GROWTH RATE OF THOROUGHBREDS. EFFECT OF AGE OF DAM, YEAR AND MONTH OF BIRTH, AND SEX OF FOAL

R. L. Hintz
Oklahoma State University, Stillwater

H. F. Hintz
Cornell University

L. Dale Van Vleck
University of Nebraska-Lincoln, dvan-vleck1@unl.edu

GROWTH RATE OF THOROUGHBREDS. EFFECT OF AGE OF DAM, YEAR AND MONTH OF BIRTH, AND SEX OF FOAL

H. F. Hintz[1], R. L. Hintz[2] and L. D. Van Vleck[1]

Cornell University, Ithaca, NY 14853

SUMMARY

Weight, height, and cannon bone measurements were obtained on 1,992 Thoroughbred foals. Colts were heavier than fillies at birth and the differences increased with age. Dams under 7 years of age and older than 11 years had foals of lighter weight at birth than mares 7 to 11 years of age and the differences persisted at 510 days of age. Foals born in April, May, or June were heavier than foals born in January, February, or March. Year of birth also influenced body weight. The trends for height at withers and cannon circumference were similar to those of body weight.

(Key Words: Growth, Horses, Thoroughbreds.)

INTRODUCTION

Few studies are available in which the growth rates of a large number of horses have been examined. For example, growth curves are presented in the NRC (1973) publication on horse nutrition but with the apology, "The curves are presented as examples rather than as models because they are based on limited data." Furthermore, the effects of many factors on growth rate have not been determined. Therefore, analysis of the data collected by Windfields Farm[3] was made to estimate growth rates of Thoroughbreds and to examine the effects of age of dam, sex of foal, and month and year of birth on measurements of growth.

MATERIALS AND METHODS

Every foal at Windfields Farm is weighed and height at withers and front cannon bone circumference at the midpoint is measured on about the 15th of each month. A total of 19,883 records on 1,992 foals out of 813 dams and by 365 sires was collected from January 1958 to June 1976. The records were classified into 47 age groups (table 1). The 47 age groups were divided arbitrarily into nine sections for the estimation of variances which were then assumed to be homogeneous for all ages within a section of the data.

The following linear model was assumed for each growth measurement (weight, height, and front cannon bone circumference):

$$Y = X\beta + Zu + e$$

where Y is the vector of records; β is a vector of sex of foal effects, age of dam effects, month-year of birth of foal effects, age group effects and population mean; X is a known design matrix; u is a vector of one-half the additive genetic effects of the sires having a multivariate distribution with mean zero and nonsingular variance-covariance matrix G; Z is a known design matrix; e is a vector of residual effects including environmental and other genetic effects having a multivariate distribution with mean zero and variance-covariance matrix R; and u and e are mutually uncorrelated.

For the class of linear models assumed, the solutions to the equations:

$$\begin{bmatrix} X'R^{-1}X & X'R^{-1}Z \\ Z'R^{-1}X & Z'R^{-1}Z+G^{-1} \end{bmatrix} \begin{bmatrix} \hat{\beta} \\ \hat{u} \end{bmatrix} = \begin{bmatrix} X'R^{-1}y \\ Z'R^{-1}y \end{bmatrix}$$

namely, β and u are generalized least squares (GLS) solutions of functions of the fixed effects (Henderson *et al.*, 1959, 1973) and best linear unbiased prediction (BLUP) of the random effects (Henderson, 1963, 1973), respectively.

For this investigation, the vector u was expanded to include one-half the additive genetic effects of all 4,214 animals which

[1] Department of Animal Science.

[2] Present address: Department of Animal Science, Oklahoma State University, Stillwater.

[3] The cooperation of Windfields Farms, Oshawa, Ontario, Can. in supplying the data is greatly appreciated.

TABLE 1. ESTIMATES OF GROWTH MEASUREMENTS OF FOALS ADJUSTED TO THE BASIS OF 8-YEAR-OLD MARES THAT FOALED IN MARCH OF 1958

Age of foals	Weight		Height		Cannon bone	
	Colts	Fillies	Colts	Fillies	Colts	Fillies
days	— kg —		—— cm ——			
2	55	54	100.6	100.1	12.5	12.3
7	63	62	102.3	101.9	12.6	12.4
12	71	71	104.6	104.1	12.9	12.7
17	79	79	106.5	106.1	13.0	12.9
22	86	85	107.8	107.4	13.3	13.1
27	91	90	109.2	108.8	13.4	13.2
32	98	97	110.8	110.4	13.7	13.4
37	103	102	112.0	111.6	13.8	13.6
42	110	109	113.3	112.9	14.0	13.8
47	121	120	116.0	115.7	14.2	13.9
52	128	127	117.6	117.3	14.5	14.3
57	132	131	118.5	118.2	14.6	14.4
62	137	135	119.6	119.3	14.8	14.5
67	144	143	120.6	120.3	15.0	14.7
72	148	147	120.9	120.6	15.0	14.7
77	154	153	122.1	121.8	15.3	15.0
82	162	160	123.4	123.1	15.4	15.2
87	165	163	124.4	124.0	15.5	15.2
97	170	166	125.2	124.4	15.5	15.2
112	185	182	127.2	126.4	15.8	15.5
127	195	192	128.9	128.0	15.8	15.5
142	207	204	130.3	129.4	15.9	15.6
157	221	212	131.6	130.3	16.5	16.1
172	235	227	133.4	132.0	16.6	16.2
187	245	236	134.6	133.2	16.8	16.4
202	258	250	135.8	134.5	16.9	16.5
217	270	260	137.1	135.7	18.1	17.7
232	283	272	138.5	137.1	18.3	17.9
247	297	280	139.5	138.1	18.4	18.0
262	301	290	140.7	139.3	18.5	18.1
277	310	296	141.8	140.4	18.6	18.1
292	318	304	142.6	141.3	18.8	18.3
307	325	311	143.6	142.2	18.9	18.4
322	334	320	144.4	143.1	19.0	18.5
337	336	320	145.1	143.4	19.2	18.6
352	345	329	145.9	144.2	19.4	18.9
374	359	343	147.2	145.5	19.6	19.1
404	373	355	148.8	146.8	20.1	19.5
434	392	375	150.2	148.3	20.4	19.9
464	415	392	151.8	149.8	20.7	20.1
494	428	406	152.8	150.7	20.9	20.3
524	440	417	153.8	151.7	21.0	20.4
554	446	424	154.5	152.4	21.2	20.6
584	454	432	155.4	153.3	21.3	20.7
614	461	439	156.1	154.0	21.3	20.7
644	470	448	156.5	154.5	21.4	20.8
674	482	459	156.0	154.9	21.4	20.8

include the foals, dams of the foals, sires of the foals, granddams of the foals, and grandsires of the foals. The variance-covariance matrix, G, is defined to be $A\frac{1}{4}h^2\sigma_y^2$, where A is the numerator relationship matrix of all animals with order 4,214; h^2 is heritability; and σ_y^2 is the total variance of records. Estimates of heritability obtained by Hintz *et al.* (1978) were used. It was assumed that $R = I\sigma_e^2 = I(1-\frac{1}{4}h^2)\sigma_y^2$, where I is an identity matrix with order equal to the number of records which implies that the e's are uncorrelated and that all records have common variance, σ_e^2. The assumption of a common variance may not be appropriate but is convenient from a computing standpoint, and any deviation from equality of variance was not considered an important source of error. The equations now become:

$$\begin{bmatrix} X'X & X'Z \\ Z'X & Z'Z+A^{-1}\frac{4-h^2}{h^2} \end{bmatrix} \begin{bmatrix} \beta \\ u \end{bmatrix} = \begin{bmatrix} X'y \\ Z'y \end{bmatrix}$$

The inverse of A is easily obtained using the rapid procedure developed by Henderson (1975).

An iterative solution was obtained since a direct solution to the full set of equations is impossible because of the large number of equations. Estimable functions of interest to this investigation were the differences between levels of the fixed effects such as the difference between the effects of two ages of dam. The inverse of the coefficient matrix needed for computing variances of estimable functions was not obtained since the equations were solved iteratively. However, approximate variances of differences were estimated using the following equation:

Estimated variance of differences

$$\left[\frac{1}{n_1} + \frac{1}{n_2}\right] (TSS-RED)/(N-S)$$

where n_1 and n_2 are the number of observations containing the levels of the fixed effects involved in the difference; TSS is the total sum of squares; RED is the reduction in sum of squares due to fitting the complete model; N is the total number of observations; and S is the rank of X. Approximate *t* statistics with N–S degrees of freedom were calculated by dividing the estimated difference by the square root of the approximate variance of the difference.

Correlations between measurements at 0, 4, 6 and 12 months were determined on 62 foals which were measured at the appropriate times.

RESULTS

Point estimates of growth for the 47 periods adjusted to the basis of mares 8 years of age and foaling in March of 1958 are shown in table 1. Differences between colts and fillies for nine periods are summarized in table 2. The colts were heavier (P<.05), taller (P<.05), and had bigger bones (P<.01) than fillies during the first period and the size of the difference increased with time. The effects of age of dam on the growth measurements for nine periods are shown in table 3. Dams younger than 7 years of age had lighter (P<.01) and shorter (P<.01) foals with smaller cannon bones (P<.05) than mares 7 to 11 years of age during the time period and the differences persisted at 510 days. Some of the measurements of foals of dams over 12 years of age were significantly different from those of foals with dams 8 years of age. Year of birth affected measurements of growth but no pattern was recognized (table 4). The percentage of foals born in various months were: January 1.5, February 7.3, March 22.8, April 31.4, May 30.3 and June 6.6.

Foals born in January, February, or March were lighter (P<.01), shorter (P<.01), and had a smaller cannon bone than foals born in April, May, or June (table 5). The differences between the foals born during the first three months and those born in April, May, and June persisted throughout all ages studied.

Discussion

Green (1969, 1976) measured cannon bone circumference and height of withers but not weight of Thoroughbred foals in England. The measurements he reported were similar to those shown in table 1 for the younger ages but were slightly smaller for horses over 18 months of age. Mature weights of the horses in this study were not available. Furthermore, mature weight can be easily influenced by level of feed intake. However, if the average mature weight of Thoroughbred stallions is assumed to be 545 kg and that of Thoroughbred mares assumed to be 500 kg (Willoughby, 1975), then the foals in this study attained about 46, 67 and 80% of mature weight at 6, 12 and 18 months, respectively. Cunningham and Fowler (1961) reported that Quarter Horses attained 44, 63 and 79% of their mature weight at 6, 12 and 18 months. Reed and Dunn (1977) reported that Arabian horses attained 46, 66 and 80% of their mature weight at 6, 12 and 18 months. Half Arabs and Anglo-Arabs had values of 45, 67 and 81% of mature weight (Budzynski *et al.*, 1971). The uniformity of these results for several different breeds of horses suggest that these values might be used as reasonable guides for rate of development for most light horse breeds. Ponies would probably reach mature weight sooner. Jordan (1977) suggested that ponies with a mature weight of 180 kg might be expected to attain 55, 75 and 84% of mature weight at 6, 12 and 18 months, respectively. Large draft horses apparently reach mature weights later than light horses. Trowbridge and Chittenden (1932) reported that Percherons attained 38, 55 and 73% of mature weight at 6, 12 and 18 months, respectively. Harper (1921) reported values of 34, 52 and 69% for draft horses.

If the mature height at withers for the Thoroughbred was assumed to be 162 cm for stallions and 160 cm for mares (Willoughby, 1975), then the Thoroughbred foals attained 83, 90 and 95% of mature height at 6, 12 and 18 months, respectively. Reed and Dunn (1977) reported that Quarter Horses attained 84, 91 and 95% of mature height at 6, 12 and 18 months and Half-Arabs and Anglo-Arabs reached 83, 92 and 95% of height at those times (Budzynski *et al.*, 1971). Heird (1973) reported values of 90, 93 and 99% for Quarter Horses. With the exception of Heird's data, the values are remarkably uniform.

The data in table 1 demonstrate that the early growth of foals is quite rapid. The foals gained 110 kg during the first 90 days after birth, 75 kg during the second 90 days, 60 kg

TABLE 2. DIFFERENCES BETWEEN COLTS AND FILLIES BY NINE AGE PERIODS

Avg age of foals	No. of colts	No. of fillies	Weight colts minus fillies	Height colts minus fillies	Cannon bone colts minus fillies
days			kg	— cm —	
22	1004	941	1.1*	.4*	.2**
66	884	818	1.3*	.3	.3**
118	1067	1013	3.3**	.8**	.3**
178	1086	1078	8.3**	1.3**	.4**
239	1125	1101	10.9**	1.4**	.4**
299	1170	1131	14.1**	1.4**	.5**
358	1108	1070	15.9**	1.7**	.5**
419	1012	1016	17.3**	2.0**	.5**
510	1639	1570	22.6**	2.1**	.6**

*P<.05.
**P<.01.

TABLE 3. AGE OF DAM EFFECT (DIFFERENCES FROM 8-YEAR-OLD DAMS)

Age of dam	No. of foals	Weight	Height	Cannon bone
		kg	—— cm ——	
		22-day-old foals		
3	26	-8.5**	-3.1**	-.4**
4	115	-6.4**	-2.8**	-.3**
5	207	-4.3**	-2.0**	-.2**
6	262	-2.7**	-1.3**	-.2*
7	233	-.6	-.2	-.1
8	207	0	0	0
9	180	1.2	0	-.1
10	143	1.4	.3	0
11	115	1.8	.3	0
12	102	3.1**	1.5**	.2*
13	94	1.5	.8	.2**
14	63	2.9*	.5	.2*
15	58	3.8**	1.3*	.1
16	48	1.7	1.2*	.1
17	25	1.7	.9	.2
18	24	.4	.5	0
19	18	1.3	-1.1	-.1
20	25	-1.6	-1.6*	-.2
		66-day-old foals		
3	22	-9.7**	-2.8**	-.2
4	86	-11.7**	-3.1**	-.4**
5	161	-5.7**	-1.8**	-.2**
6	234	-3.0*	-.9**	0
7	242	-.8	0	-.1
8	199	0	0	0
9	160	1.6	.4	0
10	119	1.8	.2	-.1
11	95	2.1	.6	0
12	77	6.9**	1.6**	.1
13	72	4.9**	.7	0
14	55	3.0	.6	0
15	49	4.1*	1.2*	0
16	43	.7	1.4**	.1
17	29	2.9	.1	0
18	22	-1.7	.4	-.2
19	13	-.6	-1.22	-.2
20	24	-4.0	-.8	-.2
		118-day-old foals		
3	28	-10.9**	-1.7**	-.1
4	146	-13.0**	-2.6**	-.3**
5	216	-8.0**	-1.4**	-.2**
6	295	-4.4**	-.7**	-.1
7	271	-1.6	.2	-.1
8	224	0	0	0
9	175	.6	.9**	-.1
10	146	3.1	.6	-.1
11	130	2.4	.5	.1
12	90	5.3**	1.6**	.1
13	97	3.6	1.0*	.1
14	69	2.9	.2	0
15	57	1.2	0	-.1
16	40	-2.6	.9	-.2
17	28	-3.4	.5	.1
18	23	-6.8	.3	-.2
19	19	-7.4*	-1.5	-.3
20	26	-5.7	-1.6*	-.4
		178-day-old foals		
3	30	-7.6*	-1.9**	-.1
4	149	-14.4**	-2.5**	-.3**
5	246	-7.5**	-1.3**	-.1
6	309	-4.6**	-1.2**	0
7	283	-2.9	-.4	-.1
8	205	0	0	0
9	206	.3	.2	.1
10	144	4.6	.6	.1
11	131	2.9	0	0
12	84	4.1	1.2**	0
13	105	6.0**	.9*	.1
14	73	2.4	0	.2*
15	62	-2.9	-.3	0
16	38	-4.0	.5	-.1
17	32	-1.4	.3	.1
18	19	-6.6	-.1	-.1
19	23	-3.8	-.2	0
20	25	-6.2	-1.3*	-.1
		284-day-old foals		
3	32	-9.3**	-2.1**	0
4	143	-16.7**	-2.9**	-.3**
5	250	-9.7**	-1.9**	-.3**
6	317	-5.3**	-1.2**	.1*
7	282	-5.5**	-.5	-.1
8	218	0	0	0
9	200	-1.2	.1	-.1
10	158	.8	0	0
11	125	-.3	.1	0
12	97	2.2	.5	-.2*
13	112	1.1	.6	-.1
14	80	-.8	-.5	.1
15	67	-6.6**	-.5	-.1
16	40	-7.9*	.3	-.1
17	30	1.3	.6	-.4**
18	26	-7.9*	-.2	-.2
19	25	-10.5**	-1.5*	-.5**
20	24	-10.7**	-2.0**	-.2
		299-day-old foals		
3	30	-5.4	-1.4*	.1
4	158	-14.8**	-2.9**	-.2**
5	283	-7.3**	-1.6**	-.2**
6	321	-3.7*	-1.2**	-.1
7	296	-2.6	-.4	0
8	230	0	0	0
9	208	.1	.1	0
10	163	.9	0	0
11	129	-.3	-.1	0
12	91	3.3	.4	0
13	106	2.1	.6	-.1
14	81	-.1	-.1	.2
15	61	-6.5*	-.5	-.1
16	45	-6.8*	.2	-.1
17	27	6.5	.8	0
18	26	-3.6	-.6	-.1
19	26	-9.9**	-1.5*	-.4**
20	20	-13.0**	-1.8*	-.5**

(TABLE 3 continued on following page.)

		358-day-old foals		
3	30	-.6	-.9	.1
4	144	-14.1**	-2.5**	-.2**
5	260	-4.7*	-1.5**	-.1
6	314	-3.0	-1.1**	-.1
7	287	-2.5	-.5*	-.1
8	220	0	0	0
9	197	2.4	.4	0
10	163	1.7	.1	.1
11	124	.1	-.2	0
12	92	5.1	.6	0
13	91	2.9	.4	.1
14	74	-.4	-.4	0
15	57	-6.3*	-.3	0
16	36	-7.4	.7	-.2
17	24	11.0*	1.4*	0
18	24	-6.1	.2	-.2
19	20	-6.8	-1.3	-.2
20	21	-10.9*	-1.3*	-.3
		419-day-old foals		
3	27	5.3	-.7	.4**
4	138	-14.0**	-2.1**	-.3**
5	253	-4.4*	-1.1**	0
6	288	-.2	-.5	0
7	260	-2.1	-.2	-.1
8	201	0	0	0
9	165	4.2	.3	.1
10	142	.1	.1	-.1
11	112	-.1	-.3	-.1
12	89	3.4	.7	.1
13	82	0	.2	.1
14	75	-4.3	-.1	0
15	63	-.8	.2	0
16	39	-7.6	.7	-.1
17	25	11.3*	1.4*	.1
18	28	-6.8	-.9	-.3
19	21	-12.8*	-1.6*	-.4*
20	20	-9.2	-1.4	-.3
		510-day-old foals		
3	37	-2.0	-1.3*	-.1
4	216	-18.5**	-2.6**	-.3**
5	399	-8.9**	-1.3**	-.2**
6	438	-4.9**	-1.0**	-.1**
7	422	-5.3**	-.3	-.1*
8	319	0	0	0
9	285	-3.6	0	-.1*
10	237	.9	.3	-.1
11	161	3.0	.4	0
12	153	-.7	.4	-.1
13	137	-6.2*	.3	0
14	117	-7.1**	-.3	-.2*
15	80	-5.1	-.1	-.1
16	58	-.9	1.0*	-.2*
17	33	8.7	.1	-.2
18	37	-5.0	.1	-.1
19	41	-14.7**	-1.5**	-.3**
20	39	-18.3**	-2.7**	-.5**

* P<.05.
**P< 01.

TABLE 4. EFFECT OF YEAR OF BIRTH (DIFFERENCES FROM YEAR 1958)

Year of birth	No. of foals	Weight	Height	Cannon bone
		kg	cm	cm
		22-day-old foals		
1958	54	0	0	0
1959	77	-2.1	-.8	-.1
1960	53	-2.0	-1.0	-.3
1961	78	1.6	.8	.4**
1962	56	-1.3	1.1	.7**
1963	54	-2.6	.3	.2
1964	43	-3.7	-1.3	.6**
1965	17	.2	.4	.5**
1966	43	.5	.9	.9**
1967	158	-3.8*	.2	.2*
1968	90	-3.8*	.2	.4**
1969	92	-2.2	.4	.5**
1970	138	-2.3	1.5*	1.0**
1971	149	-3.7*	-1.3*	.2
1972	163	-.5	.8	0
1973	168	-4.1**	-.1	.2*
1974	179	-5.3**	-.6	.4**
1975	184	-3.7**	0	.3**
1976	149	-3.6*	.6	.1
		66-day-old foals		
1958	76	0	0	0
1959	76	-2.5	-1.4**	0
1960	24	-2.8	-2.1**	-.5**
1961	81	3.3	.9	.9**
1962	29	.8	1.5*	1.3**
1963	70	.2	-.4	.7**
1964	25	4.6	.8	1.0**
1965	47	-4.0	-.7	.7**
1966	47	-.6	1.0	.4*
1967	138	-2.3	0	1.0**
1968	94	3.0	.7	.3**
1969	110	2.1	0	.8**
1970	142	-.7	1.2*	2.0**
1971	117	-3.2	-1.4**	-.1
1972	143	-.8	.3	-.5**
1973	132	.1	.1	.8**
1974	140	-3.9	-.9*	.2
1975	132	-1.3	.5	.2
1976	79	-4.0	.9	.2
		118-day-old foals		
1958	93	0	0	0
1959	106	1.4	-1.2**	.2
1960	3	-15.4	-2.2	-.9
1961	87	12.6**	1.3**	1.1**
1962	3	10.9	.2	-.2
1963	93	9.1**	.4	1.1**
1964	73	2.4	1.1*	1.0**
1965	132	7.0**	.7	.9**
1966	130	5.1*	.1	.6**
1967	148	2.4	-.2	.9**
1968	128	7.9**	1.0*	.2
1969	136	8.7**	.8	1.1**
1970	155	6.2**	1.0*	1.9**
1971	144	2.4	-.8	-.1
1972	150	5.1*	.4	-.7**
1973	163	2.8	-.1	1.0**

(TABLE 4 continued from preceding page.)

1974	163	.9	.1	.3**
1975	155	4.8*	.5	.3**
1976	18	-4.9	-1.2	-.1
		178-day-old foals		
1958	92	0	0	0
1959	101	-1.3	-1.2**	-.1
1960	47	7.2*	-.9	.1
1961	112	14.8**	1.5**	.1
1962	37	9.0**	.8	-.3*
1963	77	5.6*	1.7**	.1
1964	112	4.1	1.6**	-.3**
1965	160	8.7**	1.6**	.1
1966	148	-.5	.2	-.1
1967	122	3.2	.4	-.1
1968	136	8.7**	1.5**	-.3**
1969	92	4.6	1.5**	.4**
1970	151	2.9	.2	0
1971	144	.6	-.2	-.5
1972	148	3.1	1.4**	-.7**
1973	161	-2.0	.4	.3**
1974	171	-1.9	1.3**	-.5**
1975	153	-1.7	.5	-.7**
1976	0	0	0	0
		239-day-old foals		
1958	96	0	0	0
1959	91	-1.4	-1.2**	-.2*
1960	120	5.3*	.2	-.4**
1961	114	10.5**	.6	-.7**
1962	108	6.5*	.8	-.8**
1963	125	3.9	.2	-1.0**
1964	117	5.1*	.9*	-1.3**
1965	146	8.4**	.9*	-1.0**
1966	137	.8	-.3	-1.2**
1967	103	4.7	.2	-.9**
1968	141	6.9**	.2	-.7**
1969	51	-2.7	1.0*	-.5**
1970	139	4.2	.2	-.7**
1971	137	3.8	.7	-.7**
1972	130	-1.9	.4	-.9**
1973	153	-1.4	.8*	-.4**
1974	163	.8	1.7**	-1.0**
1975	155	1.6	1.5**	-1.4**
		299-day-old foals		
1958	119	0	0	0
1959	65	.5	-.7	-.4**
1960	133	6.6**	.7*	-1.0**
1961	112	12.9**	1.2**	-.4**
1962	103	6.1*	.3	-1.3**
1963	132	5.8*	.3	-1.3**
1964	121	7.3**	1.2**	-1.5**
1965	128	7.6**	0	-1.1**
1966	147	6.3**	.6	-1.4**
1967	178	6.6**	.4	-1.1**
1968	141	7.7**	.7*	-.8**
1969	105	.1	-.3	-.7**
1970	120	6.0*	.1	-.9**
1971	130	4.8*	.6	-.8*
1972	123	-4.3	0	-1.0**
1973	144	-3.5	.2	-1.0**
1974	153	7.5**	2.6**	-1.0**
1975	147	10.1**	2.3**	-1.4**
		358-day-old foals		
1958	128	0	0	0
1959	54	-1.0	-.4	-.4**
1960	90	4.7	1.4	-.9**
1961	102	12.9**	1.4**	-.4**
1962	92	8.9**	.5	-1.4**
1963	120	5.2	.9	-1.5**
1964	111	7.8**	1.8**	-1.5**
1965	122	12.6**	.6	-1.2**
1966	136	4.7	1.3**	-1.5**
1967	160	8.6**	1.4**	-1.1**
1968	144	11.5**	1.5**	-.9**
1969	129	8.5**	.8*	-.7**
1970	120	3.9	.1	-1.1**
1971	131	-1.3	.2	-1.0**
1972	127	-6.2*	-.6	-1.2**
1973	120	-4.2	1.2**	-1.1**
1974	143	10.5**	2.5**	-.9**
1975	149	13.4**	1.3**	-1.2**
		419-day-old foals		
1958	122	0	0	0
1959	65	3.8	.2	-.1
1960	45	3.7	.9	-1.1**
1961	97	18.9**	1.2**	-.6**
1962	89	9.8**	.1	-1.1**
1963	112	14.3**	1.4**	-1.5**
1964	101	9.3**	1.0*	-1.6**
1965	83	5.3	-.1	-1.1**
1966	118	4.7	1.0	-1.5**
1967	189	6.1*	1.1**	-1.3**
1968	141	15.0**	1.6**	-.8**
1969	125	10.6**	1.0*	-.7**
1970	133	5.5	0	-1.1**
1971	125	-7.5*	-.7	-1.2**
1972	125	-4.2	-.9*	-1.2**
1973	118	-1.0	1.0*	-1.1**
1974	143	12.4**	2.2**	-.7**
1975	97	11.3**	.8	-1.2**
		510-day-old foals		
1958	224	0	0	0
1959	81	3.3	.4	0
1960	173	16.6**	1.0**	-.9**
1961	160	24.2**	1.5**	-.7**
1962	130	13.5**	.4	-.9**
1963	179	12.2**	.9**	-1.3**
1964	210	8.4**	1.6**	-1.4**
1965	104	10.0**	.2	-1.2**
1966	141	7.7**	.7*	-1.2**
1967	208	14.7**	1.3**	-1.0**
1968	154	20.1**	1.8**	-.3**
1969	142	8.3**	.9**	-.2**
1970	254	4.8*	.3	-.8**
1971	197	1.1	.2	-.9**
1972	289	2.8	.6*	-.9**
1973	268	2.9	1.4**	-.8**
1974	274	17.6**	2.2**	-.7**
1975	21	16.5**	2.6**	-.7**

* $P<.05$.
**$P<.01$.

TABLE 5. EFFECT OF MONTH OF BIRTH (DIFFERENCES FROM PERIOD I)[a]

Month of birth	No. of foals	Weight	Height	Cannon bone
		kg	—— cm	——
		22-day-old foals		
I[a]	573	0	0	0
II[b]	588	2.4**	1.8**	.2**
III[c]	784	5.6**	1.9**	.3**
		66-day-old foals		
I	546	0	0	0
II	519	4.0**	1.5**	.3**
III	637	5.5**	1.6**	.5**
		118-day-old foals		
I	613	0	0	0
II	633	2.2*	.5**	.3**
III	834	3.6**	.3	.1**
		178-day-old foals		
I	654	0	0	0
II	650	2.4**	.2	-.3**
III	860	3.7**	.2	.6**
		239-day-old foals		
I	681	0	0	0
II	674	2.0*	.6**	-.3**
III	871	.5	.4**	-.5**
		299-day-old foals		
I	673	0	0	0
II	736	.7	.7**	-.1**
III	892	-.1	.9**	-.1**
		358-day-old foals		
I	707	0	0	0
II	659	2.2	.8**	.1
III	812	8.8**	1.3**	.3**
		419-day-old foals		
I	602	0	0	0
II	612	12.9**	1.2**	.2**
III	814	19.6**	1.1**	.4**
		510-day-old foals		
I	1347	0	0	0
II	1063	5.9**	.5**	.1**
III	799	5.7**	.5**	.1**

[a]Includes the 1.5% foals born in January, the 7.3% born in February, and the 22.8% born in March.

[b]April (31.4% of the foals).

[c]Includes the 30.3% foals born in May, 6.6% born in June, and the .1% born in July.

*P<.05.

**P<.01.

during the third 90 days, and only 45 kg during the fourth 90 days. The data clearly demonstrate the greatest amount of elongation of bone takes place during the first few months of life. Proper nutrition would be of great importance during the periods of rapid growth.

The results that offspring of the younger mares are smaller is similar to that reported for cattle (Burris and Blunn, 1952). The smaller foals are probably related to the decreased ability of the younger dams to provide nutrients to the fetus. No conclusions can be made as to why year of birth affected growth. Many factors such as weather, management practices, feed supply, and health conditions are probably involved. Nevertheless, year of birth should be considered in standardizing growth records.

Further studies are also needed to determine why foals born in April and May were larger at birth than foals born earlier. Diet was probably not a factor, because none of the mares was turned out to pasture until the last of May. The mares with late spring foals had a gestation period about 3 days shorter than those of mares with early foals. Thus, the late foals were not only larger but also attained the larger size during a shorter gestation period.

Length of daylight influences the reproductive cycle of the mare. The size difference in the foals might be related to hormonal responses to changes in length of day. The latitude at Windfields is 44°N, which would result in a difference of 6 hr in day length between the longest and shortest days.

Green (1969) reported no apparent difference in size of Thoroughbred foals at birth during the months of February to May but the study included only 33 animals.

Several previous studies have also suggested that on the average colts are larger than fillies at birth and that the difference increases during the growth period (Green, 1969; Cunningham and Fowler, 1961; Willoughby, 1975; Reed and Dunn, 1977).

The correlations between the measurements at 0, 4, 6 and 12 months are shown in table 6. Weight at birth was highly correlated with weights at later ages. The small correlations observed between height at birth and height at the later ages was not expected. Reed and Dunn (1977) reported a highly significant correlation between height at birth and height at maturity and concluded that mature height could be accurately predicted from height at birth. Correlations of circumference of cannon bone with weight and with height were relatively low.

In conclusion, although the data presented

TABLE 6. CORRELATIONS BETWEEN MEASUREMENTS AT VARIOUS MONTHS OF AGE FOR 62 FOALS

Age	Weight				Height				Bone			
(months)	0	4	6	12	0	4	6	12	0	4	6	12
Weight												
0	1.0	.70	.63	.61	.52	.63	.59	.47	.49	.23	.28	.46
4		1.0	.89	.69	.23	.71	.65	.45	.33	.39	.36	.55
6			1.0	.67	.24	.61	.61	.37	.38	.35	.37	.53
12				1.0	.24	.51	.57	.55	.29	.24	.24	.64
Height												
0					1.0	.37	.37	.20	.38	-.09	.12	.19
4						1.0	.86	.70	.44	.47	.41	.48
6							1.0	.77	.34	.32	.41	.54
12								1.0	.23	.32	.27	.53
Bone												
0									1.0	.30	.19	.33
4										1.0	.42	.32
6											1.0	.37
12												1.0

are from only one farm, they appear to provide reasonable estimates of the expected growth rate of Thoroughbred foals. Factors such as sex of foal, age of dam, and year and month of birth can influence size as measured by body weight, height at withers, and circumference of cannon bone and require consideration in analysis of growth data.

LITERATURE CITED

Budzynski, M., E. Sasimowski and R. Tyszkowski. 1971. Biometric changes during the growth process in halfbreed horses at Janow Podlaski State Stud. Roczniki Nauk Rolniczych Series B 93:21.

Burris, M. J. and C. T. Blunn. 1952. Some factors affecting gestation length and birth weight of beef cattle. J. Anim. Sci. 11:34.

Cunningham, K. and S. H. Fowler. 1961. A study of growth and development in the Quarter Horse. Louisiana State Univ. Agr. Exp. Sta. Bull. 546.

Green, D. A. 1969. A study of growth rate in Thoroughbred foals. Brit. Vet. J. 124:539.

Green, D. A. 1976. Growth rate in Thoroughbred yearlings and two year olds. Equine Vet. J. 8:133.

Harper, M. W. 1921. Raising colts. Cornell U. Agr. Exp. Sta. Bull. 403. 26 p.

Heird, J. C. 1973. Growth parameters in the Quarter Horse. Proc. Third Equine Nutr Phys. Symp.:81.

Henderson, C. R., O. Kemthorne, S. R. Searle and C. M. vonKrosigk. 1959. The estimation of environmental and genetic trends from records subject to culling. Biometrics 15:192.

Henderson, C. R. 1963. Selection index and expected advance. P. 141–163 *In* Hanson, W. D. and H. F. Robinson (Ed.) Statistical Genetics and Plant Breeding. National Academy of Science – National Research Council, Washington, Pub. 982.

Henderson, C. R. 1973. Sire evaluation and genetic trends. Proc. Anim. Breeding and Genetics Symp. in Honor of Dr. Jay L. Lush. ASAS-ADSA, p. 10.

Henderson, C. R. 1975. Rapid method for computing the inverse of a relationship matrix. J. Dairy Sci. 58:1727.

Hintz, R. L., H. F. Hintz and L. D. VanVleck. 1978. Estimation of heritabilities for weight, height, and front cannon bone circumference of Thoroughbreds. J. Anim. Sci. 47:1243.

Jordan, R. M. 1977. Growth pattern of ponies. Proc. Fifth Equine Nutr. Phys. Symp. 63.

Reed, R. R. and N. K. Dunn. 1977. Growth and development of the Arabian Horse. Proc. Fifth Equine Nutr. Phys. Symp.:99.

Trowbridge, E. A. and D. W. Chittenden. 1932. Horses grown on limited grain rations. Univ. Missouri Ag. Exp. Sta. Bull. 316, 19 p.

Willoughby, D. P. 1975. Growth and Nutrition of the Horse. A. S. Barnes, Cranbury, NJ.