2.81
1	49688.13	
50	55523.90	

Table VIIB
Ram: 626

Analysis of variance of weights (pounds)

Dates	11	28984.07	2634.92
D_L	1	27806.73	27806.73
D_2	1	1113.57	1113.57
Deviations	9	63.77	7.09
Lambs	15	7465.19	497.68
Dates x Lambs	163	2237.92	13.73
D_L x Lambs	15	1637.16	109.13
Residual	148	600.76	4.06
G.F.M.	1	337051.98	
Total (Uncor.)	190	375739.15	

Table VIIIB
Ram: 668

Analysis of variance of weights (pounds)

11	7532.95	684.81
1	7381.82	7381.82
1	95.89	95.89
9	55.24	6.14
3	316.31	105.44
33	479.49	14.53
3	200.84	66.95
30	278.65	9.29
1	98790.45	
48	107119.20	

Table IXB
Ram: 671

Analysis of variance of weights (pounds)

Source of variation	df	SS	MS
Dates	11	12754.95	1159.54
D_L	1	12314.61	12314.61
D_2	1	422.23	422.23
Deviations	9	18.11	2.01
Lambs	7	3298.93	471.28
Dates x Lambs	74	520.73	7.04
D_L x Lambs	7	394.82	56.40
Residual	67	125.91	1.88
C.F.M.	1	163539.81	
Total (Uncor.)	93	180114.41	

Table XB
Ram: 675

Analysis of variance of weights (pounds)

df	SS	MS
11	9316.65	846.97
1	8889.65	8889.65
1	328.06	328.06
9	98.94	10.99
4	1928.68	482.17
40	429.86	10.75
4	136.30	34.08
36	293.56	8.15
1	109329.09	
56	121004.28	

Table XIB
Ram: 676

Analysis of variance of weights (pounds)

Source of variation	df	SS	MS
Dates	11	4486.26	407.84
D_L	1	4254.98	4254.98
D_2	1	185.54	185.54
Deviations	9	45.74	5.08
Lambs	2	4136.42	2068.21
Dates x Lambs	21	460.42	21.92
D_L x Lambs	2	351.08	175.54
Residual	19	109.34	5.75
C.F.M.	1	55664.54	
Total (Uncor.)	35	64747.64	

Table XIIB
Ram: 690

Analysis of variance of weights (pounds)

df	SS	MS
11	13312.21	1210.20
1	13042.73	13042.73
1	238.89	238.89
9	30.59	3.40
7	3153.20	450.46
77	296.22	3.85
7	176.15	25.16
70	120.07	1.72
1	149554.99	
96	166316.61	

Table XIIIB

Ram: 743

Analysis of variance of weights (pounds)

Source of variation	df	SS	MS
Dates	11	17715.48	1610.50
D_L	1	17245.24	17245.24
D_2	1	453.44	453.44
Deviations	9	16.80	1.87
Lambs	7	1922.19	274.60
Dates x Lambs	75	409.67	5.46
D_L x Lambs	7	215.97	30.85
Residual	68	193.70	2.85
C.F.M.	1	204481.42	
Total (Uncor.)	94	224528.76	

Table XIV: Ranges, residual mean squares, deviations from quadratic regression, and number of lambs for the data of Tables 1 to 13.

Table No.	Range in weight											Mean square		No. of lambs
	5/9	6/16	6/17	7/2	7/10	7/18	7/25	7/26	8/2	8/7	8/12	Residual	Deviation from regression	
1	18.2	24.0	25.5	26.0	28.5	32.5	34.0	33.5	31.5	34.5	37.5	1.74	7.62	25
2	14.1	26.5	25.5	29.5	32.5	36.0	35.0	34.5	37.0	-	-	1.91	1.95	7
3	6.3	18.0	18.5	17.5	24.5	26.0	25.0	26.5	30.0	31.5	30.0	3.84	9.04	8
4	4.5	9.0	8.0	12.0	11.5	10.5	8.5	7.0	6.5	6.0	7.0	3.48	4.33	4
5	12.2	20.0	20.0	27.5	27.5	34.0	41.5	41.5	31.0	-	-	5.24	19.66	9
6	9.8	9.0	8.5	7.0	13.5	16.0	15.0	13.0	17.5	-	-	2.81	5.73	5
7	14.4	17.5	17.0	19.0	20.5	23.0	29.5	29.0	29.5	31.5	33.5	4.06	7.09	16
8	16.1	13.0	10.0	14.0	8.5	6.5	6.0	7.0	10.0	11.5	10.5	9.29	6.14	4
9	12.0	21.0	21.0	21.0	20.0	22.0	22.0	21.5	25.0	27.0	28.5	1.88	2.01	8
10	9.3	22.0	21.0	24.0	19.5	18.0	13.5	13.0	20.5	21.1	22.5	8.15	10.99	5
11	9.1	23.5	25.5	25.5	26.5	30.0	32.0	32.5	31.0	25.4	36.0	5.75	5.08	3
12	11.8	15.0	15.5	19.5	19.0	19.0	18.5	20.0	20.0	21.5	21.5	1.72	3.40	8
13	12.7	14.5	14.0	15.0	18.0	17.5	19.0	17.0	20.0	16.8	17.8	2.85	1.87	8
												3.29 = wt'd aver.	6.39 = wt'd aver.	

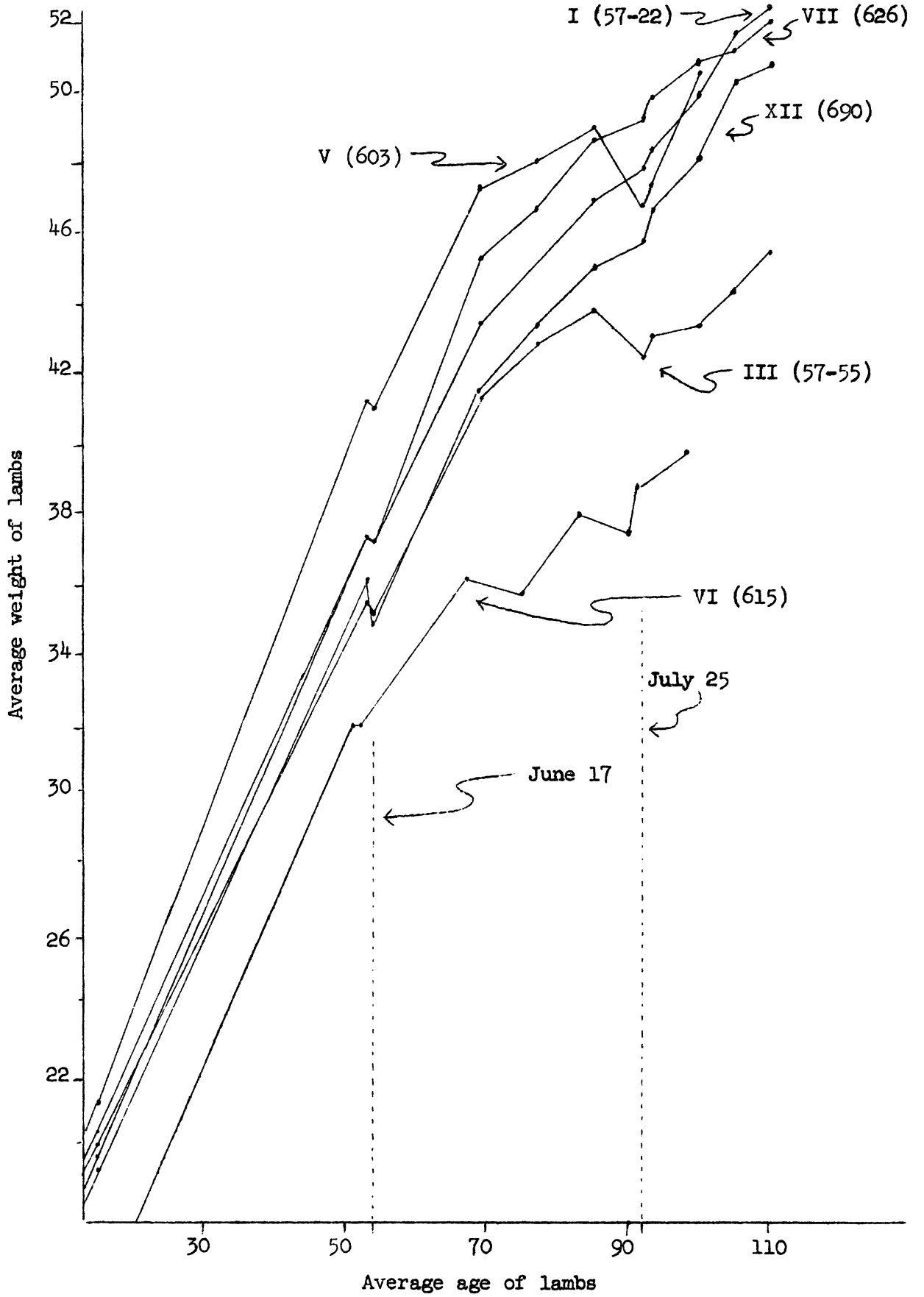

Figure 1. Weight of lambs versus average age of lambs for six rams