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A Study of the Inheritance of Feed

Utilization Efficiency in the Growing Domestic Fowl

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A STUDY OF THE INHERITANCE OF FEED UTILIZATION EFFICIENCY IN THE GROWING DOMESTIC FOWL

By

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Modern trends in poultry production have clearly emphasized the need for research on the efficiency of feed utilization in the domestic fowl. Feed cost is the largest single item of cost and amounts to 50 percent or more of the expense of a poultry enterprise. It is very evident that if we can suggest ways and means whereby this chief item of cost can be reduced by the poultrymen of Maryland and throughout the country, it would mean a tremendous saving. If, for example, it is possible to develop strains of chickens that require even as little as 10 percent less feed than other strains it would amount to a sizable saving to the poultry industry.

With this in mind, the present research was initiated. The chief purpose was to determine whether the efficiency of feed utilization in meat production in the domestic fowl is inherited, and whether or not is is possible to develop strains of chickens that will excel others in their ability to utilize feed more efficiently. The work of Morris, Palmer and Kennedy (1933) has given the author encouragement in this phase of the work. These workers were able to develop by several years of selection and breeding two lines of rats, one of which was approximately 40 percent less efficient in feed utilization than the other.

The efficiency of feed utilization is a very involved phenomenon that is influenced by a great number of physiological, environmental,as well as individual differences. Rate of growth, sex, amount of feathering, exposed surface area, the capacity to consume large quantities of feed, and general health of the individual are just a few of the discrepancies that may affect the results of a study of efficiency of feed utilization.

It is generally agreed that there are at least two components that make up the gross efficiency or the utilization of feed by the growing domestic fowl. One is the growth requirement or that amount of feed which is utilized by the animal for gain or for increasing its body weight, while the other is the maintenance requirement or that amount of feed which is used to carry on the normal body and muscular functions and maintain the existing body weight. From a practical point of view, of course, we are more interested in the gross efficiency than we are in the separate components. It is of far greater importance to the poultryman to select a fowl which required three pounds of feed instead of three and one-half pounds, rather than one which was initially efficient and decreased very rapidly in efficiency, or one which was initially not as efficient but decreased slowly in its efficiency. However, from a scientific point of view we are interested in the separate growth and maintenance requirements for they may give us some valuable information on this extremely complicated problem.

REVIEW OF THE LITERATURE

Data on the utilization of feed by the domestic fowl on an individual or family basis is very limited. With only a few exceptions, feed utilization data have been assembled in connection with some growth experiment, nutritional experiment, or some general management problem. Consequently, most of these data help us in obtaining an estimate of the efficiency of the poultry population as a whole, but do not give us an indication of the efficiency on a family basis.

Platt (1934) reported values of feed consumption per pound gain during the week for battery raised White Leghorn chicks of mixed sexes. The values increased progressively from 1.3 at one week of age or a weight of 0.15 pounds, to 6.5 at eleven weeks or at 2.23 pounds. The accumulative feed consumption varied from 1.3 to 3.9 for the same period.

Waite (1935) observed in a study of thirty-five White Leghorn chicks grown in close confinement that as they became heavier they became less efficient. It required 3.0 pounds of feed per pound of chicken up to eight weeks or 1.3 pounds in weight, and 3.3 pounds of feed to ten weeks or 1.7 pounds of chicken.

Jeffrey (1938) concluded from his work with 72 Rhode Island Reds, 238 Barred Plymouth Rocks, and 243 Rhode Island Red X Barred Plymouth Rock Crosses that it took 4.9 pounds of feed per pound of gain for all males from 1 to 20 weeks, against 5.2 for females. However, he had the sexes mixed until ten weeks of age and so his results may not be too reliable. On the other hand, Jull (1938) states that females require approximately 10 percent less feed than the males to attain a certain weight.

The fact has been pretty well established by numerous workers that crossbreds are more efficient in utilizing their feed than purebreds. Hess, Byerly and Jull (1941), observed that in most instances the crossbred chickens of a given sire are more efficient than the purebreds from the same sire. However, in several instances it was noted that the advantage of the crossbreds over the purebreds was not very pronounced. Advantages of crossbreds over purebreds were also noted by Bice and Tower (1939), Poffenberger and DeVault (1937), and Horlacher and Smith (1938). On the other hand, although Jeffrey (1938) observed a more rapid growth for the crossbreds than the purebreds, the former were not superior in efficiency.

Glazener and Jull (1946) made observations on the feed utilization of 222 short-shanked and 138 long-shanked New Hampshires and 196 short-shanked and 86 long-shanked Barred Plymouth Rocks because numerous investigators observed less variability in the length of the appendicular skeletal bones than in the body weight of the fowl. These workers observed that both Barred Plymouth Rock and New Hampshire long-shanked chickens grew faster and utilized the feed more efficiently than the short-shanked strains. Although the authors did not compare the efficiency between the New Hampshires and Barred Plymouth Rocks, it is noted that the New Hampshires were more efficient than the Barred Plymouth Rocks at 1000 grams body weight when compared on the basis of efficiency as a function of live weight, as well as at 2000 grams feed consumption when weight is studied as a function of feed consumption.

Working with hens, Waite (1934) made some very interesting observations on feed consumption of the hens entered in the Maryland egg laying contest over a period of six years. He reported that Rhode Island Reds consumed 92.20 pounds of feed per bird per year and 6.13 pounds per dozen of eggs, Barred Plymouth Rocks consumed 88.47 pounds of feed per bird per year or 4.8 pounds per dozen eggs. Any marked difference in production would, of course, accentuate the difference in feed consumption, but since production was reasonably uniform we may assume that the major portion of this difference may be accounted for in maintenance requirement. By grouping the White Leghorns in two groups, one with an average body weight of over 3.58 pounds and the other below 3.58 pounds, Waite obtained feed consumptions of 83.29 pounds and 77.82 pounds respectively. Kennard and Chamberlain (1939) worked with White Leghorns in individual laying cages, and even though their data were limited and their experimental conditions not too well controlled, they confirmed Waite's finding that the rate of production is most influential in determining the efficiency of hens. Their work suggests rather definite individual differences among hens in feed utilization.

Byerly (1941) made an extensive study on individual feed consumptions of 102 laying birds ranging from $1\frac{1}{2}$ to $7\frac{1}{4}$ pounds in body weight. These birds included White Leghorn, Barred Plymouth Rock, New Hampshire hens and pullets, and New Hampshire X Barred Plymouth Rock cross pullets. He calculated and applied the equation $F = 0.523W^{0.653} \pm 1.126\Delta W - 1.135E$ to his own data and that of other workers. In this equation F equals the feed consumption per bird per day, W equals the body weight, ΔW equals change in body weight, and E equals the weight of egg substance produced per day. $W^{0.653}$ is a proportionality constant relating metabolism to body weight. He found that the annual feed requirement for maintenance varied from 46.8 pounds for 3 pound birds to 81.4 pounds for 7 pound birds. It is of interest to note that all measures of feed efficiency used decreased with increasing body weight.

The fact that the maintenance requirement is very important and may materially affect the gross efficiency of the fowl is a well established fact.

Best and Taylor (1945) state that in humans the basal metabolic rate is slightly lower for females than for males, and that the metabolic rate decreases with age. Thyroxin and various other chemical substances also have a tendency to raise the basal metabolic rate. Brody (1945) also presents data showing that for most animals the basal metabolic rate is lower for males than for females. He shows that the metabolism of mature birds varies with the 2/3 power of body weight, whereas with mammals it is the 0.73 power of body weight.

Fraps and Carlyle (1939) reported a maintenance requirement of approximately 74.8 grams of feed per kilogram per day for growing chickens, and Hammond and Bird (1942) confirmed this finding when they reported a maintenance requirement of 71.7 grams of feed per kilogram per day. They observed individual variations ranging from 62.7 to 92.5 grams per kilogram live weight per day. Jull (1938) reported that for 16 month-old White Leghorn hens averaging 3.5 pounds each the gross maintenance was 64 grams of feed per day in July. Since this corresponds to approximately 40.3 grams of feed per kilogram per day, the maintenance requirement given for the hens is only slightly more than half that found for growing chicks, although the low figure for the hens may possibly be explained by the fact that these data were obtained during midsummer. Winchester and Kleiber (1938) showed that feed consumption varied in almost negative linear relationship with the temperature they studied, which ranged from 16° to 38° C.

Hammond and Bird (1942) in studying the variability among growing chickens, made some very interesting observations that are pertinent in this study. They noted less variability among chicks reared in the individual compartments than the comparable lot fed the same diet in regular battery brooders. These workers also reported the results of an experiment in which a group of 50 chicks were divided into two groups at three weeks of age. One group included all chicks that exceeded 118 grams while the other was comprised of those weighing less than 118 grams at three weeks of age. They concluded that the fast-growing chicks were more than twice as efficient as the slow-growing group on a live weight basis in their utilization of feed at six weeks of age. The slow-growing group was found to be nearly twice as variable as the fast-growing group. Another observation reported by these workers was that chicks even though they were fed definite and equal amounts in weight were approximately one fourth more variable four hours after feeding than just prior to feeding.

The author raised the question as to whether the yolk-sac might account for the variation in initial efficiencies of certain chicks. The data on the study of yolk-assimilation by Heywang and Jull (1930) shows that by the seventh day the major portion of the yolk has been absorbed in the chick. Parker (1929) in her study of handicaps on chickens as measured by yolk absorption noted that the removal of the unabsorbed yolk when chicks were one day old did not materially affect their body weights. However, the females were somewhat below the mean weight of the control females at eight weeks and the males were somewhat behind the control groups throughout the 20-week test period. Her numbers were small, but in general, her work showed that the operated chicks were somewhat retarded in growth up to six weeks as compared with the controls and all the other groups on various treatments.

Kleiber (1936) discussed some of the problems in breeding for feed utilization efficiency. He points out that one must use a uniform feed and must have a well defined characteristic for selection, such as total energy efficiency. He suggests that one must study the different factors which influence food utilization, and then investigate the genetics of each separate factor. He presents a very complex diagram in which he succeeds in impressing the reader with the complexity of the problem. He refers to such factors as appetite, eating capacity, absorption capacity, stimulus for growth, stimulus of egg production (in hens), fasting catabolism, heat requirement, and cooling power.

Lambert, Ellis, Block and Titus (1936) emphasize that the development of strains of livestock that are more efficient meat producers than those now existing is one of the basic problems in animal production. They further point out that geneticists have largely neglected this problem because of the inherent difficulties involved in such a study.

As mentioned previously, no work has been done on the inheritance of efficiency of feed utilization known to the author except for the work on rats by Morris, Palmer and Kennedy (1933), and in chickens by Hess, Byerly and Jull (1941), and Glazener and Jull (1946). However, much encouragement is furnished by such work as that of Davis, Norris and Heuser (1938), who observed a wide variation in the hatchability of different families of hens on a vitamin G depleted diet. Hatchability among families varied from 1.67 to 63.37 percent of fertile eggs. Thus if one family can utilize vitamin G more efficiently than another, we may speculate that we should also be able to develop families that utilize the total feed more efficiently than other families.

Working with Yorkshire pigs from the same litter,Crampton (1929) reported a gain of 186 and 213 pounds for two pigs that originally weighed 30 and 31 pounds, and consumed 701 and 703 pounds of feed, respectively. Crampton (1928) also reported on a pair of pigs of similar breeding and of the same weight at the outset of the trial. One of these made a gain 37 percent greater per unit of feed than the other.

Winters and McMahon (1933) made observations on 32 steers of "essentially the same breeding", age, weight and condition and showed that they differed considerably in their ability to make economical gains. As far back as 1910 Smith (1910) reported that frequently one steer would make a 20 percent larger gain than another on the same feed.

Cowgill (1928) observed that dogs varied considerably in the number of calories required to maintain a constant body weight and Thompson (1926) noted individual differences in food utilization and capacity for growth in the albino mouse.

Palmer and Kennedy (1931), working with rats, developed an efficiency index, which showed marked differences in efficiency between individual rats. Continuing this work, Morris, Palmer and Kennedy (1933), as mentioned previously, developed two lines of rats in nine generations, one of which was approximately 40 percent less efficient than the other in the utilization of feed. It is interesting to note that the high-efficiency group has remained fairly close to the efficiency of the F_2 average, while the low-efficiency group had very few individuals approaching this average. There was much less variability in the efficient line. Since only sib matings were made, it is logical that the efficient line did not exceed the F_2 average as much as the low line went below the F_2 average. However, even though they were inbreeding they still maintained average and above average efficiency. These workers concluded that heritable factors influence the efficiency of food utilization, and that there is a decided difference between the two sexes in the efficiency with which they utilize feed on a uniform diet. The males were considerably more efficient than the females.

Working with these high-efficiency and low-efficiency strains of rats, Palmer et al (1946) made an exhaustive attempt to determine why rats differ in feed utilization efficiency. They found that thyroid administration markedly reduced the efficiency of the males of the efficient strain, but it did not affect the less efficient strain significantly. Castration also decreased the efficiency in the high-efficiency strain. They concluded that the less efficient rat secreted more thyroxine than the more efficient rat and therefore there was greater wastage of energy and consequently a decreased efficiency of feed utilization. By restricting the feed intake of the high-efficiency strain to the level consumed by the low-efficiency strain, these workers observed that the former still gained more ash, protein, ether extract, dry matter, and calories, and therefore were more efficient. They observed further that the low-efficiency strain had a slightly higher basal metabolism and a lower rectal temperature than the high-efficiency strain. It is interesting to note in their data that the males were heavier than the females and the high-efficiency strain was heavier than the low-efficiency strain at any given time.

Spillman and Lang (1924) presented the idea of applying the law of diminishing increment to growth and feed consumption data in livestock experiments. Since that time a large number of papers have been published presenting the law of diminishing increment with an improved method of calculation. Jull and Titus (1928) concluded that the law of diminishing increment is applicable in expressing the relationship between feed consumption and growth of chickens. These workers used Spillman's original formula of $Y = M - AR^x$ in which $Y =$ the live weight for any amount, x, of feed consumed, $M =$ the theoretical maximum live weight attainable, $A =$ the theoretical maximum increase in live weight possible, R = ratio between gains in live weight for successive units of feed, X = the number of units of feed consumed.

Hendricks (1931), however, rewrote the equation and simplified the calculations considerably. He changed the original formula to $W = A - Be^{-kF}$ which was again rewritten in the differential form $\frac{dW}{dF} = C - mW$, where $C = kA$ and $m = k$. This calculus equation can again be changed to $\frac{\Delta W}{\Delta F} = C - mW$ in which $\frac{\Delta W}{\Delta F}$ equals the gain in live weight per unit of feed eaten, over a short interval of time, and W equals the average live weight of the period$\left(\frac{W1 + W2}{2}\right)$. This becomes a simple linear equation of the form $Y = a \quad bx$ and can be solved by the method of least squares. Hendricks used this formula and obtained very close agreement with calculations by the old method. It is logical, however, that the more frequent the interval of weighing the more accurate the results, since the differential equation is based on the theory of instantaneous weights and efficiencies. Hendricks, Jull and Titus (1932) and Titus, Jull and Hendricks (1934) showed that this curve of diminishing increment gave a very close fit to the actual data and that it could be very useful in interpreting growth studies in chickens, since it furnishes a fairly good means for expressing the live weight of growing chickens as a function of feed consumption.

Titus and Hendricks (1930) pointed out that it is much more desirable to express the live weight of chickens as a function of feed consumption than of time. They determined that for their data the average live weight of the chickens could be considered as a function of feed consumption up to a pound or even more in live weight.

Hendricks, Jull and Titus (1931) proposed a possible physiological explanation for the law of diminishing increment. They rewrote the differential form of the equation for the curve of the diminishing increment to $\frac{dW}{dF} = C - mW$. (The author used a modification of this formula in which $\frac{dW}{dF}$ equals E and

M equals K; therefore, making the equation $E = C - kW$). They suggested that if no feed is used for maintenance, then $\frac{dW}{dF}$ equals C and therefore mW would equal the maintenance requirement. If this is true, then m (k in the equation used by the author) would equal the maintenance requirement per unit of weight, W, and C would equal the growth requirement. Hankins and Titus (1939) presented a procedure for determining the standard error of C and k, as well as an example for calculating these constants.

That the law of diminishing increment also applies to other fowls has been shown by Titus (1928), who found that it was applicable to feed-growth data of a group of Pekin ducklings, and by Hammond and Marsden (1939), who showed that this relationship held for turkeys as well.

MATERIALS AND PROCEDURE

The general objective of this experiment was to study the inheritance of feed utilization efficiency in growing chickens. To do this it seemed necessary to develop strains of chickens with high and low feed efficiencies, respectively. Although carrying out a project of this nature is much easier with poultry than with other types of livestock, it is considerably more difficult than with rats or mice. The author experienced considerable difficulty in obtaining eggs when desired from certain hens, as well as maintaining satisfactory fertility, hatchability, and livability in certain cases. The number of progeny obtainable from any two parents is, of course, limited by the length of time one can satisfactorily hold hatching eggs.

MATINGS

Originally 64 Barred Plymouth Rock pullets and 48 New Hampshire pullets were divided at random into eight uniform groups, each group of 8 Barred Plymouth Rock and 6 New Hampshire pullets being mated to a Barred Plymouth Rock cockerel. These matings were made up in October 1938, and in April 1939 one of the eight Barred Plymouth Rock males was replaced by a New Hampshire male and most of the hens were shifted among the different pens. These shifts in females were made on the basis of the feed efficiency data collected up to that time.

By September 1939 a number of F_1 progeny became sexually mature and so could be used in matings. Consequently, most of the hens on which no data had been accumulated were culled and the remainder chiefly mated to four F_1 Barred Plymouth Rock sires. Four Barred Plymouth Rock cocks were retained and were mated chiefly to F_1 pullets. Also the previously used New Hampshire male was replaced by one of his sons and a Dark Cornish male was purchased to head up a tenth mating. Enough New Hampshire pullets from outside sources were placed at random into these matings in order to bring the total number of New Hampshires with each sire to five.

During 1939, 1940 and 1941 numerous changes were made in the sires and dams used. Numerous F_1 males and F_1 females were introduced into the breeding pens, as well as some F_2 males and F_2 females. Data have been collected on seven F_1 and six F_2 sires during this period.

It was felt that by selecting rapid-growing and slow-growing families from some pedigreed New Hampshires at the University of Maryland poultry farm, an efficient and an inefficient strain might be developed. In June 1946 two sires, male 17 and male 18, were mated to fifteen females each. Selection was made on the basis of the progeny test. The mean body weight of the progenies of the dams mated to sire 17 was 863.2 grams and of the progenies of the dams mated to sire 18 was 730.5 grams at 10 weeks of age. Eggs were obtained and chicks hatched from eight females mated to sire 17 and eight females mated to sire 18.

In November 1946 four of the females with progeny of rapid growth and good efficiency and four with progeny of slow growth and poor efficiency were mated to sires 17 and 18, respectively. All of the available daughters from these eight females were divided at random between these two sires, and chicks were hatched from these matings in January 1947. As a comparison with the strain of Barred Plymouth Rocks used in the first part of this work, some eggs were hatched from one male and two females purchased from an R.O.P. breeder.

STARTING THE CHICKS

The eggs from these hens were marked with the sire's and dam's number and incubated in either a Buckeye or Jamesway forced-draft incubator. The eggs were usually collected over a period of two weeks in order to obtain a sufficiently large group of chicks from each dam. The chicks were wingbanded at hatching time.

All of the chicks were grown in electrically heated batteries; some of them as individual chicks in individual compartments while others consisted of a group of full sibs. The size of these latter groups varied considerably, for even though they were kept as large as possible, they were limited by the reproductive capacity of the dam. Some lots had as many as fifteen chicks, although the mode was approximately seven chicks per lot.

Data were collected up to eight weeks of age on the earliest groups, and up to twelve weeks for the latter lots. In one case 36 individual chicks were kept on experiment until they attained a weight of 1680 grams or more, regardless of age, which varied from 13 to 20 weeks.

In one hatch a portion of the chicks was divided into two comparable groups, one of two sibs in each group. The yolk-sac was removed from one of these groups in order to determine whether the yolk-sac would have any influence on the early feed utilization efficiency.

FEEDING

All of the birds were fed a uniform diet, one which is fed to all birds at the University of Maryland poultry farm. In 1938 to 1941 it consisted of the following:

Ground yellow corn	500 lbs.
Wheat bran	300 lbs.
Middlings	300 lbs.
Pulverized Oats	300 lbs.
50% Meat Scrap	150 lbs.
Dried Skim Milk	150 lbs.
Soybean Meal	100 lbs.
Fish Meal	100 lbs.
Ground Limestone	20 lbs.
Cod Liver Oil	20 lbs.
Salt	10 lbs.
Manganese sulphate	$\frac{1}{4}$ lb.

The 1946 and 1947 ration has been modified to some extent and consists of the following:

Ground yellow corn	505 lbs.
Wheat bran	250 lbs.
Middlings	200 lbs.
Ground oats	250 lbs.
Meat Scrap	100 lbs.
Dried Milk	100 lbs.
Soybean Meal	200 lbs.
Fish Meal	100 lbs.
Corn Gluten Meal	100 lbs.
Alfalfa Leaf Meal	100 lbs.
Distillers solubles (80 micrograms riboflavin per gram)	25 lbs.
Ground Limestone	40 lbs.
Bone Meal	15 lbs.
Vitamin A and D feeding oil (400 units D per gram)	10 lbs.
Salt	15 lbs.
Manganese sulphate	½ lb.

It would be expected that the feed might vary slightly from one mix to another, so in order to minimize the effect that this variation might have on the results, all lots were fed from the same mix whenever feed was weighed in. All remaining feed was discarded after it was weighed back at the end of the weekly period. Consequently, uniform feed was used for all lots of chicks on experiment at any one time.

Under ordinary circumstances feed wastage is a major problem in feed utilization studies. In this experiment, however, feed wastage was negligible because special batteries were used. These batteries have a trough with a shield approximately one-half inch behind the feeder, the shield catching the feed normally wasted. The individual chick battery which originally did not have this feature was redesigned by the author to keep wastage at a minimum. In all cases very little feed was placed into the feeder at one time, and frequent feedings were made.

No water consumption data were recorded.

CARE OF THE BIRDS

The chicks were brooded in electric batteries placed in a room automatically regulated by a thermostat at 80° F. A twenty-four hour lighting schedule was maintained, and feed and water were kept before the birds at all times. To minimize the effect of such environmental factors as position in battery and amount of light, the groups were assigned their position in the battery by drawing the dam's number.

During the first five or six weeks the chicks were kept in starting batteries, and thereafter were transferred to growing batteries.

COLLECTION OF THE DATA

Data were collected during every month from October 1938 to September 1941 and from October 1946 to April 1947. Observations were made on 935 Barred Plymouth Rock, 61 New Hampshire, 813 Crossbreds (Barred Plymouth Rock male X New Hampshire females and the reciprocal cross), 21 single comb White Leghorns, and 35 Cornish crosses (Cornish male X New Hampshire females and Cornish male X Barred Plymouth Rock females) during 1938-1941. In 1946-1947 observations on 138 New Hampshires and seven Barred Plymouth Rocks were recorded.

In most cases weekly and in some cases bi-weekly weights were observed and recorded as well as the feed consumption for each corresponding period. The birds were individually weighed to the nearest gram on a Toledo scale.

The feed was removed and weighed back in the late evening and the chicks were weighed early the next morning. The purpose of this eight to ten hour fasting at night was to have the birds as uniform as possible at weighing time, and still not retard them by starvation. It is recalled that Hammond and Bird (1942) noted much less variability in chicks weighed eight hours after the last feeding and prior to the next feeding than in chicks fed a uniform amount and weighed four hours thereafter.

ANALYSIS OF THE DATA

The data collected were analyzed chiefly from the standpoint of the sires used. A comparison was made between the P_1 sires used and the F_1 and F_2 sons. Both purebred and crossbred progeny were obtained from most sires and consequently a comparison between the purebred and crossbred progeny was made. The efficiencies of the dams and sisters of the F_1 and F_2 sires were also noted.

Furthermore, a comparison was made between the efficiencies of the two sexes. Since they were reared in individual cages the data furnished excellent material for such a study. Also, a comparison between the efficiency of slow-growing and fast-growing individuals, and between New Hampshires and Barred Plymouth Rocks was extremely interesting.

To remove the effect of body weight, or rate of growth, the progeny of a few sires with large number of progeny were grouped by pairing weights. This was to eliminate the effect of time and weight and to obtain the heritable difference in feed utilization efficiency between the sires studied.

To test the validity of determining the efficiency of feed utilization by a 12-week experiment regardless of weight, a group of birds was kept on experiment until they reached a definite weight of about 3.75 pounds, regardless of age.

The efficiencies and the constants in the equation $E = C - kW$ were compared for the data at 12 weeks and for the same individuals at the definite weight.

In the first comparison, body weight was plotted as a function of accumulative feed consumption, and a simple regression line ($y = a + bx$) was calculated by the method of least squares, for the purebreds and crossbreds of each sire, respectively. The weekly and bi-weekly observations were used. In exceptionally rare cases a certain week's feed consumption was lost or known to be inaccurate for some definite reason. It was found by trial with the known cases that by taking the weight and gain of the previous and following week and the corresponding feed consumption figures, against the weight and gain of the missing week, the missing value could be calculated quite accurately. In the cases of mortality the mean feed consumption per chick was calculated on a chick-day basis, and in a few cases where a chick was lost feed consumption was charged to the chick for one-half period.

The second comparison was between efficiency and weight. The author employed the equation $E = C - kW$, and E or the efficiency was plotted as a function of live weight. To obtain the average weight for the week or any given period, the formula $\frac{W1 + W2}{2}$ was used and thus the observed weights for the period were calculated. E, or the efficiency, was determined by taking $\frac{\text{gain for the period}}{\text{feed consumption for the period}}$. $E = C - kW$ was solved by the method of least squares.

Thirdly, some observations were made on the simple basis of units of feed per unit of gain. This consisted of dividing the total feed consumption by the final weight minus the original weight, or units of feed per unit of gain $= \frac{\text{total feed consumption}}{W_2 - W_1}$, where W_1 is the original weight and W_2 is the final weight.

EXPERIMENTAL RESULTS

The regression of weight on feed consumption for the purebred progenies of Barred Plymouth Rock sires 7 and 8 and the purebred progenies of their sons, 7A and 8A respectively are shown in Figures 1 to 4. The actual observations are plotted and the simple regression line is drawn. It is very probable that the curve of diminishing increment would give a better fit to the data than the linear relationship used by the author, but it may be noted in Figures 1 to 6 that a straight line represents the observed data reasonably well and well enough to be of value in interpreting the data at hand. It was observed that this straight line relationship is applicable in all cases up to 600 grams body weight, in almost every instance up to 900 grams, and in many cases the data can still be represented by a straight line at 1200 grams body weight. Beyond 1200 grams live weight a straight line no longer conforms to the data. This latter fact can be observed in Figures 5 and 6, where the actual observations of the progenies of two New Hampshire sires are plotted to approximately four pounds body weight. No regression line was calculated and plotted, because there was no apparent difference in the efficiency of the progeny of the two sires. Beyond 1200 grams body weight some of the fowls tend to approach maturity, the rate of gain tends to be slow and, consequently, one may expect to further confuse the already complicated problem by fattening, maximum body size, and egg formation in females. These figures, 5 and 6, show clearly that feed consumption increases much more rapidly than body weight at a point where the rate of gain is low, the line becoming parallel to the x-axis when the maximum body weight is attained and the gain equals zero.

FIGURE 1. Regression of live weight on feed consumption for the purebred progeny of Barred Plymouth Rock sire 7.

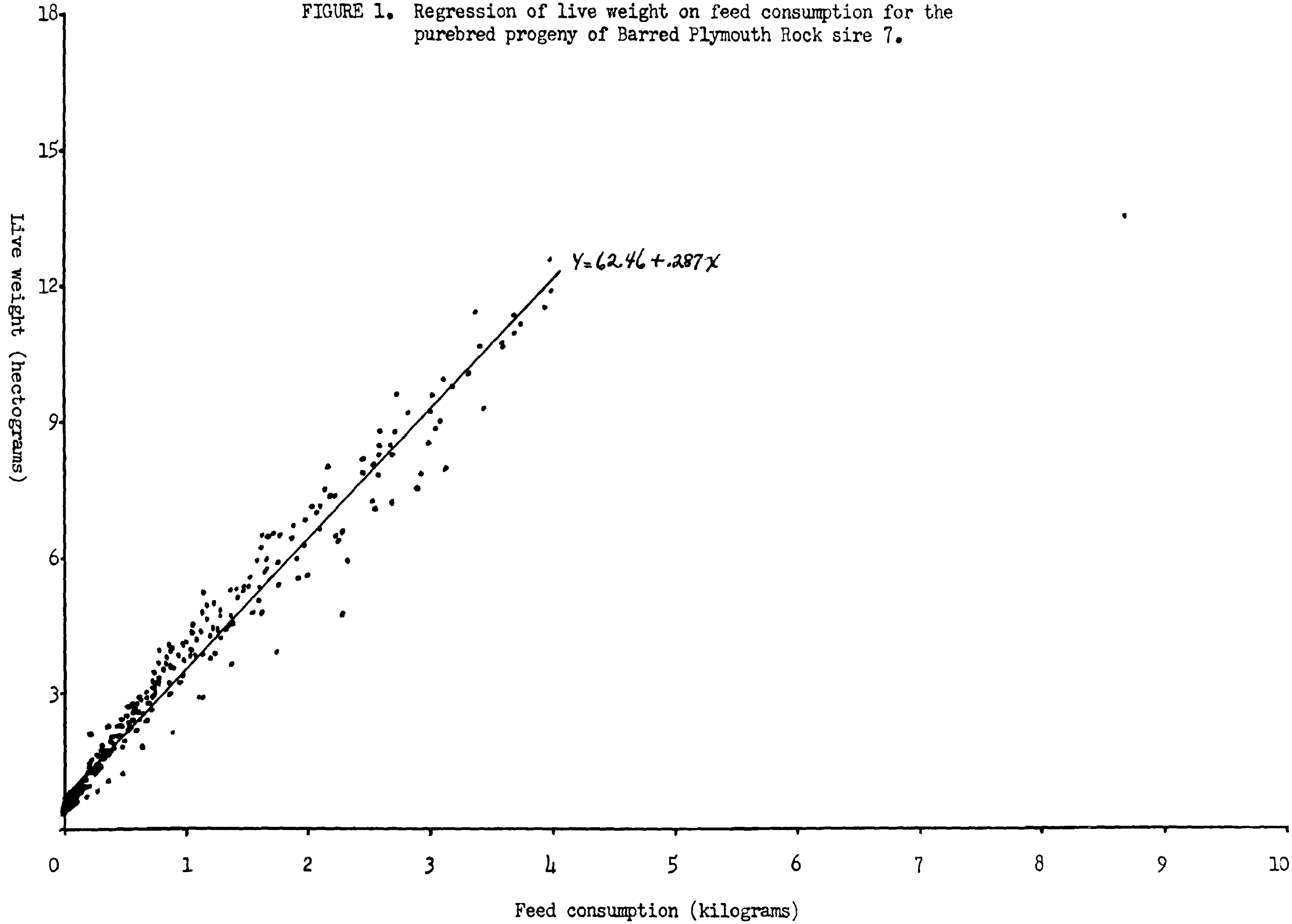


FIGURE 2. Regression of live weight on feed consumption for the purebred progeny of Barred Plymouth Rock sire 7A.

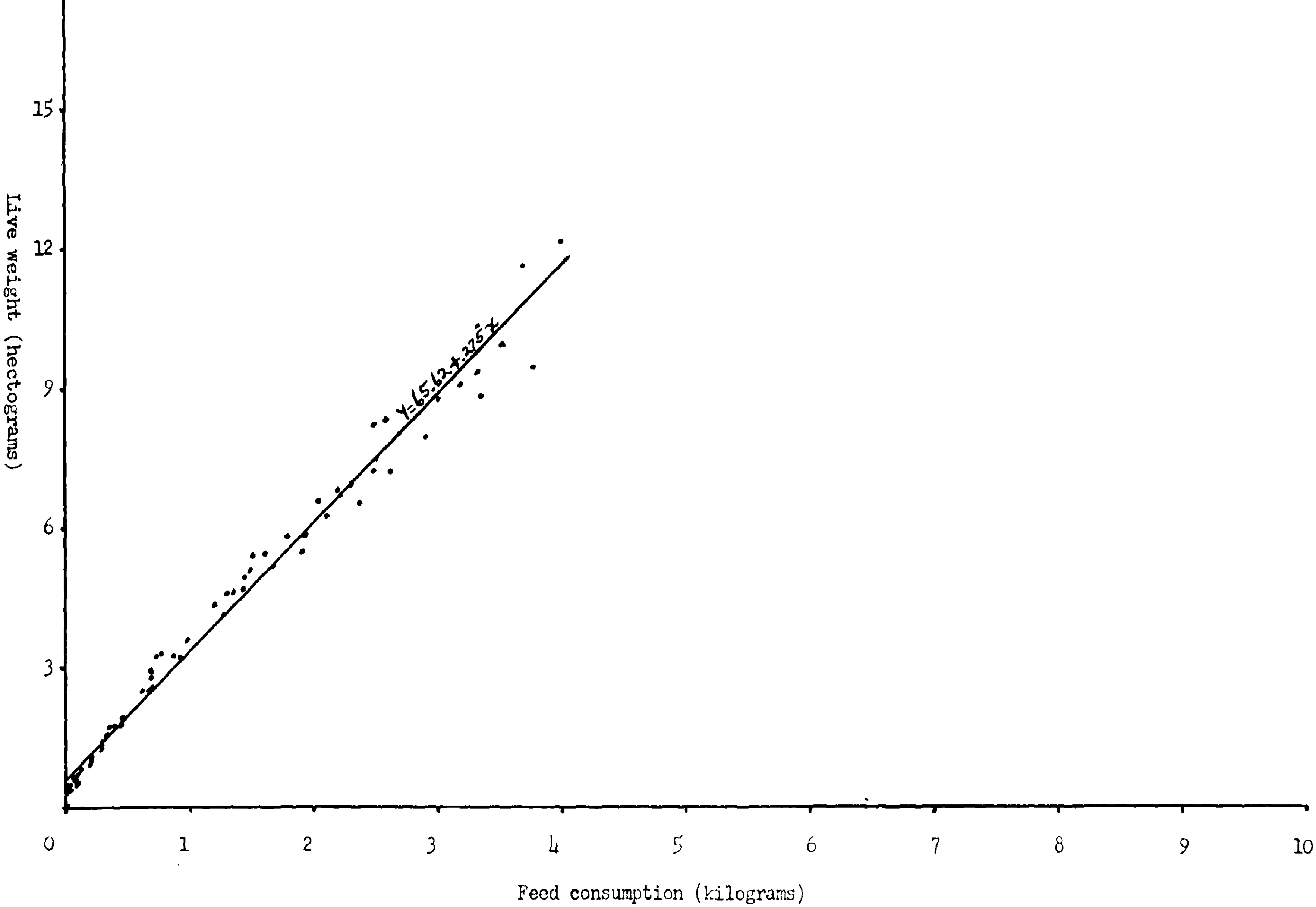


FIGURE 3. Regression of live weight on feed consumption for the purebred progeny of Barred Plymouth Rock sire 8.

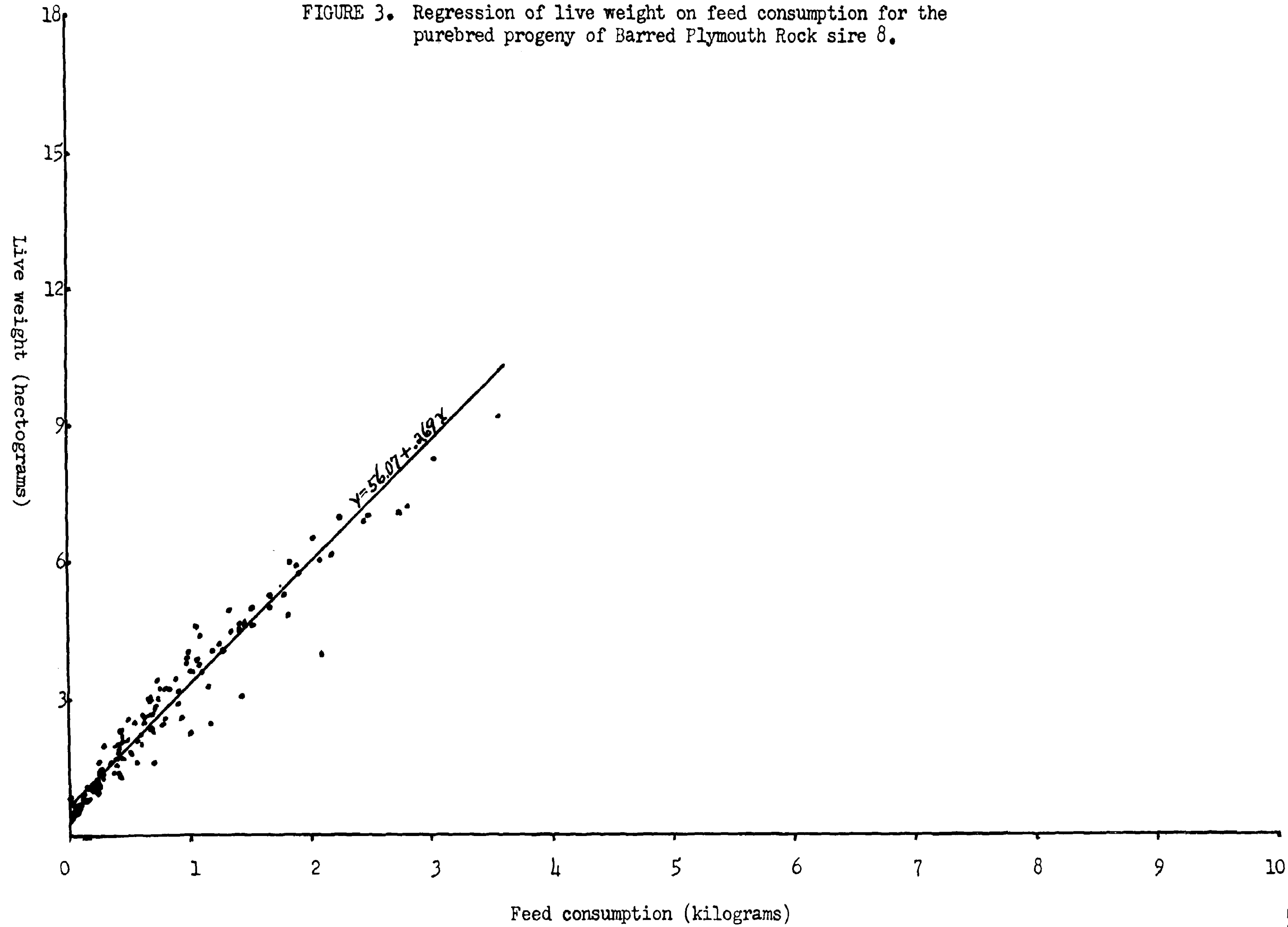


FIGURE 4. Regression of live weight on feed consumption for the purebred progeny of Barred Plymouth Rock sire 8A.

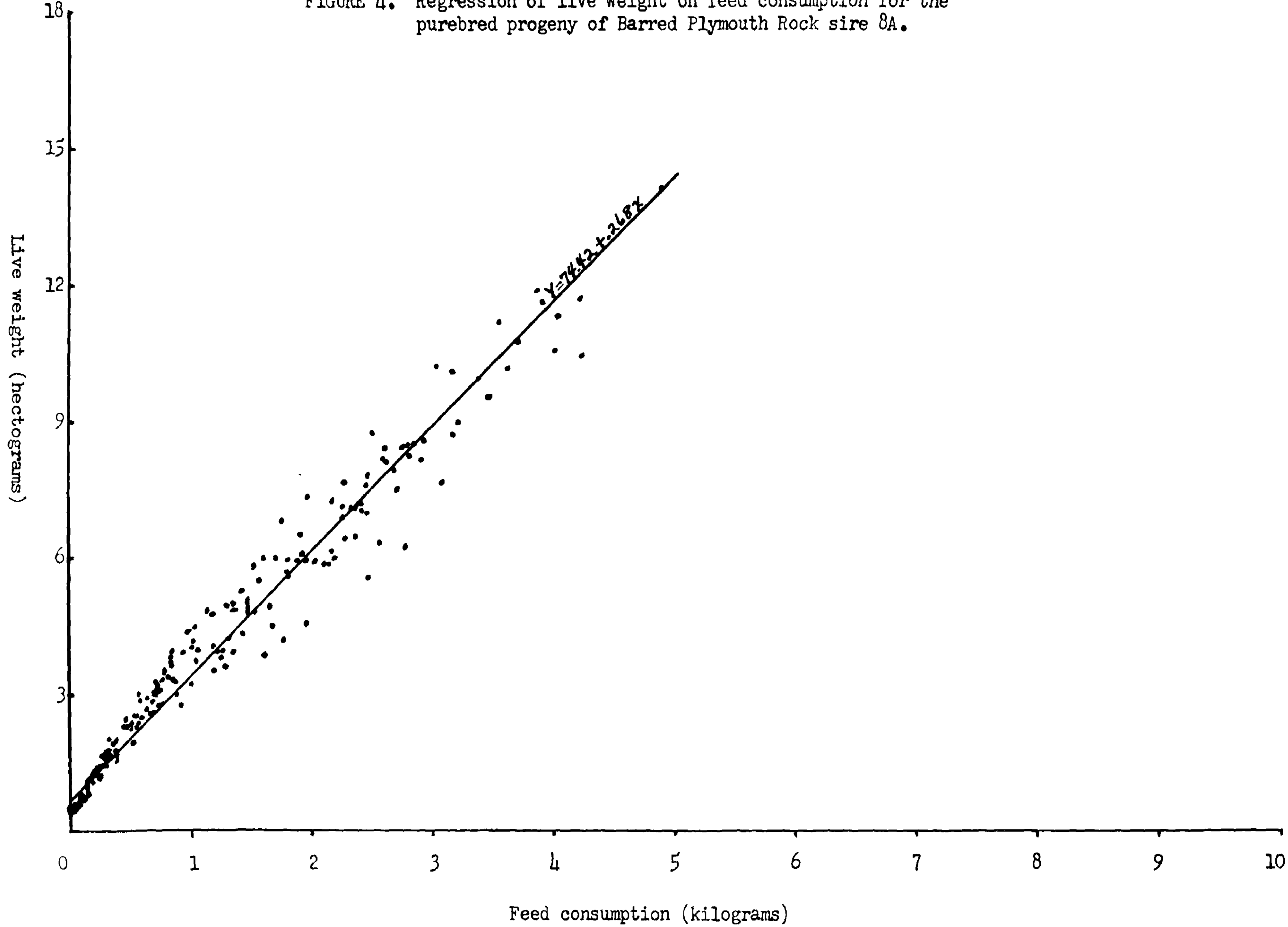


FIGURE 5. Live weight plotted as a function of feed consumption for the purebred progeny of New Hampshire sire 17.

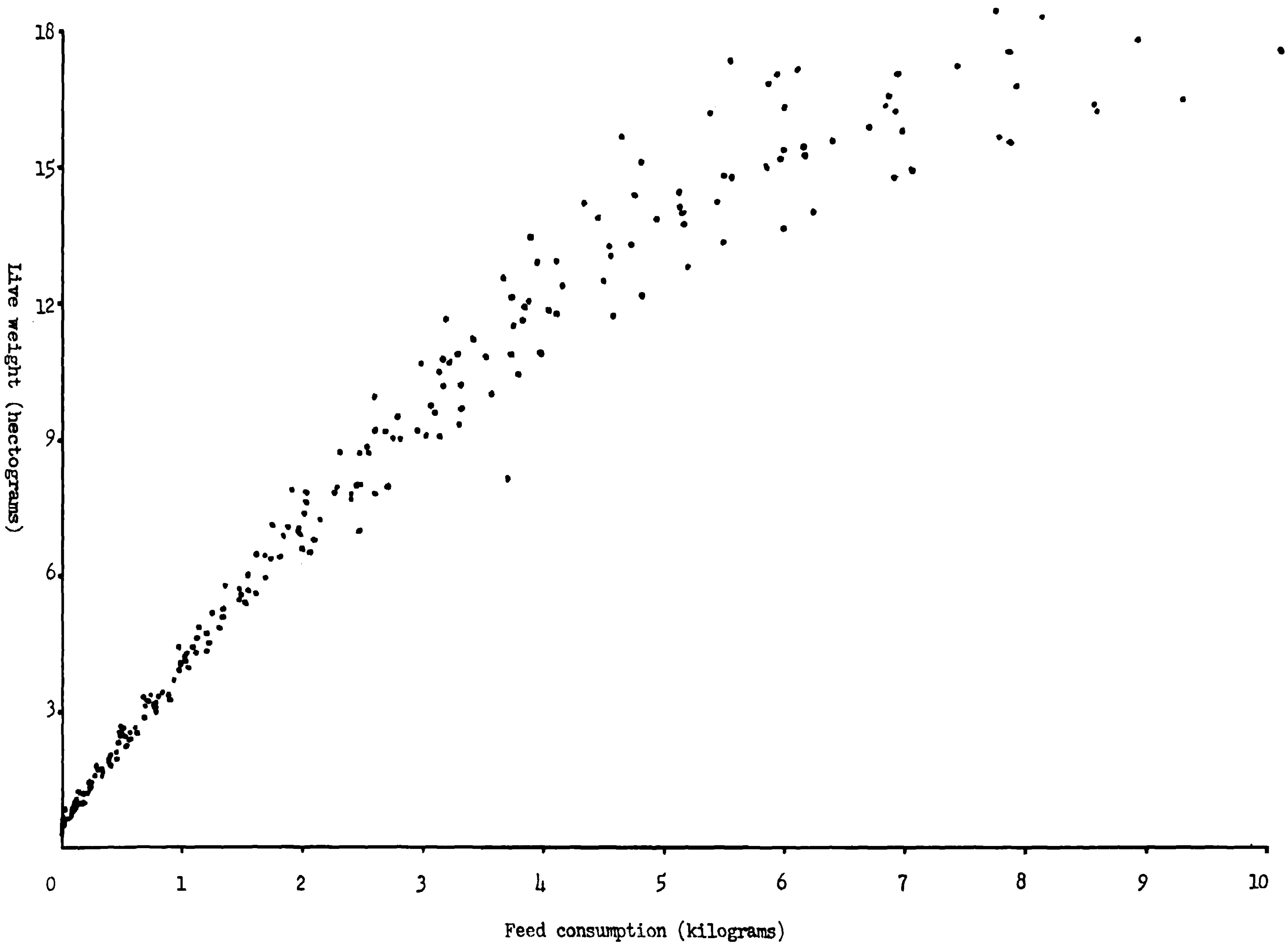
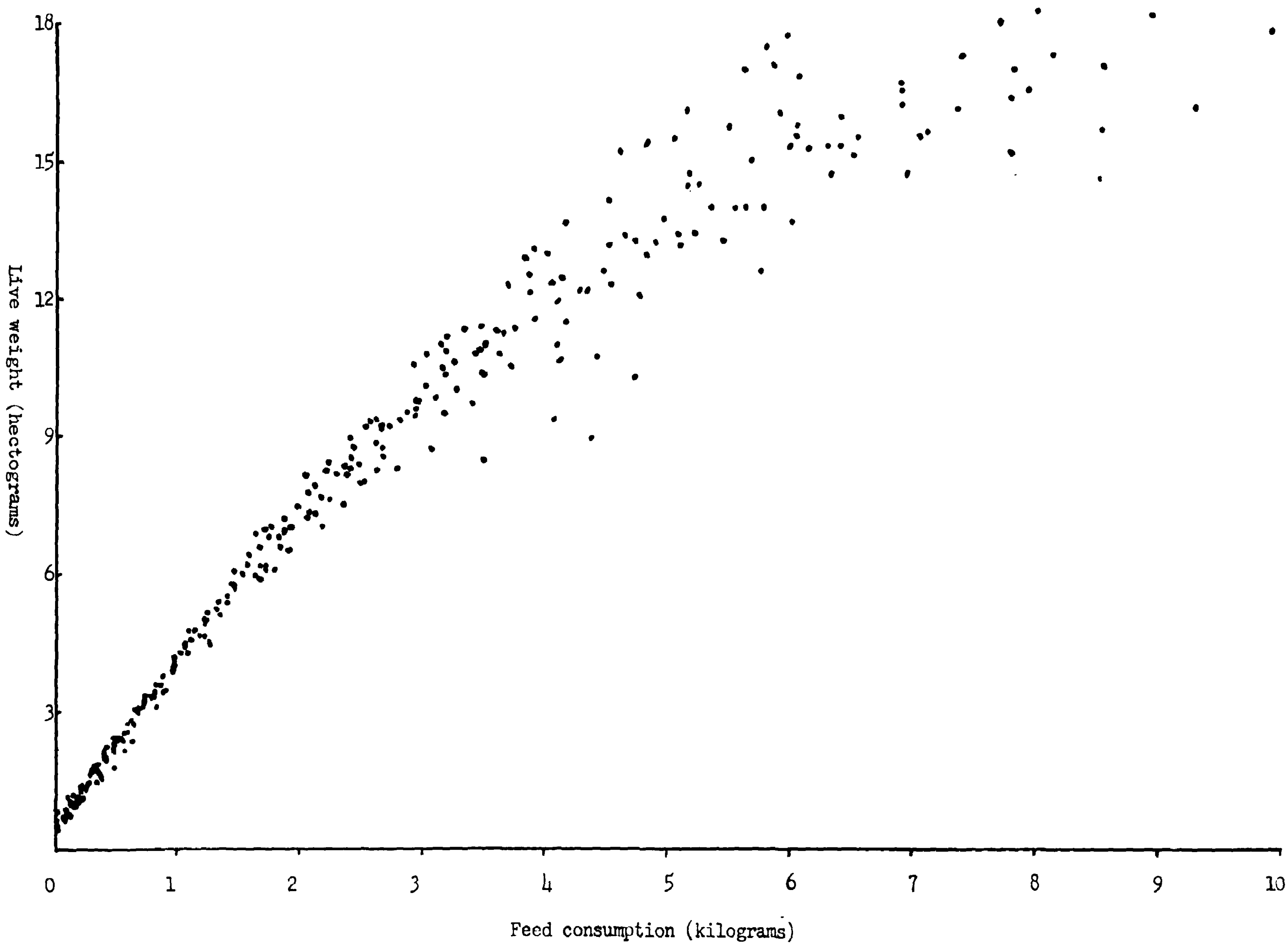


FIGURE 6. Live weight plotted as a function of feed consumption for the purebred progeny of New Hampshire sire 18.



Of course, the equation $y = a + bx$ has a very definite interpretation. The constant "a" is the y-intercept and in this particular case would represent the original weight of the chick at zero feed consumption or at the initiation of the experiment. Actually this value is higher than the initial weight of the chicks in most instances, and it is very variable. If this "a" value actually coincided with the initial weight, then the "b" value would be equivalant to the weight increase per unit of feed consumed. Analytically "b" or the coefficient of x represents the slope of the regression line and in this study is the grams of gain per gram of feed. Consequently, if this deviation from observed in the "a" constant did not exist then the "b" values would furnish an excellent means for comparing efficiencies. Generally, the higher the "a" value when the "b" values are the same, or the higher the "b" value with identical "a" values the more efficient will be a chicken or a group of chickens.

The regression constants and weights at various levels of feed consumption for the sires studied in 1938-1941 are presented in Tables I and II. It is shown that the progenies of sire 4A and two of his three sons had almost identical efficiencies, while the progeny of a third son, 4A3, was somewhat less efficient but still close to the others. The data for 4B, a half brother of 4A, are very limited but show that the progeny of 4B had approximately the same initial weight, although their efficiency decreased rapidly, due to a low "b" value.

Table I also shows that "a" values are almost identical for the progenies of sire 7 and his son 7A, and that the slope or "b" value is approximately the same. The regression equations for the progenies of sire 8 and his son 8A are also very similar. It is of interest to note that the White Leghorns started off at a low efficiency but became relatively more and more

TABLE I. Values of the constants in the regression equations of weight on feed consumption for the progenies of the sires studied.

Sire	Sire's No.	Sire's Sire	Sire's Dam	a		b	
				Purebreds	Crossbreds	Purebreds	Crossbreds
1	E2201	-	-	47.16	71.55	.308	.302
3	E2212	-	-	42.99	57.92	.289	.323
4	E2206	-	-	53.02	54.15	.288	.319
4A	L3492	4	I343	73.38	95.92	.269	.275
4A1	M4128	4A	I353	72.37	-	.276	-
4A2	M5229	4A	H225	68.49	77.33	.276	.321
4A3	M6022	4A	H272	58.64	42.20	.273	.312
4B	L2828	4	I380	61.81	73.02	.254	.296
4B1	M1176	4B	I366	72.45	-	.300	-
5	E2225	-	-	49.28	59.60	.310	.322
5A	L2711	5	H211	86.74	91.43	.280	.277
5B	L3531	5	I351	32.12	83.76	.294	.309
5B1	M5220	5B	I341	75.24	80.24	.270	.281
6	E2210	-	-	49.83	59.43	.305	.324
7	E2191	-	-	62.46	68.37	.287	.304
7A	L3567	7	I372	65.62	82.46	.275	.290
8	E2404	-	-	56.07	67.34	.269	.295
8A	L3586	8	H234	74.42	73.29	.268	.298
9	Red #6	-	-	48.21	53.39	.316	.321
9A	L3426	9	H278	78.41	-	.285	-
9A1	M2506	9A	I388	69.35	-	.272	-
White Leghorns	-	-	-	24.04	-	.295	-
Cornish	449	-	-	-	88.97	-	.302

TABLE II. Live weights of the progenies of the sires studied, at various levels of feed consumption substituted in the regression equations of weight on feed consumption.

Sire	Weights at various levels of feed consumption							
	at 500 gms.		at 1000 gms.		at 2000 gms.		at 3000 gms.	
	Pure-breds	Cross-breds	Pure-breds	Cross-breds	Pure-breds	Cross-breds	Pure-breds	Cross-breds
1	201.2	222.6	355.2	373.6	663.2	675.6	971.2	977.6
3	187.5	219.4	332.0	380.9	621.0	703.9	-	-
4	197.0	213.7	341.0	373.2	629.0	692.2	-	1011.2
4A	207.9	233.4	342.4	370.9	611.4	645.9	880.4	920.9
4A1	210.4	-	348.4	-	624.4	-	900.4	-
4A2	206.5	237.8	344.5	398.3	620.5	719.3	896.5	1040.3
4A3	195.1	198.2	331.6	354.2	604.6	666.2	877.6	978.2
4B	188.8	221.0	315.8	369.0	569.8	665.0	823.8	961.0
4B1	222.5	-	372.5	-	672.5	-	972.5	-
5	204.3	220.6	359.3	381.6	669.3	703.6	-	-
5A	226.7	229.9	366.7	368.4	646.7	645.4	926.7	922.4
5B	179.1	238.3	326.1	392.8	620.1	701.8	914.1	1010.8
5B1	210.2	220.7	345.2	361.2	615.2	642.2	885.2	923.2
6	202.3	221.4	354.8	383.4	659.8	707.4	-	-
7	206.0	220.4	349.5	372.4	636.5	676.4	923.5	980.4
7A	203.1	227.5	340.6	372.5	615.6	642.5	890.6	952.5
8	190.6	214.8	325.1	362.3	594.1	657.3	-	952.3
8A	208.4	222.3	342.4	371.3	610.4	669.3	878.4	967.3
Arithmetic mean	202.6	222.6	344.1	374.1	626.9	677.1	903.1	969.1
9	206.2	213.9	364.2	374.4	680.2	695.4	-	-
9A	220.9	-	363.4	-	648.4	-	933.4	-
9A1	205.4	-	341.4	-	613.4	-	885.4	-
White Leghorn	171.5	-	319.0	-	614.0	-	909.0	-
Cornish	-	240.0	-	391.0	-	693.0	-	995.0

efficient until at 3000 grams feed consumption their body weight was equal to the simple mean weight for all of the Barred Plymouth Rocks. On the other hand, the Cornish crossbreds started off efficiently and remained so throughout the experiment. It may thus be noted that wherever sufficient data are available, the body weights of the sons are reasonably close to those of the sire for any given feed consumption.

Although Tables I and II show that the crossbreds are more efficient than purebreds in utilizing their feed, this fact is emphasized in Table III, where the units of feed required per unit of gain at 500 grams live weight, calculated according to the respective regression equations, are arranged in descending order. The ten most efficient or lowest values are represented by crossbreds and the fifteen least efficient or highest values are purebreds. The most efficient crossbreds required 13.5 per cent less feed than the least efficient, while the most efficient purebreds required 21.0 per cent less than the least efficient.

Whereas Figures 1 to 4 show some typical scatter along the regression line, Figures 7 and 8 present a graphic comparison of the purebred and crossbred progenies of sire 7 and sire 8, and the purebred and crossbred progenies of their sons, respectively. It is noted that the progeny of the son of sire 7 was slightly less efficient than the progeny of sire 7, while the progeny of the son of sire 8 was slightly more efficient than the progeny of sire 8. It is of interest to observe that there is approximately the same difference between the purebreds and the crossbreds of the four sires plotted; namely, the crossbreds weighted 30 to 100 grams more than the purebreds at a given level of feed consumption. It should be noted also that the regression lines of the crossbreds are almost identical for the progenies of the four sires shown, but that the regression line for the

TABLE III. Units of feed per unit of gain at 500 grams body weight calculated according to the regression equation of weight on feed consumption.

Sire	Breed	Units of feed required per unit of gain
4A2	Crossbreds	2.633
5B	Crossbreds	2.694
6	Crossbreds	2.720
Cornish	Crossbreds	2.722
5	Crossbreds	2.735
3	Crossbreds	2.737
9	Crossbreds	2.783
4	Crossbreds	2.795
1	Crossbreds	2.837
7	Crossbreds	2.840
4B1	Barred Plymouth Rock	2.850
9	New Hampshires	2.859
8A	Crossbreds	2.864
7A	Crossbreds	2.880
4B	Crossbreds	2.885
5	Barred Plymouth Rock	2.908
8	Crossbreds	2.933
4A3	Crossbreds	2.935
4A	Crossbreds	2.939
1	Barred Plymouth Rock	2.940
5A	Crossbreds	2.950
5A	Barred Plymouth Rock	2.952
6	Barred Plymouth Rock	2.952
9A	New Hampshires	2.958
5B1	Crossbreds	2.988
7	Barred Plymouth Rock	3.049
4A1	Barred Plymouth Rock	3.099
4	Barred Plymouth Rock	3.104
4A2	Barred Plymouth Rock	3.127
5B1	Barred Plymouth Rock	3.146
7A	Barred Plymouth Rock	3.159
3	Barred Plymouth Rock	3.163
9A1	New Hampshires	3.166
4A	Barred Plymouth Rock	3.172
8A	Barred Plymouth Rock	3.176
5B	Barred Plymouth Rock	3.183
White Leghorn	White Leghorn	3.227
4A3	Barred Plymouth Rock	3.233
8	Barred Plymouth Rock	3.301
4B	Barred Plymouth Rock	3.450

FIGURE 7. Regression lines of live weight on feed consumption for the purebred and crossbred progenies of the two Barred Plymouth Rock sires 7 and 7A.

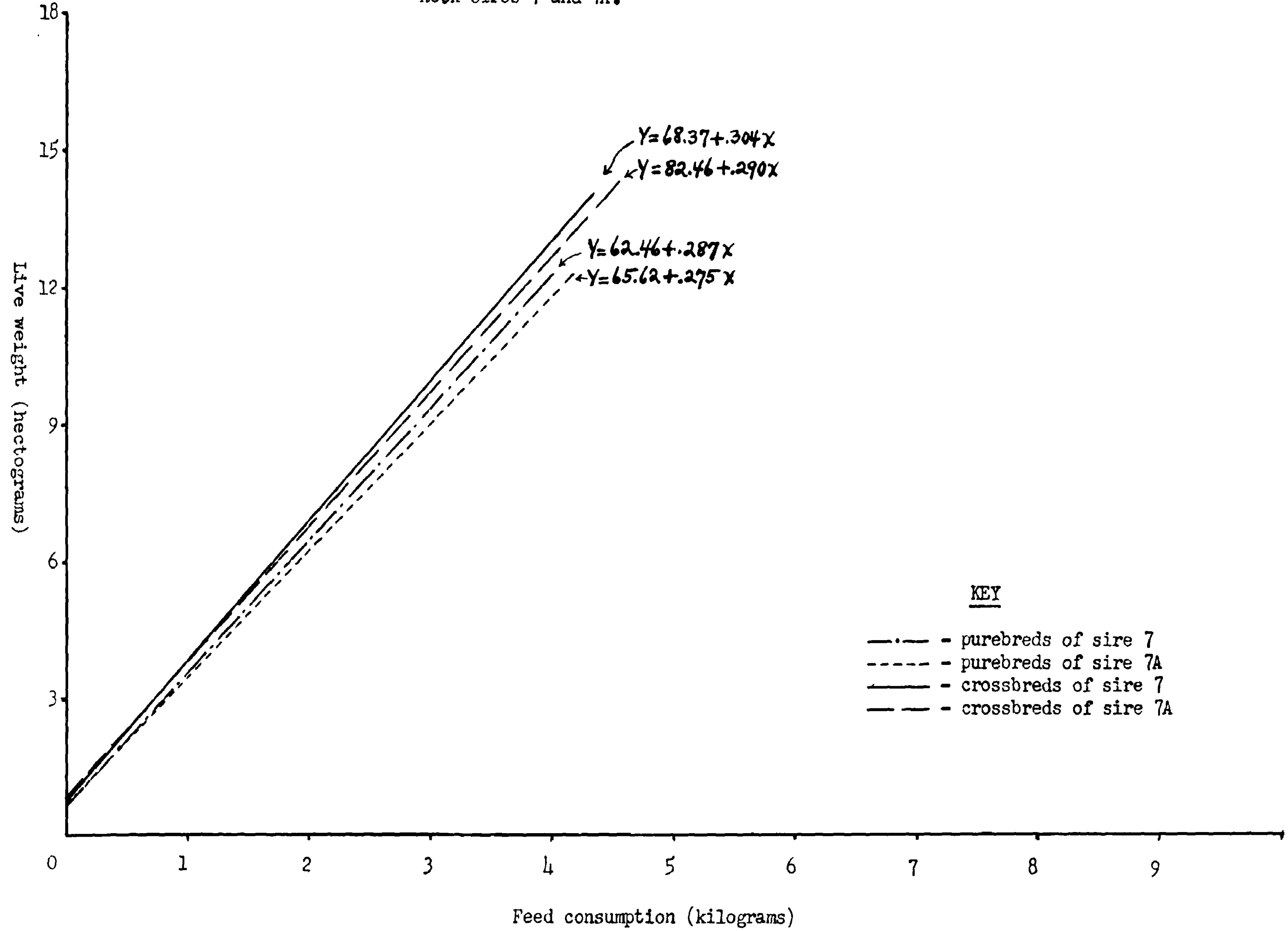
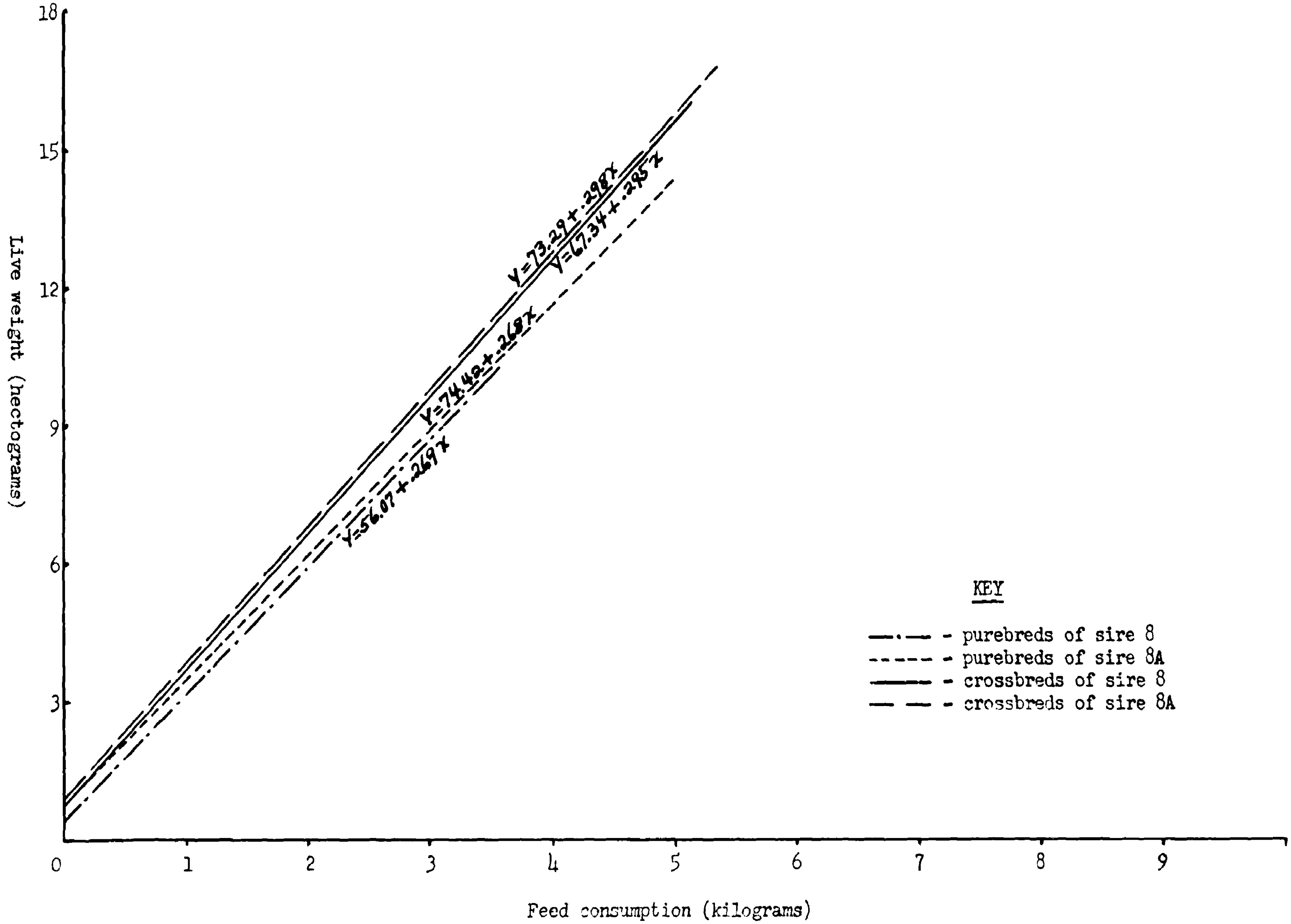


FIGURE 8. Regression lines of live weight on feed consumption for the purebred and crossbred progenies of the two Barred Plymouth Rock sires 8 and 8A.



purebred progenies of sire 7 and sire 7A are above the regression lines for the purebred progenies of sire 8 and sire 8A. This indicates that the crossbreds of 7 and 7A are identical to the crossbreds of 8 and 8A, but the purebred progenies of the former two sires are more efficient than the purebred progenies of the latter two.

The mean body weights of the progenies of the sires studied are presented in Table IV. With very few exceptions, the crossbreds are heavier than the purebreds of any given sire at any given week. The various sires studied, for example sire 6 and sire 8, differed considerably in the mean weights of their respective progenies.

From a practical standpoint, a very simple method for determining the relative efficiency of individuals or families is needed. Consequently, an attempt was made to calculate the units of feed per unit of gain by simply dividing the accumulative feed consumption by the final body weight minus the original weight. These data are presented in Table V for the progenies of the sires studied and in Table VI for the progenies of the dams and sisters of the sons and grandsons of the original sires. Although this procedure has a tendency to penalize the rapid growing chickens by not considering body weight or rate of gain, there are some interesting observations presented. For example, the progenies of 4A and 4B were both less efficient than the progeny of their sire 4, while the progenies of the sons of 4A were identical with their sire's progeny and amongst themselves in the units of feed required per unit of gain for both the purebreds and crossbreds. The purebred progenies of 5A and 5B were not as efficient as the progeny of 5, their sire, but they were quite homogenous among themselves, and the progeny of the son of 5B was similar to the progeny of his sire, 5B. Also, the progenies of 7A and 8A were very similar to their

TABLE IV. Mean weekly body weights for the progeny of the sires studied.

	0		1		2		3		4		5	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	38.2	44.6	57.3	66.3	76.8	110.8	141.8	180.0	188.9	279.4	287.9	369.9
3	39.2	43.3	52.0	62.6	82.2	98.7	132.1	158.6	191.9	245.2	259.8	348.2
4	37.6	41.3	48.3	54.9	72.1	87.5	114.6	145.8	175.2	201.9	242.7	281.4
4A	39.6	42.4	56.2	61.5	79.0	88.4	104.8	150.3	176.6	209.7	228.3	301.7
4A1	36.6	-	46.8	-	81.1	-	130.5	-	191.4	-	266.8	-
4A2	39.7	44.3	56.4	60.1	88.9	85.1	147.9	-	178.9	180.7	280.2	-
4A3	36.0	41.6	45.3	41.3	64.0	56.0	-	-	151.3	102.5	-	-
4B	38.8	34.8	43.3	54.3	66.3	81.8	-	-	143.0	201.8	211.3	-
4B1	36.0	-	47.8	-	83.5	-	138.8	-	209.5	-	277.2	-
5	37.1	42.6	52.2	57.1	80.8	92.8	125.7	167.5	187.2	221.9	264.3	297.6
5A	47.0	44.4	62.5	61.7	89.0	102.4	141.0	164.0	207.0	227.9	265.0	314.8
5B	41.0	42.8	55.7	62.9	88.9	108.2	138.6	171.6	202.1	246.9	254.0	325.4
5B1	38.7	40.5	50.8	51.4	76.2	76.6	123.9	126.8	172.2	185.2	274.6	290.1
6	38.0	41.4	52.1	56.5	79.2	88.2	120.4	152.7	189.7	239.4	286.1	355.3
7	37.6	41.7	51.1	58.9	76.0	87.0	124.3	143.5	180.4	204.1	263.5	289.0
7A	38.6	43.5	48.4	58.3	65.8	84.3	107.2	141.6	148.1	184.0	212.7	270.2
8	37.4	42.7	51.4	59.2	72.8	87.8	112.3	139.4	167.0	203.1	231.4	275.6
8A	41.1	41.2	55.3	56.3	82.0	84.5	135.3	135.0	183.7	198.6	272.1	291.5
9	41.9	37.6	62.1	63.6	93.5	95.7	147.3	150.4	217.9	225.0	299.5	311.3
9A	45.6	-	63.3	-	103.8	-	146.0	-	223.3	-	285.0	-
9A1	40.9	-	51.3	-	77.1	-	121.7	-	163.6	-	265.0	-
White Leghorn	37.0	-	48.5	-	78.9	-	122.7	-	161.3	-	222.3	-
Cornish	-	41.6	-	62.5	-	99.5	-	153.8	-	227.0	-	319.3

	6		7		8		9		10		11		12	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	368.5	479.5	486.5	588.0	568.2	712.1	-	-	823.3	-	-	-	1174.6	-
3	385.5	446.7	509.2	568.7	620.9	734.0	-	-	-	-	-	-	-	-
4	328.3	387.7	420.2	504.2	524.9	630.3	-	-	665.7	909.7	-	-	-	1117.5
4A	344.1	405.4	368.3	513.1	543.6	663.6	581.0	785.0	709.7	941.2	804.9	1098.0	892.1	1229.9
4A1	351.1	-	457.6	-	600.0	-	708.1	-	841.9	-	944.9	-	1065.0	-
4A2	349.6	349.0	482.7	-	568.8	595.0	738.2	-	839.3	902.0	984.3	-	1106.2	1079.3
4A3	306.7	181.0	-	-	454.3	479.0	-	-	653.3	768.0	-	-	969.0	1162.0
4B	289.3	401.0	-	-	497.7	615.8	-	-	683.0	915.5	-	-	-	1163.0
4B1	375.5	-	485.8	-	654.2	-	748.0	-	896.5	-	1032.3	-	1148.2	-
5	356.1	446.1	444.6	577.1	581.2	710.0	-	-	-	-	-	-	-	-
5A	375.0	423.5	436.5	520.0	490.0	644.3	593.0	775.7	709.0	914.6	-	-	866.0	1148.8
5B	349.5	432.0	441.7	520.0	546.5	674.0	641.9	790.6	749.0	950.9	852.5	1058.9	972.3	1166.1
5B1	334.5	368.9	447.0	481.6	522.0	580.5	597.6	714.7	736.4	840.0	865.7	978.8	963.8	1116.5
6	397.2	461.0	512.9	565.0	640.7	737.0	-	-	-	-	-	-	-	-
7	337.7	377.5	448.0	508.8	534.9	598.1	688.3	770.5	743.2	820.0	951.1	1045.5	971.2	1124.3
7A	297.9	353.4	377.5	494.3	496.7	616.6	580.5	784.6	720.0	885.3	803.5	1052.1	989.0	1154.5
8	297.4	372.2	355.7	467.7	450.1	587.1	440.3	731.7	566.6	852.6	761.3	948.0	686.6	1091.4
8A	333.0	367.4	417.7	477.2	496.8	590.8	651.3	753.8	704.7	849.6	877.8	988.3	1016.8	1134.4
9	403.5	413.3	523.3	523.3	673.9	653.4	-	-	-	-	-	-	-	-
9A	417.6	-	484.0	-	673.3	-	751.0	-	962.5	-	-	-	1300.5	-
9A1	308.8	-	479.4	-	518.6	-	690.7	-	779.0	-	960.0	-	1001.2	-
White Leghorn	315.9	-	404.7	-	544.9	-	651.6	-	744.9	-	827.6	-	933.0	-
Cornish	-	433.7	-	547.8	-	692.6	-	838.5	-	952.0	-	-	-	1298.6

(1) Purebreds
(2) Crossbreds

TABLE V. Units of feed per unit of gain for the progenies of the sires studied.

Sire	Purebreds P_1	Purebreds F_1	Purebreds F_2	Crossbreds P_1	Crossbreds F_1	Crossbreds F_2
1	3.4960	-	-	3.3088	-	-
3	3.4457	-	-	2.8788	-	-
4	3.3502	-	-	3.0909	-	-
4A	-	3.6679	-	-	3.3660	-
4A1	-	-	3.6233	-	-	-
4A2	-	-	3.7112	-	-	3.2713
4A3	-	-	3.7175	-	-	3.2708
4B	-	4.0354	-	-	3.4717	-
4B1	-	-	3.3580	-	-	-
5	3.3620	-	-	3.3932	-	-
5A	-	3.5849	-	-	3.8406	-
5B	-	3.6746	-	-	3.2830	-
5B1	-	-	3.7410	-	-	3.5355
6	3.3890	-	-	2.9337	-	-
7	3.5238	-	-	3.2348	-	-
7A	-	3.6361	-	-	3.5070	-
8	3.5688	-	-	3.3536	-	-
8A	-	3.7330	-	-	3.3282	-
9	3.2890	-	-	3.1713	-	-
9A	-	3.4605	-	-	-	-
9A1	-	-	3.8570	-	-	-
Arithmetic mean	3.4281	3.6846	3.6680	3.1706	3.4661	3.3592
White Leghorn	3.9843	-	-	-	-	-
Cornish	-	-	-	3.3801	-	-

TABLE VI. Units of feed per unit of gain for the dams and sisters of the F_1 and F_2 sires used.

	Efficiency when dam was mated to sire																
	1	3	4	4A	4A1	4A3	5	5A	5B	5B1	6	7	7A	8	8A	9	9A
Mean for purebreds	3.496	3.446	3.350	3.668	3.623	3.718	3.362	3.585	3.675	3.741	3.389	3.524	3.636	3.569	3.733	3.289	3.461
Mean for crossbreds	3.309	2.879	3.091	3.366	-	3.271	3.393	3.841	3.283	3.536	2.934	3.235	3.507	3.354	3.328	3.171	-
4A - 343	2.584	-	3.572	-	-	-	3.149	-	3.429	3.313	-	-	-	-	-	-	-
4A1 - 353	-	-	-	-	-	-	-	-	-	-	3.736	-	-	-	3.875	3.493*	-
- 853 (4Ax353)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.390	-	-
4A2 - 225	3.900	-	-	3.262	-	-	-	-	-	-	-	-	-	-	-	-	-
- 411 (1x225)	-	-	-	4.206	-	-	-	-	-	-	-	-	-	-	-	-	-
- 517 (5x225)	-	-	-	-	-	-	-	-	-	-	-	3.806	-	-	-	-	-
4A3 - 272	4.081	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4B - 380	-	-	2.905	-	-	-	-	-	-	-	-	3.015	-	-	-	-	-
-494 (4x380)	-	-	-	-	-	-	-	-	-	-	-	-	-	3.864	-	-	-
4B1 - 366	-	3.057	-	-	-	-	2.880	-	-	-	-	-	3.435	-	3.279	-	-
- 936 (8Ax366)	-	-	-	3.813	-	-	-	-	-	-	-	-	-	-	-	-	-
- 942 (8Ax464)	-	-	-	-	3.684	-	-	-	-	-	-	-	-	-	-	-	-
5A - 211	-	-	-	-	-	-	-	3.585	-	-	-	3.276	-	2.916	-	-	-
5B - 351	-	-	-	-	-	-	3.253	-	3.546	3.471	-	-	-	-	-	-	-
- 519 (5x351)	-	-	-	-	-	-	-	-	-	4.092	-	4.239	-	-	-	-	-
- 531 (5x351)	-	-	-	-	-	-	-	-	-	-	-	3.516	-	-	-	-	-
- 533 (5x351)	-	-	-	-	-	-	-	-	-	-	-	-	3.655	-	-	-	-
- 513 (5x351)	-	-	-	-	-	-	-	-	-	3.979	-	3.533	-	-	-	-	-
- 957 (7x513)	-	-	-	-	-	-	-	-	-	3.858	-	-	-	-	-	-	-
- 949 (7x513)	-	-	-	-	-	3.900	-	-	-	-	-	-	-	-	-	-	-
- 440 (7x351)	-	-	-	-	-	-	-	-	3.778	-	-	-	-	-	-	-	-
5B1 - 341	-	-	-	-	-	-	-	-	3.741	-	-	-	-	-	-	3.265*	-
7A - 372	-	2.613	-	-	-	-	-	-	-	-	-	3.313	-	-	-	-	-
8A - 234	-	-	3.380	-	-	-	-	-	-	-	-	-	-	3.297	3.565	-	-
- 601 (8x234)	-	-	3.790	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9A - 278	-	-	3.947*	-	-	-	-	-	-	-	-	-	-	-	-	3.406	-
- 457 (9x278)	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.165*	-	-
- 460 (9x278)	-	-	-	-	-	-	-	-	-	-	-	-	3.554*	-	-	-	-
- 443 (9x278)	-	-	-	-	-	-	-	-	-	-	-	-	-	3.647*	-	-	-
- 456 (9x278)	-	-	-	-	-	-	-	-	3.222*	-	-	-	-	-	-	-	-
9A1 - 388	-	-	-	-	-	-	-	-	-	3.081*	-	-	-	-	-	-	3.759
- 996 (9Ax388)	-	-	-	-	-	3.271*	-	-	-	-	-	-	-	-	-	-	-
- 1001 (9Ax388)	-	-	-	-	-	-	-	-	-	3.734*	-	-	-	-	-	-	-

* Crossbreds

sire's progeny in their feed requirement per unit of gain. It is noted that the units of feed per unit of gain are somewhat lower for the progeny of the original sires than for the two succeeding generations. This may possibly be accounted for by the fact that at first the majority of the birds were reared to eight weeks of age, while the latter generations were maintained on experiment until twelve weeks of age.

The date in Table VI are presented in order to show the efficiency of the progeny of the dam when mated to various sires. The mean units of feed per unit of gain for the progeny of each sire are given in order to compare the efficiency of the progeny of a dam when mated to a given sire, with the mean for that sire. It is shown, for example, that the progeny of the dam of sire 4A, dam 343, was more efficient than the mean for the sire with four out of the five males that sired her chicks. On the other hand, the progeny of the dam 4A1, dam 353, was less efficient than the sire's mean in three out of the three cases. In most cases the progeny of the sisters were less efficient than the progeny of the dam; probably again due to the greater age and consequently heavier weight to which the later chickens were reared.

Studying efficiency as a function of live weight is probably the most satisfactory procedure for analyzing the data presented here. For this analysis the equation $E = C - kW$ is employed, in which: E = the theoretical maximum efficiency if no feed is used for maintenance, W = the average weight for the animal or the period, calculated from the formula $\left(\frac{W_1 + W_2}{2}\right)$, k = a constant representing the decrease in efficiency per unit of weight or which has been interpreted by some as the maintenance requirement per unit of weight.

Table VII, which presents the efficiency for the purebred Barred Plymouth Rocks, the purebred New Hampshires and the Crossbreds, shows again

TABLE VII. Comparison of the sexes, and of all purebred Barred Plymouth Rocks, purebred New Hampshires, and Crossbreds (Barred Plymouth Rock male x New Hampshire female).

	No.	E	k x 1000	E when W = 500	E when W = 1000
B.P.R. male x B.P.R. female	928	.3815	.2075	.2778	.1740
N.H. male x N.H. female	199	.3720	.1299	.3070	.2421
B.P.R. male x N.H. female	752	.4072	.1861	.3142	.2211
B.P.R. males	85	.3692	.1835	.2775	.1857
B.P.R. females	69	.4119	.2571	.2834	.1548
N.H. males	24	.3736	.1283	.3095	.2453
N.H. females	22	.3806	.1638	.2987	.2168
(B.P.R. males x N.H. females) males	42	.4088	.1743	.3217	.2345
(B.P.R. males x N.H. females) females	43	.4075	.1844	.3153	.2231

that the crossbreds had a higher initial efficiency than the purebreds and that they decreased in efficiency more slowly than the purebred Barred Plymouth Rocks, due to a lower "k" value. On the other hand, the New Hampshires had a lower "k" value than either the Barred Plymouth Rocks or Crossbreds, and at 1000 grams live weight the New Hampshires were more efficient in utilizing their feed than the Barred Plymouth Rock or Crossbred chickens. This is shown graphically in Figure 9. At 500 grams live weight the Crossbreds required 13.1 per cent less feed than the Barred Plymouth Rocks and 2.3 per cent less than the New Hampshires, and the New Hampshires required 10.5 per cent less than the Barred Plymouth Rocks. At 1000 grams body weight this had changed to where the New Hampshires required 39.1 per cent less feed than the Barred Plymouth Rocks and 9.5 per cent less than the Crossbreds, and the Crossbreds required 27.1 per cent less than the Barred Plymouth Rocks. Thus the New Hampshires initially were the least efficient but at 150 grams live weight had exceeded the Barred Plymouth Rocks and at 700 grams both the Barred Plymouth Rocks and Crossbreds in feed utilization efficiency.

Figure 10 as well as Table VII show a comparison between the efficiency of the two sexes. In all three cases, namely the New Hampshires, Barred Plymouth Rocks, and Crossbreds, the males had a slightly lower "k" value than the females. This would mean that theoretically the males have a lower maintenance requirement than females, or another explanation is that the females approach their maximum or mature body weight sooner than the males and consequently get into the area of slower growth and lower efficiency before the males do. The actual efficiency at 500 grams body weight shows that the purebred Barred Plymouth Rock females required 2.1 per cent less feed than the males, the purebred New Hampshire males

FIGURE 9. Efficiency as a function of live weight for the purebred progenies of the New Hampshire sires, and the purebred and crossbred progenies of the Barred Plymouth Rock sires.

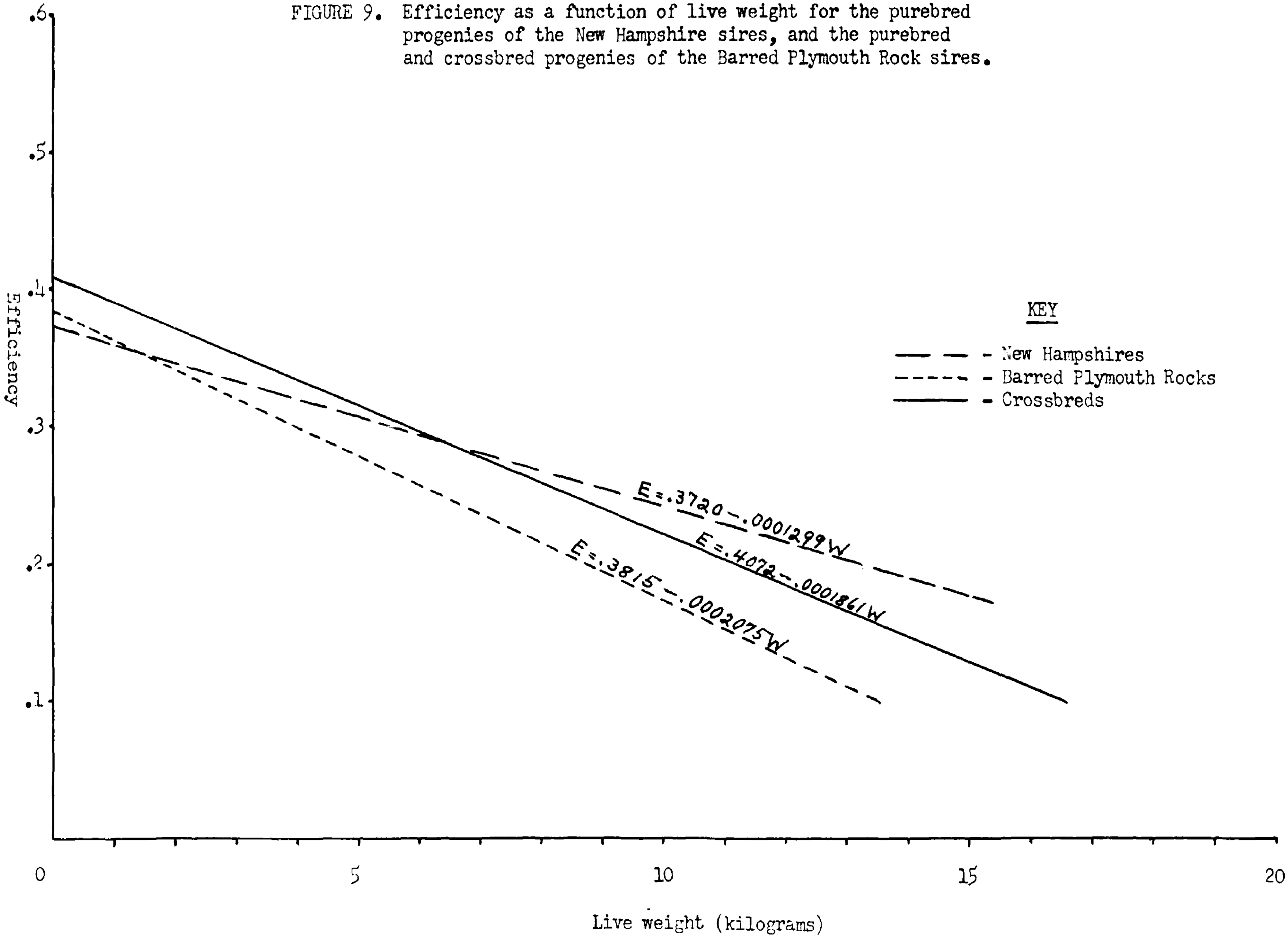
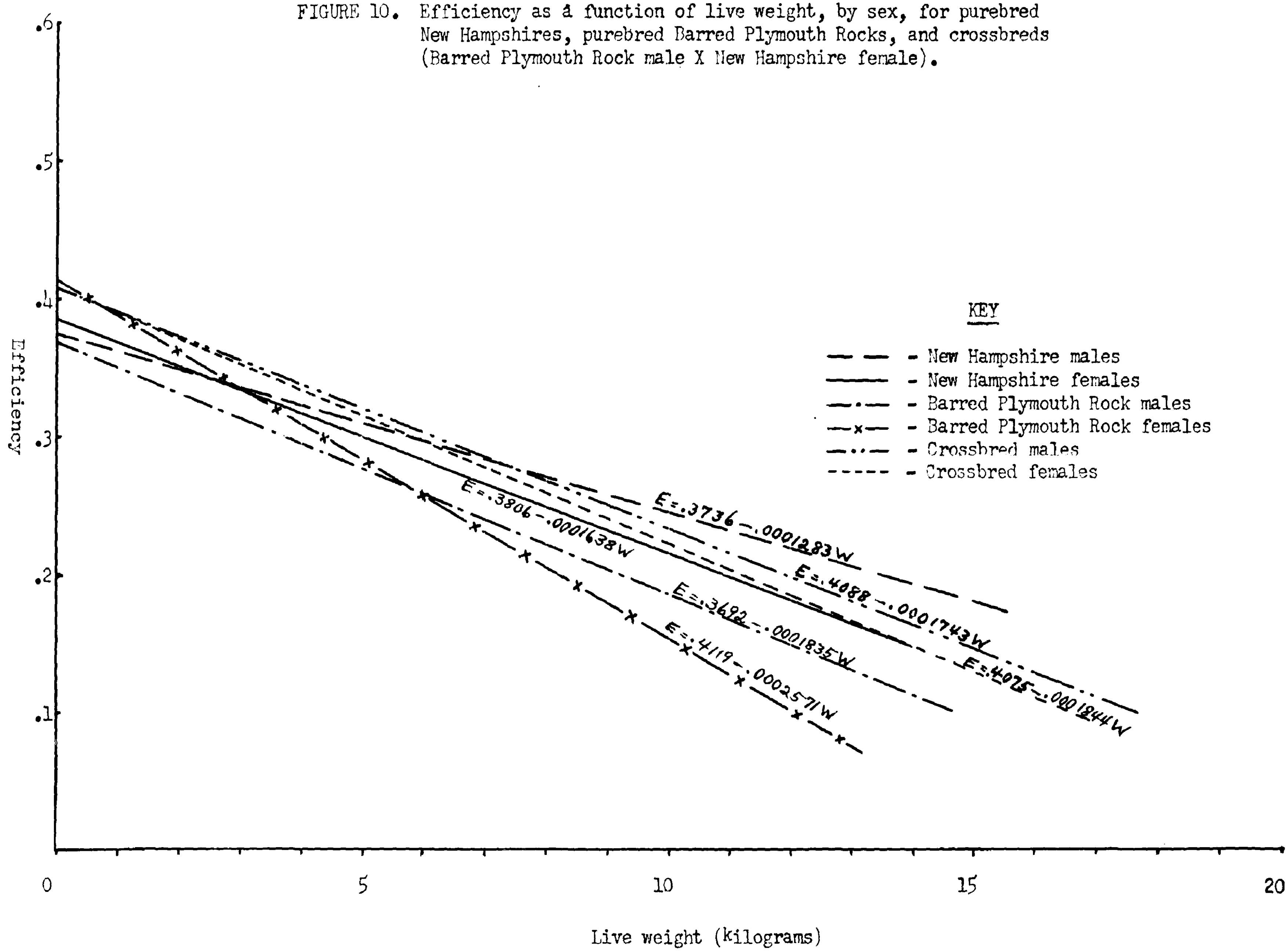


FIGURE 10. Efficiency as a function of live weight, by sex, for purebred New Hampshires, purebred Barred Plymouth Rocks, and crossbreds (Barred Plymouth Rock male X New Hampshire female).



3.6 per cent less feed than the females, and the crossbred males required 2.0 per cent less feed than the females. In other words, there was very little difference in efficiency between the sexes at 500 grams body weight. At 1000 grams body weight the crossbred males, the purebred New Hampshire, and the purebred Barred Plymouth Rock males required 5.1 per cent, 13.1 per cent, and 20.0 per cent less feed than the females, respectively. It would seem, therefore, that there is not much difference between the sexes until they get into the higher weights or even approach maturity. For the males at 1000 grams live weight the New Hampshires were the most efficient and the Barred Rocks the least efficient, while for the females the Crossbreds were the most efficient and the Barred Plymouth Rocks the least efficient.

Table VIII, giving the values for the constants, and Table IX, the efficiencies at various body weights for the various sires studied, verify the previous finding that in almost every case the crossbreds are more efficient than the purebreds of any given sire. Table VIII also shows that there is a marked difference in the behaviour of the efficiency of the progeny of different sires. For example, the progeny of sire 4B had a very low initial efficiency but the decrease was so slow that the efficiency almost remained a straight line, whereas, the progeny of sire 5A had a very high initial efficiency and as the body weight increased the efficiency dropped very rapidly. Still another type of behaviour is exhibited by the efficiency of the crossbred progeny of sire 4A3. In this case the initial efficiency increased with an increase in body weight. Apparently this reversal of the normal slope is due to a slow start by the chicks, and could undoubtedly be brought about by an attack of coccidiosis or some other abnormal condition which would affect the intestinal tract and interfere with the absorption of food in early life.

TABLE VIII. Values of the constants in the equation E = C - kW for the purebred and crossbred progenies of various sires.

	C		k x 1000	
Sire	Pure-bred	Cross-bred	Pure-bred	Cross-bred
1	.3799	.4388	.1792	.3362
3	.3628	.3998	.2194	.1642
4	.3522	.3756	.1628	.1317
4A	.3898	.4079	.2414	.1651
4A1	.3818	-	.1727	-
4A2	.3959	.4515	.1874	.2316
4A3	.4051	.2830	.2614	-.0261
4B	.2811	.4124	.0838	.1877
4B1	.4248	-	.2049	-
5	.3822	.4078	.1638	.2042
5A	.4333	.4166	.3035	.2362
5B	.3789	.4490	.1999	.2235
5B1	.4116	.4049	.2571	.1955
6	.3600	.4281	.1897	.2439
7	.4105	.4053	.2442	.1788
7A	.3654	.4106	.1722	.1960
8	.3437	.4243	.1740	.2124
8A	.4186	.4076	.2992	.1839
9	.4048	.4142	.2520	.2733
9A	.3828	-	.1457	-
9A1	.3747	-	.1887	-
White Leghorn	.3460	-	.1757	-
Cornish	-	.4402	-	.2060

TABLE IX. Efficiencies of the progenies of the sires used in 1938-1941, at various weights.

Sire	No. of groups		Sex (1)		Sex (2)		Average weights		E when W = 400		600		800		1000	
	(1)	(2)	(3)	(4)	(3)	(4)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
1	18	6	39	37	24	30	860.7	678.2	.3082	.3043	.2724	.2371	.2365	-	-	-
3	11	10	28	18	24	17	371.6	410.3	.2750	.3341	-	-	-	-	-	-
4	20	31	36	38	52	49	451.5	482.6	.2871	.3229	-	-	-	-	-	-
4A	9	5	25	26	15	16	833.9	1115.2	.2932	.3419	.2450	.3089	.1967	.2759	-	.2429
4A1	3	-	11	7	-	-	1005.0	-	.3127	-	.2782	-	.2436	-	.2091	-
4A2	5	1	14	3	3	4	902.8	1079.3	.3209	.3589	.2835	.3125	.2460	.2662	.2085	.2199
4A3	3	1	-	3	2	5	820.7	1162.0	.3005	.2934	.2483	.2987	.1960	.3039	-	.3091
4B	1	1	1	3	2	2	683.0	1163.0	.2476	.3373	.2308	.2998	-	.2622	-	.2247
4B1	1	-	2	4	-	-	1148.2	-	.3428	-	.3019	-	.2609	-	.2199	-
5	20	14	29	32	22	31	385.2	390.1	.3167	.3261	-	-	-	-	-	-
5A	2	5	2	-	5	8	866.0	1049.3	.3119	.3221	.2512	.2749	.1905	.2276	-	.1804
5B	30	13	17	21	15	20	766.0	1090.4	.2989	.3596	.2590	.3149	.2190	.2702	-	.2255
5B1	14	8	28	26	30	40	787.3	1116.5	.3088	.3267	.2573	.2876	.2059	.2485	-	.2094
6	8	7	24	16	20	18	411.5	449.8	.2841	.3305	-	-	-	-	-	-
7	46	40	59	63	63	52	672.7	679.1	.3128	.3338	.2640	.2980	-	-	-	-
7A	9	6	26	24	13	12	989.0	1154.5	.2965	.3322	.2621	.2930	.2276	.2538	.1932	.2146
8	34	21	48	47	32	30	391.4	573.2	.2741	.3393	-	.2969	-	-	-	-
8A	30	13	47	54	40	35	839.8	1021.0	.2989	.3340	.2391	.2973	.1792	.2605	-	.2237
Simple average	-	-	-	-	-	-	-	-	.2995	.3311	.2610	.2933	.2183	.2632	.2077	.2278
9	5	8	10	10	30	31	673.9	633.7	.3040	.3049	.2536	.2502	-	-	-	-
9A	3	-	6	5	-	-	1111.1	-	.3245	-	.2954	-	.2662	-	.2371	-
9A1	10	-	11	19	-	-	838.9	-	.2992	-	.2615	-	.2237	-	-	-
White Leghorn	4	-	11	10	-	-	933.0	-	.2757	-	.2406	-	.2054	-	.1703	-
Cornish	-	7	-	-	21	14	-	1197.4	-	.3578	-	-	-	-	-	-

(1) Purebreds
(2) Crossbreds
(3) Males
(4) Females

Table IX shows the wide variability in efficiency among the progeny of the various sires used. For example, the purebred progeny of sire 7 representing 124 individuals had an efficiency of .3128 at 400 grams body weight, while the progeny of sire 8 representing 95 individuals had an efficiency of .2741 at the same weight; or 14.1 per cent less feed was required by the progeny of sire 7 than by those of sire 8. It will be noted that the efficiency for the crossbreds is considerably higher than that for the purebreds, and somewhat less variable. However, the 35 crossbred chicks of sire 5B and the 54 crossbred chicks of sire 1 also differed considerably, the progeny of sire 5B requiring 14.9 per cent less feed than the progeny of sire 1 at 400 grams body weight, and 32.8 per cent less feed at 600 grams.

Table X presents a summary of the dams and sisters of the F_1 and F_2 males used. Some interesting results are presented here. For example, comparing efficiencies at 500 grams body weight, the progeny of sire 5 had an efficiency of .3003, and the progeny of dam H211 had an efficiency of .2767, but the son of sire 5 and dam H211 produced progeny with an efficiency of .2815. Furthermore, the progeny of dam I351 had an efficiency of .2891, and that of the progeny of sire 5 was .3003, while sire 5 and dam I351 produced a son whose progeny had an efficiency of .2789, and daughters whose progeny had an efficiency of .2887. In other cases the association between the efficiencies of the sire's, dam's, and son's progeny was not nearly as good.

Table XI presents data on some New Hampshire chicks grown in individual cages to 12 weeks and to a definite weight. From these data it has been determined that up to 12 weeks of age and at 1000 grams body weight all male progeny required 8.7 per cent less feed than all female progeny, and that there was no difference between the progenies of the two males used. Carrying these chickens to a definite weight shows fundamentally the same result.

TABLE X. Summary of the dams and sisters of the F_1 and F_2 males.

Dam	Son	No. of groups	(1)	(2)	Mean weeks on test	Mean weight	C	k x 1000	Efficiency (when W = 500) of progeny of son's dam	son's sire	son
I343	4A	11	23	14	9.2	686.5	.3934	.1907	.2980	.2708	.2691
I353 Purebred	4A1	4	11	10	10.5	855.3	.3754	.2020	.2744	.2691	.2954
I353 Crossbred	-	1	4	2	8.0	568.3	.4101	.3893	.2154	-	-
I353 Daughter	-	1	5	8	12.0	813.3	.3072	-.0452	.2846	-	-
H225	4A2	3	5	5	8.7	640.1	.3634	.2139	.2564	.2691	.3022
H225 Daughter	-	2	2	2	11.0	771.8	.3812	.2945	.2339	-	-
H272	4A3	1	2	3	8.0	667.3	.3796	.3386	.2103	.2691	.2744
I380	4B	8	8	13	6.5	478.4	.3730	.1454	.3003	.2708	.2392
I380 Daughter	-	2	1	2	11.0	662.7	.3322	.1968	.2338	-	-
I366	4B1	11	11	7	7.0	502.9	.3535	.0839	.3115	.2392	.3223
I366 Daughter	-	2	8	7	12.0	1026.0	.3661	.1681	.2820	-	-
H211	5A	9	5	4	7.6	488.9	.3903	.2272	.2767	.3003	.2815
I351	5B	10	14	12	7.1	479.6	.3367	.0952	.2891	.3003	.2789
I351 All daughters	-	34	31	29	8.3	882.5	.3718	.1821	.2807	-	-
I351 Daughter (5 x 351)	-	23	25	23	6.9	903.0	.3822	.1870	.2887	-	-
I351 Daughter (7 x 351)	-	11	6	6	11.1	839.7	.3542	.1818	.2633	-	-
I351 Daughter (513)	-	13	18	11	11.4	992.8	.4043	.2032	.3027	-	-
I351 Grand-daughter (daughter of 513)	-	4	3	5	11.5	807.0	.3952	.2774	.2565	-	-
I341 Purebred	5B1	1	1	-	12.0	1166.0	.4510	.2798	.3111	.2789	.2830
I341 Crossbred	-	2	8	9	8.0	629.3	.3929	.2439	.2709	.3373	.3071
I372	7A	7	9	5	6.3	432.1	.3651	.1807	.2747	.2884	.2793
H234	8A	7	7	13	8.6	605.2	.3703	.1838	.2784	.2567	.2690
H234 Daughter	-	1	-	1	10.0	688.0	.3305	.1934	.2338	-	-
H278 New Hampshire	9A	2	4	6	8.0	690.5	.4032	.2698	.2683	.2788	.3099
H278 Crossbred	-	1	-	1	8.0	342.0	.3909	.6521	.0648	.2776	-
H278 Daughter	-	7	6	6	12.0	997.0	.4229	.1827	.3315	-	-
I388 New Hampshire	9A1	1	1	-	12.0	1273.0	.3805	.1658	.2976	.3099	.2803
I388 Crossbred	-	1	3	1	8.0	792.8	.4562	.2921	.3101	-	-
I388 Daughter crossbred	-	2	8	9	12.0	1149.8	.3610	.1305	.2957	-	-

(1) Male
(2) Female

TABLE XI. New Hampshires grown in individual cages to a definite age and to a definite weight.

	No.	Mean weight	Units of feed per unit gain	E = C - kW	E when W = 1000	E when W = 1500
				TO 12 WEEKS		
Males of 17	7	1423.4	3.4063	E = .4018 - .0001610 W	.2408	-
Males of 18	13	1212.8	3.3659	E = .3735 - .0001227 W	.2508	-
Females of 17	9	1140.4	3.6367	E = .3718 - .0001481 W	.2318	-
Females of 18	8	1109.0	3.4528	E = .3840 - .0001522 W	.2237	-
All males	20	1268.2	3.3804	E = .3833 - .0001365 W	.2468	-
All females	16	1125.7	3.5505	E = .3782 - .0001511 W	.2271	-
All of 17	15	1249.2	3.5221	E = .3851 - .0001533 W	.2318	-
All of 18	21	1178.2	3.3948	E = .3768 - .0001316 W	.2452	-
				TO DEFINITE WEIGHT		
Males of 17	6	1726.7	3.8546	E = .3869 - .0001346 W	.2523	.1850
Males of 18	12	1621.5	3.9459	E = .3735 - .0001261 W	.2474	.1843
Females of 17	7	1742.6	4.8906	E = .3757 - .0001613 W	.2144	.1337
Females of 18	6	1718.0	4.8710	E = .3889 - .0001731 W	.2158	.1292
All males	18	1656.6	3.9130	E = .3780 - .0001290 W	.2490	.1845
All females	13	1731.2	4.8811	E = .3824 - .0001672 W	.2152	.1316
All of 17	13	1735.2	4.4188	E = .3825 - .0001547 W	.2278	.1504
All of 18	18	1653.7	4.3035	E = .3820 - .0001512 W	.2308	.1552

There is still no difference between the efficiency of the progenies of sire 17 and sire 18, as shown in Figure 11, but the difference between the sexes as shown in Figure 12 is very marked. At 1500 grams body weight the males required 40.2 per cent less feed than the females. It is also noteworthy to observe that the "k" value is very uniform, and that of the males is much lower than that of females when reared to a definite weight.

Table XII gives the mean weight, and values for the constants in the equation $E = C - kW$ for the data up to 12 weeks and up to a definite weight. It should be noted that both the "C" and "k" values are exceptionally uniform for the progeny of a given dam whether the data were collected up to a definite time or a definite weight. Dam 808 mated to sire 17 and dam 734 mated to sire 18 gave the heaviest 12-week chicks, and they also had a relatively high initial efficiency and a low slope or slow decrease in efficiency. On the other hand, dam 832 produced progeny that was the lightest at 12 weeks and which also had a relatively low efficiency.

By substituting a given weight for "W" in each equation, the results in Table XIII are obtained. The efficiency values obtained at 500 grams body weight are almost identical whether the chickens were reared to a definite weight or to a definite age. The agreement is still very satisfactory at 1000 grams body weight, but these data indicate that by collecting feed efficiency data up to 12 weeks and making your comparison at 500 grams body weight, you obtain approximately the same efficiency as if you retained the birds on experiment until almost maturity. It is interesting to note that the progeny of dam 808 attained the mean weight of 1707.0 grams at 13 weeks, while the progeny of dam 747 averaged 1742.7 grams in 15 to 20 weeks or a mean of 17.3 weeks. At 1700 grams the efficiency differed enormously,

FIGURE 11. Efficiency as a function of live weight for the progenies of New Hampshire sires 17 and 18, reared to a definite age and to a definite weight.

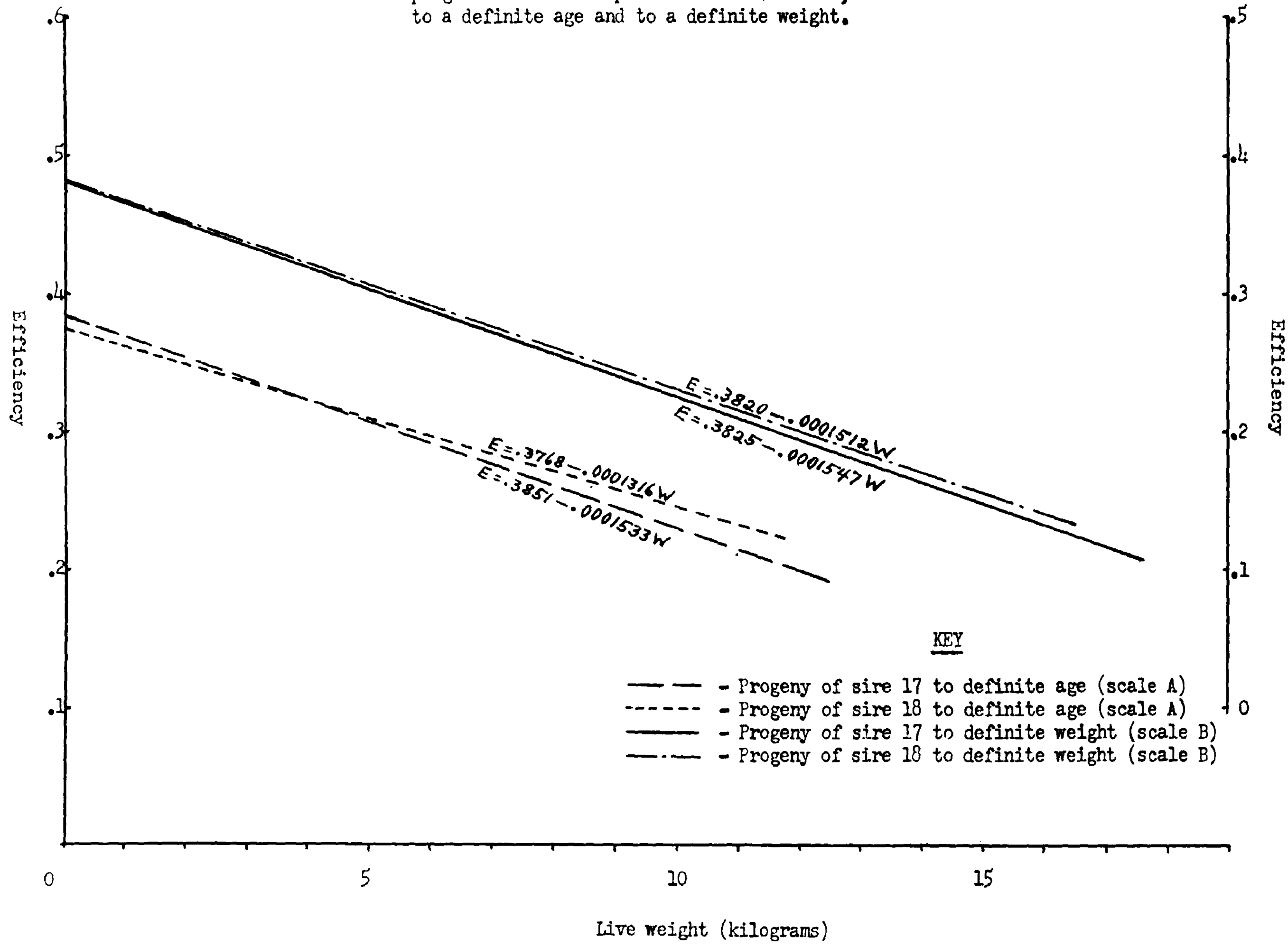


FIGURE 12. Efficiency as a function of live weight, by sex, for purebred New Hampshires reared to a definite age and to a definite weight.

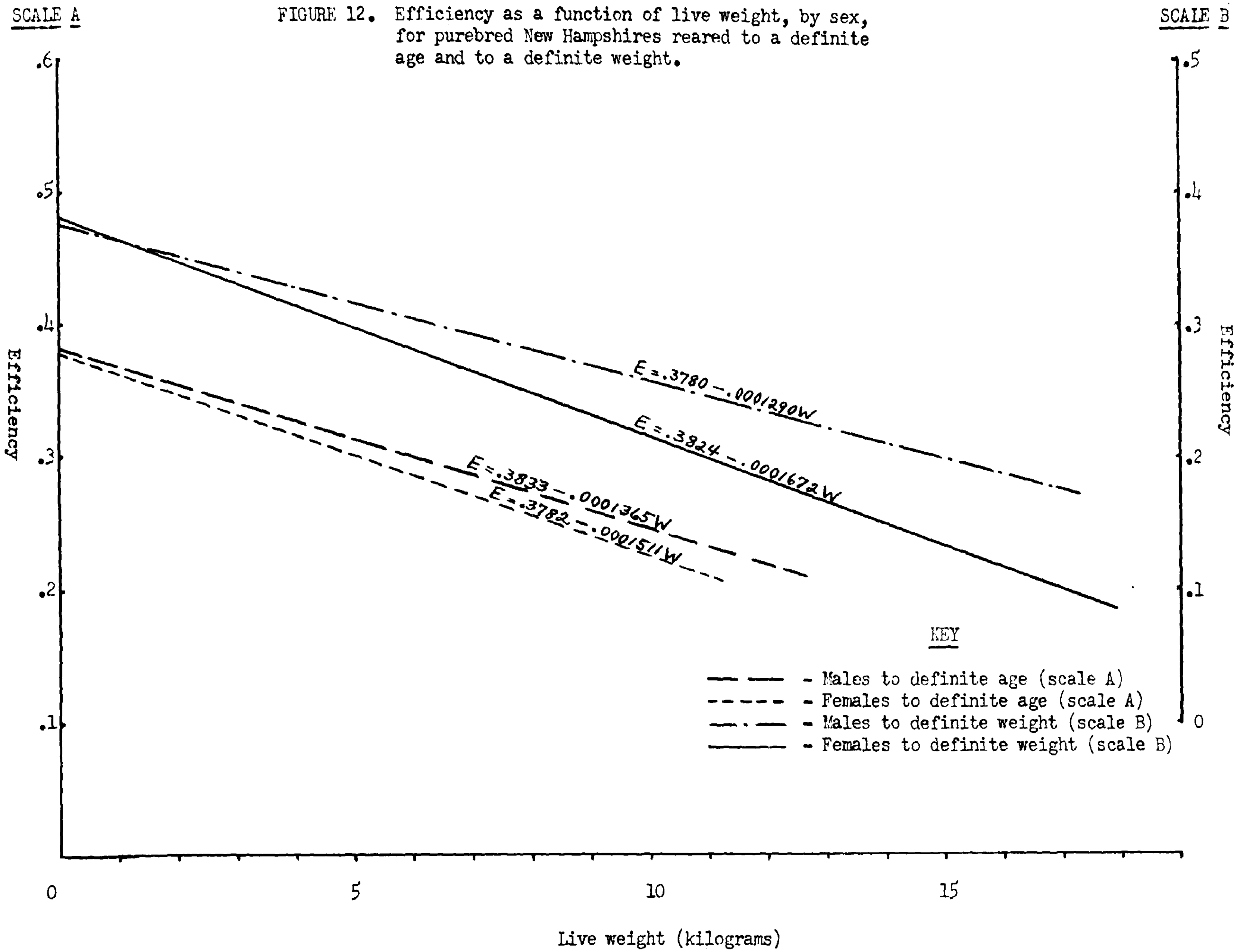


TABLE XII. Constants in the equation E = C - kW at 12 weeks and at a definite weight for the progenies of the New Hampshire dams.

	Number		Mean weight		C		k x 1000	
	Males	Females	12 weeks	Definite weight	12 weeks	Definite weight	12 weeks	Definite weight
Sire 17:								
711	1	-	693.0*	-	.4292	-	.3863	-
739	-	1	1044.0	1778.0	.3644	.3507	.1774	.1502
747	1	2	1173.0	1742.7	.3875	.3888	.1740	.1774
750	-	1	1162.0	1718.0	.3930	.3947	.1588	.1645
760	-	3	1114.3	1668.0	.3532	.3835	.1203	.1601
762	2	-	1342.0	1766.5	.3846	.3831	.1513	.1479
808	7	3	1463.8	1707.0	.4043	.4124	.1256	.1279
850	9	4	1315.7	1775.5	.3803	.3869	.1114	.1353
Sire 18:								
734	2	-	1475.0	1738.5	.4093	.4063	.1302	.1227
755	2	1	1291.3	1700.3	.3857	.3922	.1219	.1415
816	1	-	1080.0	1103.0**	.4221	.4361	.2312	.2743
825	2	2	1257.0	1722.0	.3692	.3901	.1072	.1448
830	2	1	1193.7	1735.0	.3891	.3964	.1417	.1672
832	1	1	942.5	1314.0	.3796	.3692	.1956	.1795
833	3	5	1115.3	1649.3	.3697	.3669	.1390	.1441
849	5	3	1055.4	1738.3	.3711	.3647	.1330	.1407

* 10 weeks
** 13 weeks

TABLE XIII. Efficiency values for the progenies of New Hampshire dams at various weights when reared to a definite age and to a definite weight.

	E when						Mean number of weeks on experiment		Range in weeks	
	W = 500		W = 1000		W = 1700					
Dam	age	weight	age	weight	age	weight	age	weight	age	weight
711	.2360	-	-	-	-	-	10	-	10	-
739	.2757	.2756	.1870	.2005	-	.1254	12	20	12	20
747	.3005	.3001	.2135	.2114	-	.0872	12	17.3	12	15-20
750	.3136	.3125	.2342	.2302	-	.1160	12	16	12	16
760	.2931	.3035	.2329	.2234	-	.1113	12	16	12	15-17
762	.3090	.3092	.2931	.2352	-	.1317	12	14.5	12	13-16
808	.3415	.3485	.2787	.2845	-	.1950	12	13	12	13
850	.3246	.3193	.2689	.2516	-	.1569	12	15.5	12	14-17
734	.3442	.3450	.2791	.2836	-	.1977	12	13	12	13
755	.3248	.3215	.2638	.2507	-	.1517	12	14.7	12	13-17
816	.3065	.2990	.1909	.1618	-	-	12	13	12	13
825	.3156	.3177	.2620	.2453	-	.1439	10.3	15	6-12	13-17
830	.3183	.3128	.2474	.2292	-	.1122	12	15.3	12	14-19
832	.2818	.2795	.1840	.1897	-	.0641	11.5	16.5	11-12	13-20
833	.3002	.2949	.2307	.2228	-	.1259	12	16.3	12	14-18
849	.3046	.2944	.2381	.2240	-	.1255	12	17.7	12	14-20

those of 808 requiring 123.6 per cent less feed than those of 747. The progeny of dam 734 required 208.4 per cent less feed at 1700 grams than the progeny of dam 832.

Table XIV gives a summary of the results of mating daughters from several dams to both sires 17 and 18 at random. This table again shows that there is no difference in the efficiency of the progeny of sires 17 and 18. However, the progeny of daughters of sire 18 mated to sire 17 required 9.7 per cent less feed at 1000 grams body weight than the progeny of daughters of sire 18 mated back to their father. This is also shown in Figure 13. When sires 17 and 18 were mated to a group of daughters of sire 10, a sire unrelated to either 17 or 18, then the progeny of sire 18 required 2.9 per cent less feed than the progeny of sire 17. Apparently, inbreeding, even though mild in this case, had a detrimental effect upon the efficiency of feed utilization. The fact that the Barred Plymouth Rocks were so much less efficient than the New Hampshires is interesting. The least efficient New Hampshires required 40.7 per cent less feed and the most efficient 60.5 per cent less feed than the Barred Plymouth Rocks at 1000 grams body weight. The data in Table XIV again show that growth and efficiency are very closely related and that in general the most rapid growing are also the most efficient.

To study the effect of rate of growth on efficiency, the six fastest growing males and females, and the six slowest growing males and females were selected for comparison. The summary of this study on these twenty-four birds is presented in Table XV, and shown graphically in Figure 14 and 15. At 12 weeks of age, or 1000 grams, the fast-growing males required 5.4 per cent less feed than the slow-growing males and at a 1750 grams body weight they required 16.3 per cent less feed. The fast-growing females required 24.0 per cent less feed than the slow-growing females at 1000 grams, and 55.0

TABLE XIV. Values of the constants in the equation $E = C - kW$, and the efficiency of the progenies of daughters of the New Hampshire sires and dams.

	Sex		Mean			E when
	Males	Females	weight	C	k x 1000	W = 1000
Daughter of 808	6	8	1405.4	.3461	.0826	.2635
Daughter of 830	10	12	1470.2	.3458	.0624	.2834
Daughter of 850	6	12	1408.6	.3614	.0860	.2754
Daughter of 760	2	1	1644.5	.3153	.0341	.2812
Daughter of 833	8	11	1448.8	.3596	.0962	.2634
Daughter of 849	4	5	1342.0	.3393	.0788	.2605
Dam 850	3	5	1318.9	.3701	.1216	.2485
Dam 825	5	2	1502.6	.3122	.0386	.2736
Barred Plymouth Rock	5	2	1196.7	.3376	.1610	.1766
17 x daughter of 18	9	12	1543.8	.3694	.0924	.2770
18 x daughter of 18	3	8	1224.1	.3366	.0841	.2525
17 x daughter of 10	10	10	1469.4	.3456	.0786	.2670
18 x daughter of 10	13	19	1417.8	.3471	.0724	.2747
All 17	22	27	1485.7	.3583	.0884	.2699
All 18	23	30	1390.8	.3365	.0657	.2708

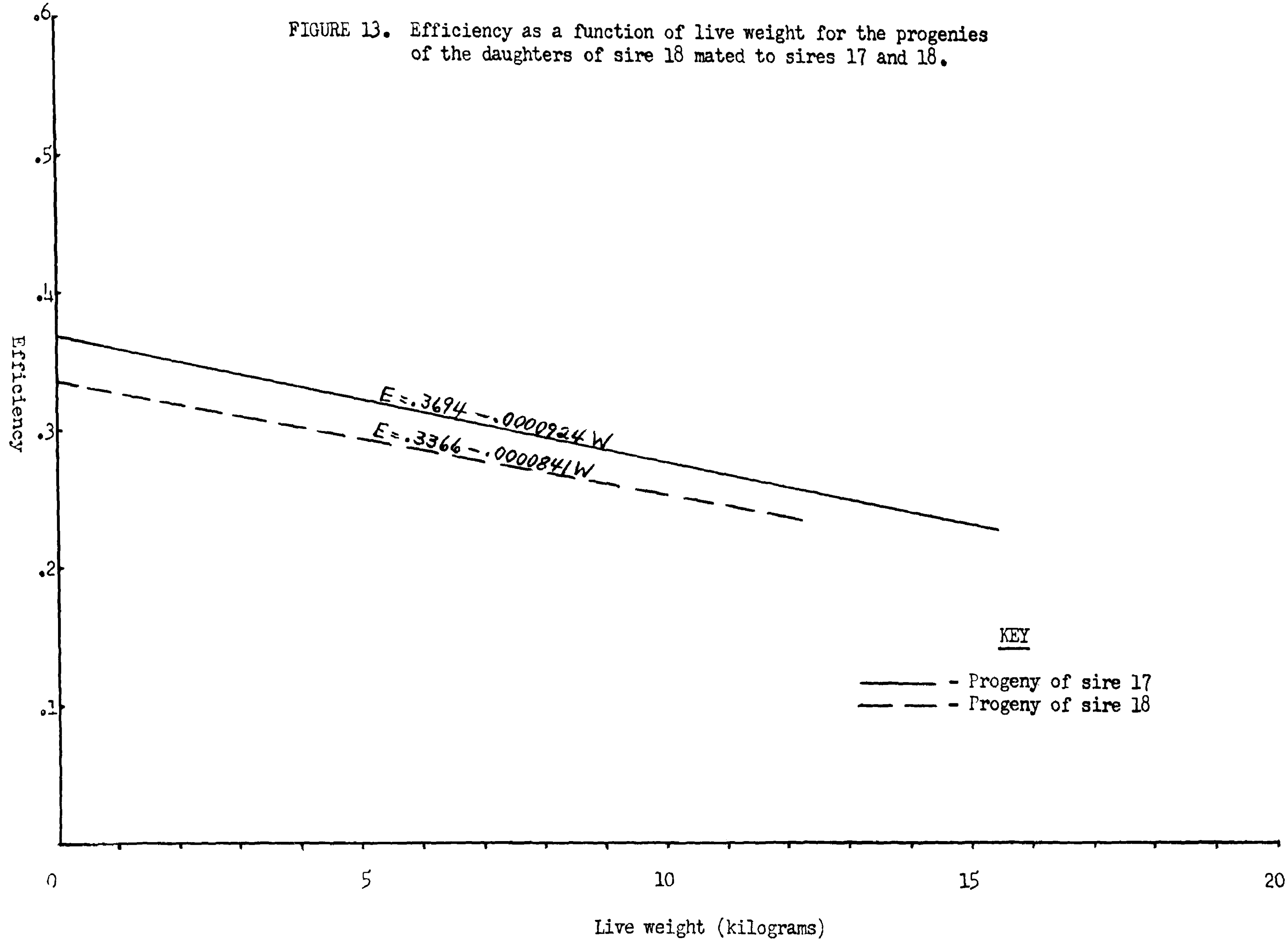


FIGURE 13. Efficiency as a function of live weight for the progenies of the daughters of sire 18 mated to sires 17 and 18.

TABLE XV. Observations on the six fastest growing and six slowest growing New Hampshire males and females.

	Mean weight	Units feed per unit gain	E = C - kW	E when W equals 1000	1200	1750
			TO 12 WEEKS			
Fast males	1496.7	3.4937	E = .3956 - .0001123 W	.2833	.2608	-
Slow males	1193.7	3.9720	E = .3524 - .0000836 W	.2688	.2521	-
Fast females	1190.7	3.4989	E = .3633 - .0001095 W	.2538	.2319	-
Slow females	1058.5	3.6116	E = .3902 - .0001856 W	.2046	.1675	-
			TO 1680 GMS. AND OVER			
Fast males	1723.8	3.2728	E = .3994 - .0001196 W	.2798	-	.1901
Slow males	1735.2	3.3684	E = .3620 - .0001135 W	.2485	-	.1634
Fast females	1766.8	4.6754	E = .3819 - .0001557 W	.2262	-	.1094
Slow females	1748.8	5.4364	E = .3851 - .0001797 W	.2054	-	.0706

FIGURE 14. Efficiency as a function of live weight for slow-growing and fast-growing New Hampshire males and females reared to a definite weight.

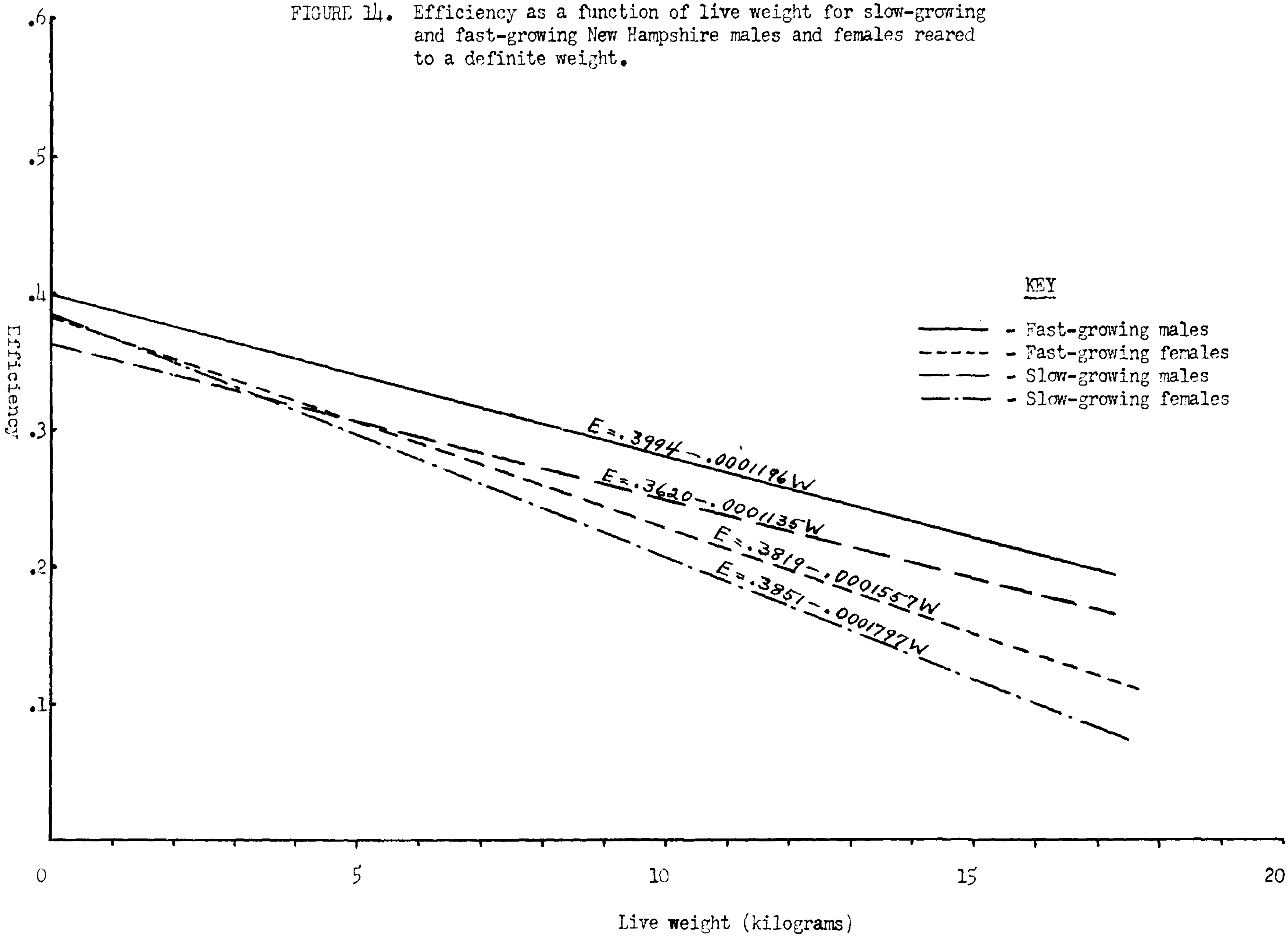
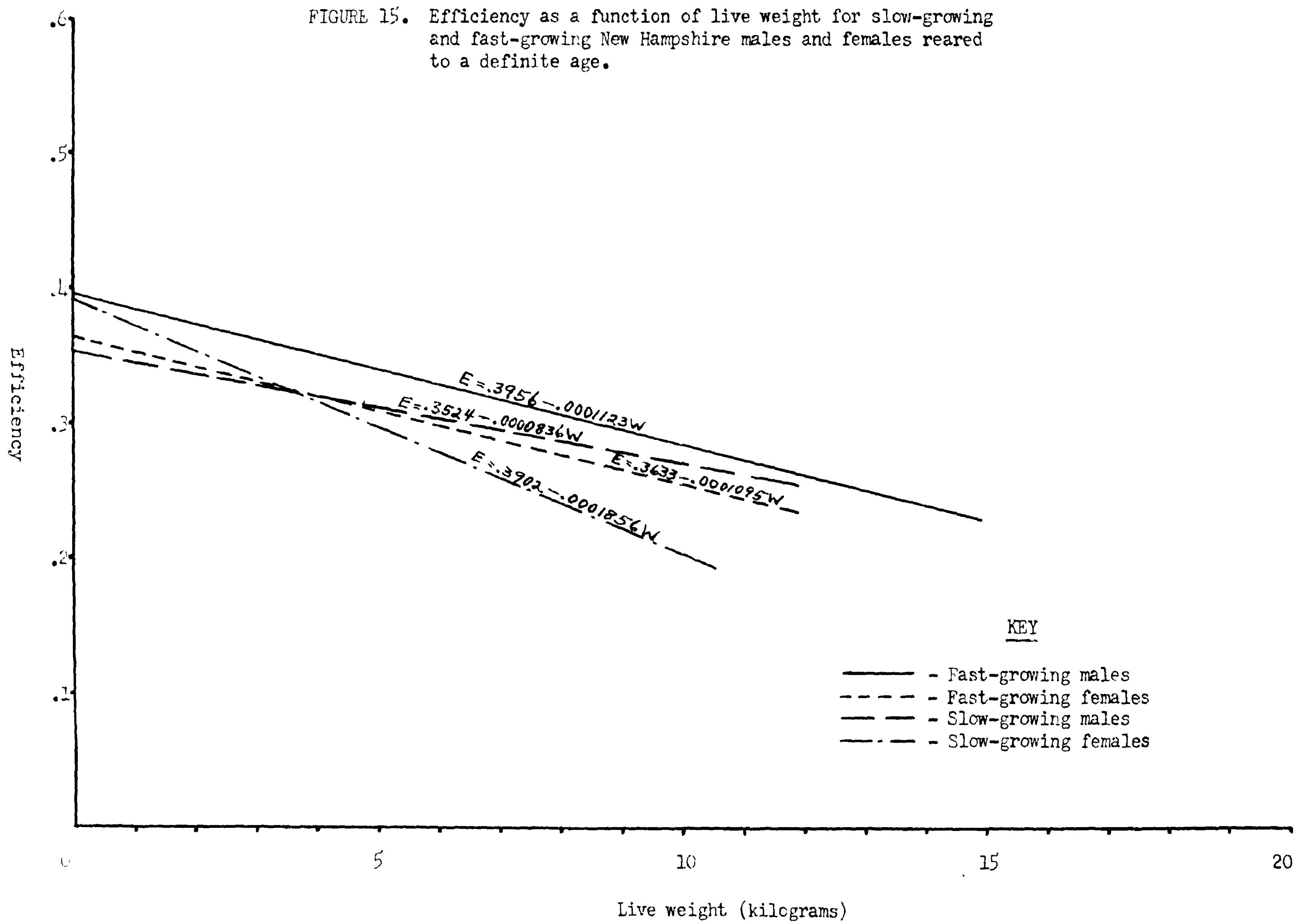


FIGURE 15. Efficiency as a function of live weight for slow-growing and fast-growing New Hampshire males and females reared to a definite age.



per cent less feed at 1750 grams. The order of efficiency in descending order at 1000 and 1750 grams body weight was fast-growing males, slow-growing males, fast-growing females, and slow-growing females. The difference between the fast-growing males and slow-growing females was most marked; the fast-growing males requiring 38.5 per cent less feed at 1000 grams and 169.3 per cent less feed at 1750 grams body weight than the slow-growing females. Here again one will notice that the "k" value is lower for the males than for the females.

Table XVI shows the variability between the constants as well as the variability in the efficiency at 1000 grams body weight among individuals, even among full sibs. For example, males A10 and A23 attained a weight of 1705 and 1825 grams at 13 and 16 weeks, respectively. At 1000 grams body weight the former required 10.2 per cent less feed than the latter, and at 1700 grams 36.0 per cent less feed. On the other hand, full brothers like A22 and A18, and A24 and A29 are very similar.

Some typical regression lines, with the actual observations plotted, are shown for some of the individually reared New Hampshire chicks in Figures 16 to 19. Figure 16 shows the great variability in efficiency that occasionally exists within an individual. It can be seen clearly that the data are very poorly represented by a straight line. On the other hand, Figure 17 is an example of a case where the observed data conform very closely to the calculated regression line. It is of special interest to observe that the regression lines for the two sons of dam 734 are almost identical. These two males were certainly homogenous in feed utilization efficiency.

Figure 18 shows graphically the marked difference in efficiency between two full brothers. In this case, the two males had approximately the same initial efficiency, but one decreased almost twice as fast as the other in

TABLE XVI. Constants in the equation E = C − kW, and efficiencies for New Hampshire chicks reared in individual cages to a definite weight.

Sex	Sire	Dam	Age in weeks	Weight at this age	C	k x 1000	E when W = 1000
A25 male	17	808	13	1683	.3832	.1158	.2674
A20 male	17	808	13	1731	.4432	.1416	.3016
A38 (5 males, 3 females)	17	808	12	1387.3	.3927	.1299	.2628
A16 male	17	850	14	1712	.4081	.1375	.2706
A2 female	17	850	17	1839	.3658	.1289	.2369
A40 (8 males, 3 females)	17	850	12	1289.2	.3896	.1272	.2624
A32 female	17	760	12	1000	.3253	.1146	.2107
A1 female	17	760	16	1586	.3987	.1766	.2221
A35 female	17	760	17	1750	.3724	.1483	.2241
A14 male	17	711	10	693	.4292	.3863	.0429
A28 male	17	747	15	1701	.3643	.1288	.2355
A17 female	17	747	17	1775	.3932	.1772	.2160
A11 female	17	747	20	1752	.4022	.2047	.1975
A10 male	17	762	13	1705	.3787	.1267	.2520
A23 male	17	762	16	1828	.3839	.1552	.2287
A27 female	17	750	16	1718	.3947	.1645	.2302
A26 female	17	739	20	1778	.3507	.1502	.2005
A22 male	18	755	14	1705	.3892	.1171	.2721
A18 male	18	755	13	1574	.4137	.1508	.2629
A15 female	18	755	17	1822	.3734	.1456	.2278
A34 male	18	734	13	1780	.4043	.1202	.2841
A31 male	18	734	13	1697	.4083	.1254	.2829
A3 male	18	830	13	1230	.3920	.1944	.1976
A33 male	18	830	14	1770	.3835	.1019	.2816
A19 female	18	830	19	1700	.4155	.2030	.2125
A8 male	18	825	12	1041	.3599	.1563	.2036
A6 male	18	825	13	1747	.3807	.0932	.2875
A7 female	18	825	17	1697	.3922	.1696	.2226
A21 female	18	825	6	318	.3718	-.0133	-
A13 male	18	816	13	1103	.4361	.2743	.1618
A29 male	18	849	14	1605	.4152	.1673	.2479
A36 female	18	849	20	1812	.3679	.1623	.2056
A4 male	18	849	19	1798	.3240	.0980	.2260
A37 (3 males, 2 females)	18	849	12	1101.4	.3996	.1627	.2369
A30 female	18	833	14	1499	.3870	.1482	.2388
A24 male	18	833	17	1725	.3246	.1032	.2214
A9 male	18	833	18	1724	.3939	.1770	.2169
A39 (2 males, 3 females)	18	833	12	1154	.3859	.1503	.2356
A5 male	18	832	11	872	.3791	.2310	.1481
A12 female	18	832	20	1778	.3809	.1792	.2017

FIGURE 16. Observed weights and efficiencies, and the regression line for a New Hampshire male of sire 18 and dam 816.

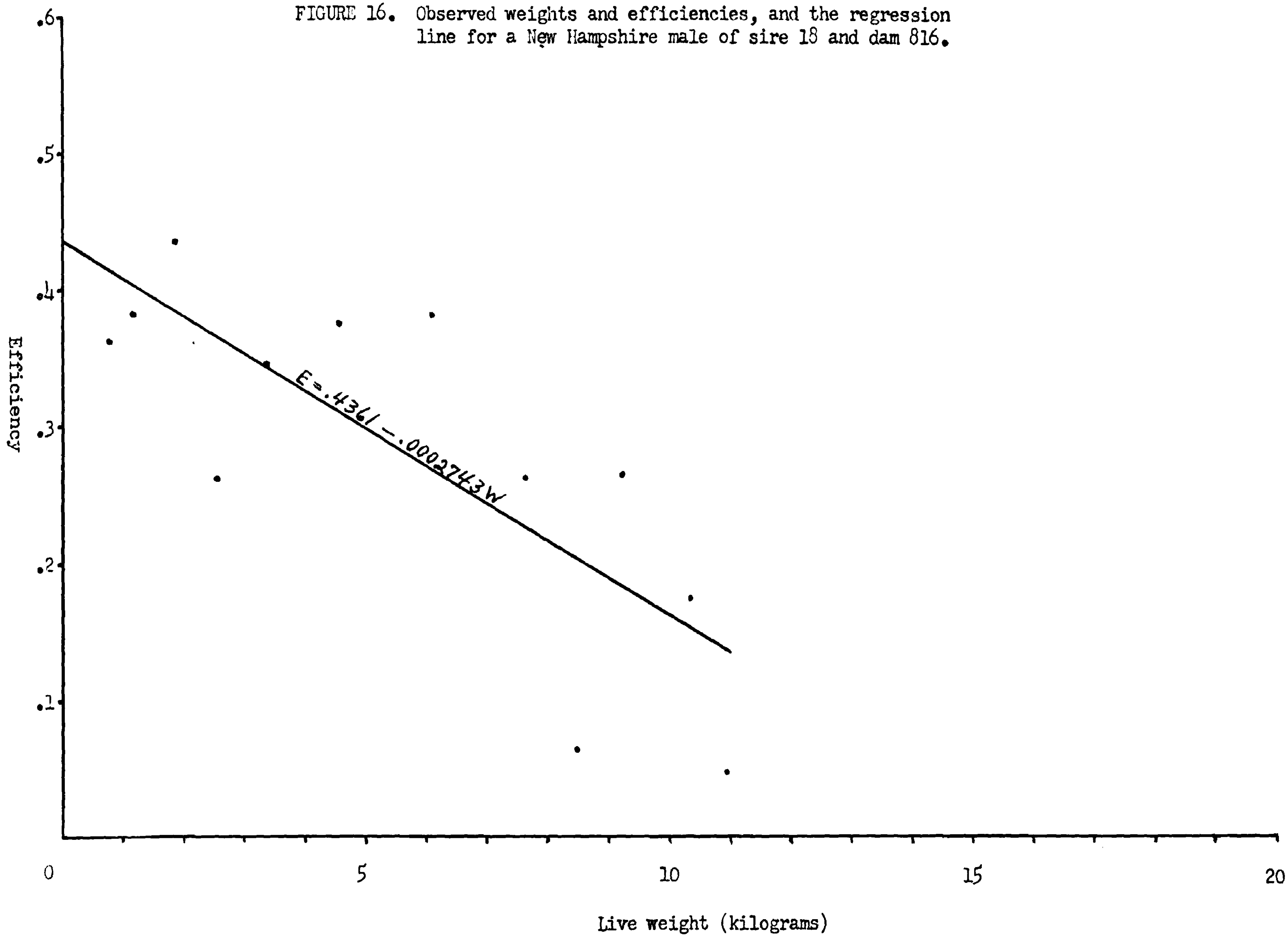


FIGURE 17. Observed weights and efficiencies, and the regression lines for two New Hampshire males of sire 18 and dam 734.

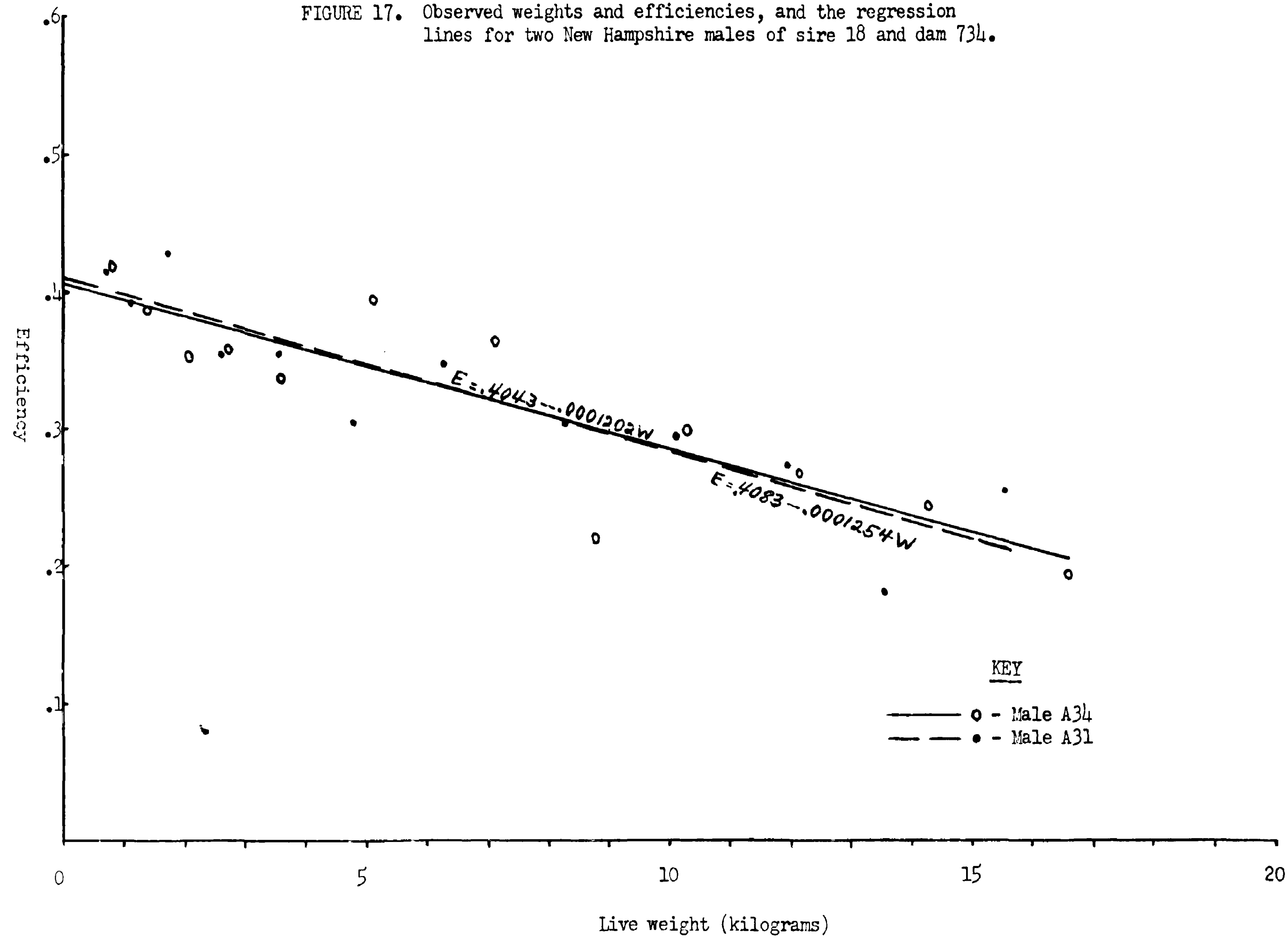


FIGURE 18. Observed weights and efficiencies, and the regression lines for two New Hampshire males of sire 18 and dam 830.

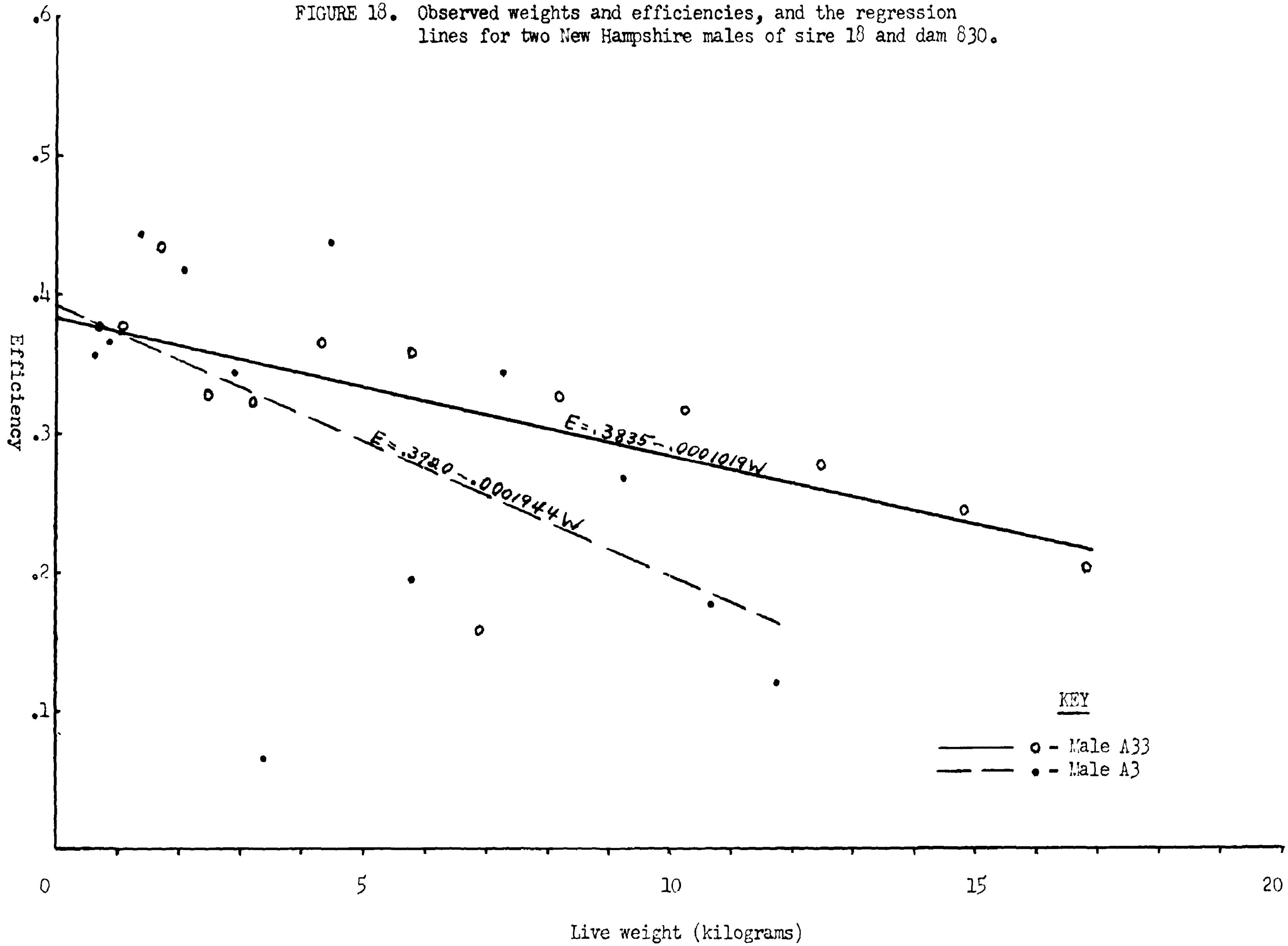
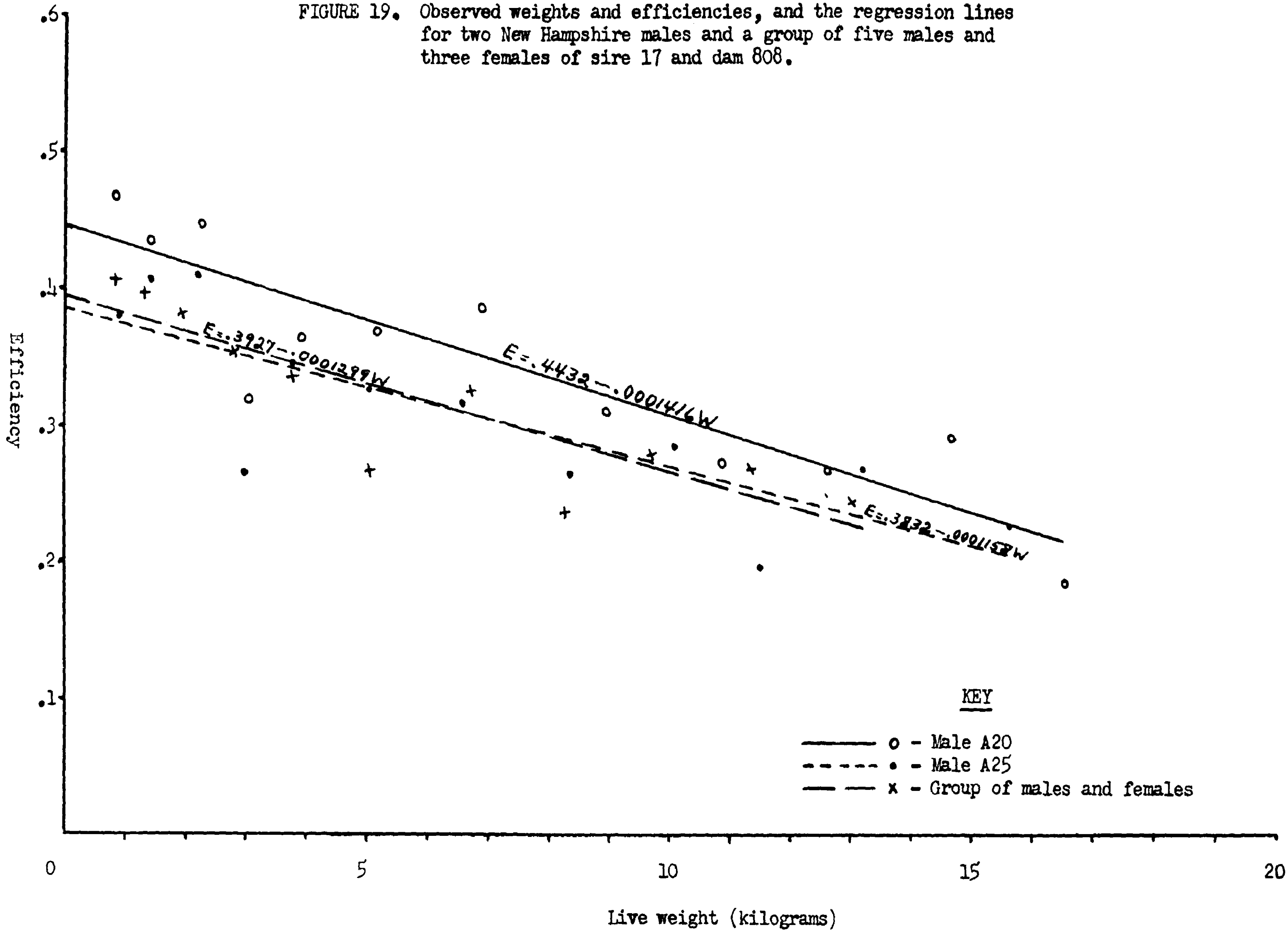


FIGURE 19. Observed weights and efficiencies, and the regression lines for two New Hampshire males and a group of five males and three females of sire 17 and dam 808.



efficiency until at 1200 grams live weight one required 64.6 per cent less feed than the other. Of course, the rate of growth between these two individuals was marked, the more efficient one weighing 1604 grams compared with 1230 grams for the inefficient one at 13 weeks of age.

The regression of efficiency as a function of weight for the progeny of dam 808 is given in Figure 19. This shows two males which, although very efficient, differed considerably. In this instance they differed in initial efficiency and tended to become more uniform in their efficiency as they increased in weight. The regression line of a group of five male and three female sibs was almost identical with that of the least efficient of the two individual males.

In general, this would indicate that it is possible to observe almost as much variability among full brothers or sisters as among individuals of a whole population.

Table XVII shows a comparison between a fast-growing and a slow-growing New Hampshire male each grown in an individual cage. Although these are individuals, rather than large groups, they have been selected for a very definite reason and should be satisfactory for the purpose intended. First, one should note that at 11 weeks the units of feed per unit of gain are identical although A20 weighed 1353 grams and A4 weighed 767 grams. Secondly, it is noted that up to 1730 grams body weight for the fast-growing male, it required 3.32 units of feed per unit of gain, while for the slow-growing male it took 4.34 units (by interpolation) of feed per unit of gain to attain a live weight of approximately 1730 grams. On this basis the fast-growing male required 30.9 per cent less feed than the slow-growing male up to a definite weight. Consequently, "units of feed per unit of gain" is not a satisfactory measure of efficiency unless the animals compared are of the

TABLE XVII. Weekly comparison between a fast-growing and a slow-growing New Hampshire male.

	Male A20 (male 17 x female 808)			Male A4 (male 18 x female 849)		
Period (weeks)	Weight	Units of feed per unit gain	E = C - kW	Weight	Units of feed per unit gain	E = C - kW
1	61	-	-	47	-	-
1 - 2	103	2.1428	-	59	4.1667	-
1 - 3	175	2.2456	E = .4508 - .0005789 W	77	3.7667	E = .0785 + .003047 W
1 - 4	268	2.2415	E = .4667 - .0001189 W	105	3.4138	E = .1785 + .001343 W
1 - 5	333	2.4559	E = .5260 - .0005896 W	151	3.1250	E = .1679 + .001502 W
1 - 6	442	2.5433	E = .4997 - .0004159 W	183	3.4265	E = .2783 + .0000349 W
1 - 7	580	2.5915	E = .4723 - .0002673 W	236	3.3227	E = .3040 - .0002652 W
1 - 8	790	2.5953	E = .4452 - .0001449 W	347	2.9967	E = .2412 + .0003523 W
1 - 9	997	2.7414	E = .4472 - .0001526 W	467	2.9381	E = .2482 + .0002941 W
1 - 10	1165	2.8877	E = .4495 - .0001602 W	621	2.9286	E = .2613 + .0002015 W
1 - 11	1353	3.0170	E = .4468 - .0001524 W	767	3.0139	E = .2782 + .0000989 W
1 - 12	1569	3.0796	E = .4375 - .0001285 W	922	3.1303	E = .2905 + .0000347 W
1 - 13	1731	3.3186	E = .4432 - .0001416 W	1092	3.3435	E = .3025 - .0000195 W
1 - 14				1239	3.4195	E = .3054 - .0000309 W
1 - 15				1322	3.7263	E = .3183 - .0000774 W
1 - 16				1397	3.9822	E = .2129 - .0001016 W
1 - 17				1526	4.1724	E = .3265 - .0001048 W
1 - 18				1670	4.2662	E = .3242 - .0000986 W
1 - 19				1798	4.4215	E = .3240 - .0000980 W

same age and of equal weight. In addition to feed consumption, it is absolutely essential that body weight, rate of gain, and time be taken into consideration or eliminated by having these factors uniform.

Table XVII further shows that the efficiency equation is approximately the same from 8 to 13 weeks inclusive for the fast-growing male while that of A4 is abnormal and unpredictable until approximately the 15th week. Male A20 started efficiently and progressively increased in efficiency up until approximately the tenth week. After this highest efficiency at ten weeks it progressively decreased to the end of the experiment.

Figure 20 shows the plotting of weight against feed consumption for these two males, while Figure 21 shows the regression lines of efficiency as a function of live weight for the two males at the twelfth and thirteenth week and for A4 at 19 weeks. It is clear that the 12-week and 13-week data would have given a poor index of the efficiency of male A4.

Since the data presented show that in general the faster the growth the higher the efficiency of feed utilization, it was considered desirable to take groups of sibs at the same age and pair them according to similarity in weight. If thus a difference would be noted, it would be an inherent difference. The weights of the available experimental groups were written down and grouped entirely on a weight basis. Typical pairings are given in Table XVIII.

Table XIX gives a comparison of the efficiency of the progenies of three pairs of males. The comparison between the Barred Plymouth Rocks of 5B and 8A shows that there is not a great deal of difference between the sires when weight and time are held constant. The same is found to be true between the purebred and crossbred progenies of sires 4 and 7. However, a comparison between the progenies of sire 7 and sire 8 reveals that there is 24.3 per

FIGURE 20. Live weight plotted against feed consumption for a fast-growing and a slow-growing male.

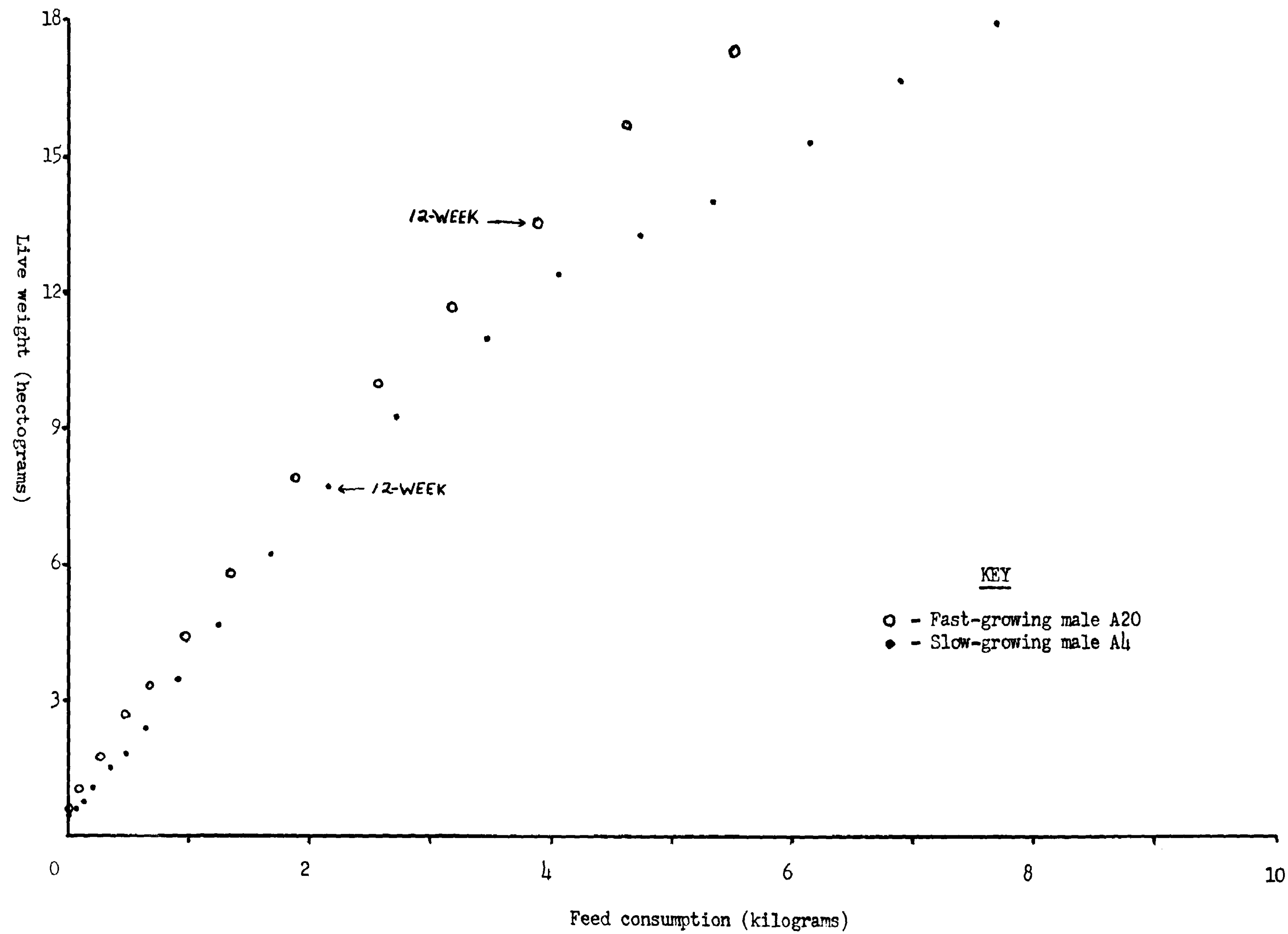


FIGURE 21. Observed weights and efficiencies, and the regression lines for a fast-growing and a slow-growing New Hampshire male at various ages.

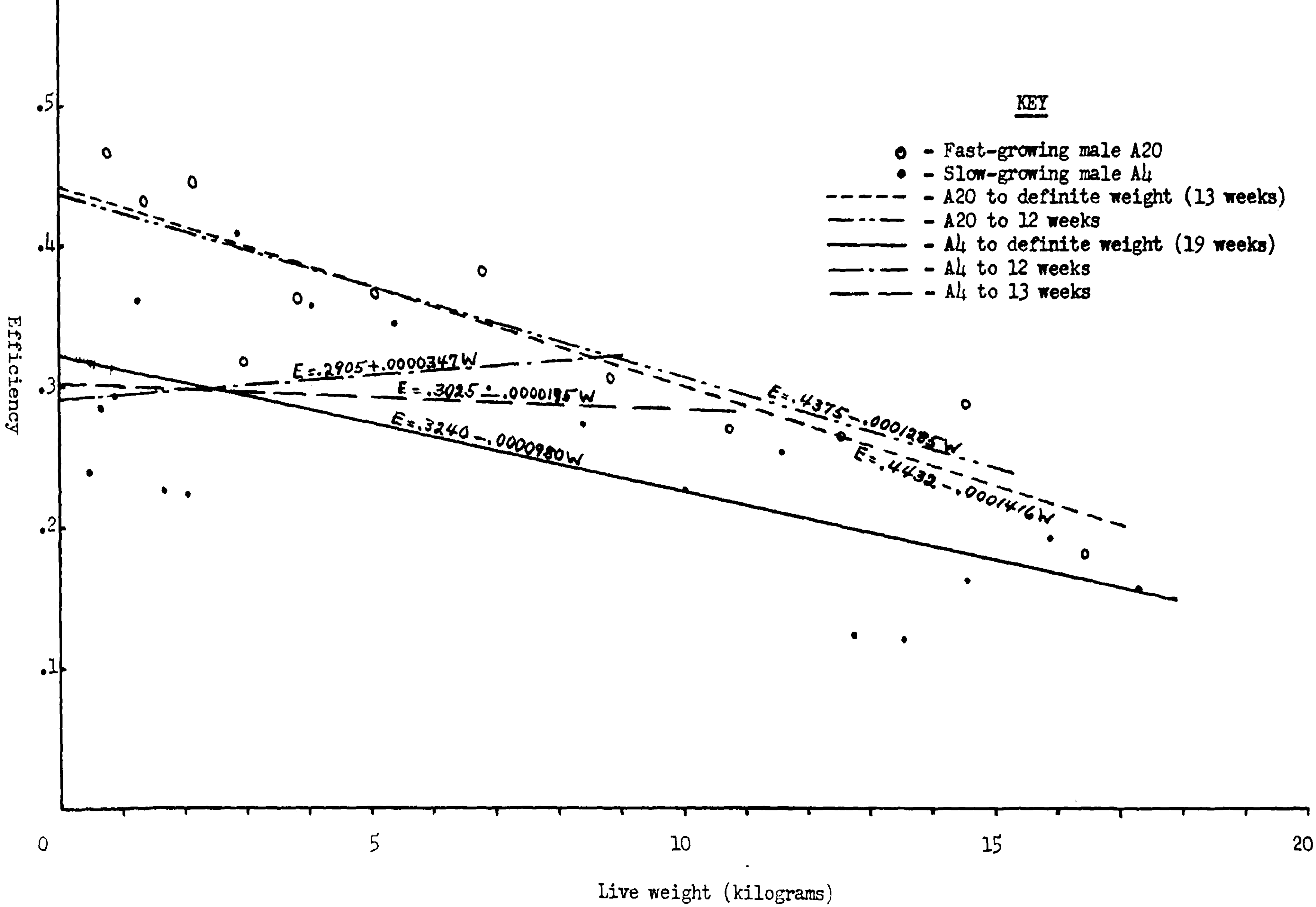


TABLE XVIII. Eight week weights used for comparing sires 7 and 8.

	Weight in grams			
	7 B.P.R.	8 B.P.R.	7 Crossbreds	8 Crossbreds
	361.0	357.0	457.0	451.0
	456.7	457.0	499.0	486.5
	423.0	405.0	636.0	633.6
	474.7	468.0	672.0	673.0
	443.0	453.0	688.0	697.0
	528.0	527.8	666.0	662.7
	523.0	525.1	627.0	647.8
	596.0	592.0	522.3	546.0
	596.0	596.1	522.0	505.5
	652.0	651.5	-	-
	645.0	664.8	-	-
	288.0	259.0	-	-
Mean weight	498.9	496.4	587.7	589.2

TABLE XIX. Comparison of efficiencies of the progenies of several sires at paired weights and at the same age.

Sire	Chicks	Age in weeks	No. of groups	Sex: Males	Sex: Females	Mean weight	E = C - kW: C	E = C - kW: k x 1000	E when W equals: 536	E when W equals: 579	E when W equals: 994
5B	(1)	12	11	6	5	995.7	.4162	.2590	-	-	.1588
8A	(1)	12	11	17	18	994.1	.3929	.2200	-	-	.1742
4	(1)&(2)	8	26	67	50	580.5	.3601	.1361	-	.2813	-
7	(1)&(2)	8	26	44	38	579.3	.4056	.2183	-	.2792	-
7	(1)&(2)	8	21	21	20	536.9	.3901	.1668	.3007	-	-
8	(1)&(2)	8	21	48	47	536.2	.4151	.3229	.2420	-	-

(1) purebred
(2) crossbred

cent less feed required by the progeny of sire 7 than by the progeny of sire 8 at 536 grams body weight. The standard error for the constants "C" and "k" are shown in Table XX and a test for significance according to the "t-table" shows that there is no significant difference between the "C" value but that there is a significant difference between the "k" values. Consequently, we may infer that the progenies of sire 7 and of sire 8 differ significantly in efficiency, since there was no significant difference in initial efficiency but a significant difference in the rate of decrease. The regression lines for the progenies of sires 7 and 8 are shown in Figure 22. Since body weight, or rate of growth, and time have been removed from the consideration, the resulting difference must be due to an inherent difference between these two sires.

The data secured from the experiment in which the yolk sac was removed at hatching time in an attempt to influence early efficiency are presented in Table XXI and Figure 23. The data are very limited but indicate the possibility that removal of the yolk sac may decrease the initial efficiency. The operation itself may have caused this effect as much as the absence of the yolk sac.

TABLE XX. Constants and standard errors for the progenies of sires 7 and 8 at paired weights and at the same age.

Sire	C	k
7	.3901 ± .01235	.0001668 ± .0000444
8	.4151 ± .01548	.0003229 ± .0000562
difference	.0250 ± .0198	.0001561 ± .00007162\4*

* Denotes significance to the 5 per cent level

TABLE XXI. Summary of yolk sac removal experiment.

	No.	Males	Females	Mean weight	E = C - kW	E when W=200	Units of feed per unit gain
Control	29	19	10	226.1	E = .3913 - .0000204 W	.3872	2.6410
Operated	25	12	13	210.2	E = .3730 + .0001893 W	.4109	2.6097

FIGURE 22. Efficiency as a function of live weight for the progenies of sire 7 and 8, when time and weight are held constant.

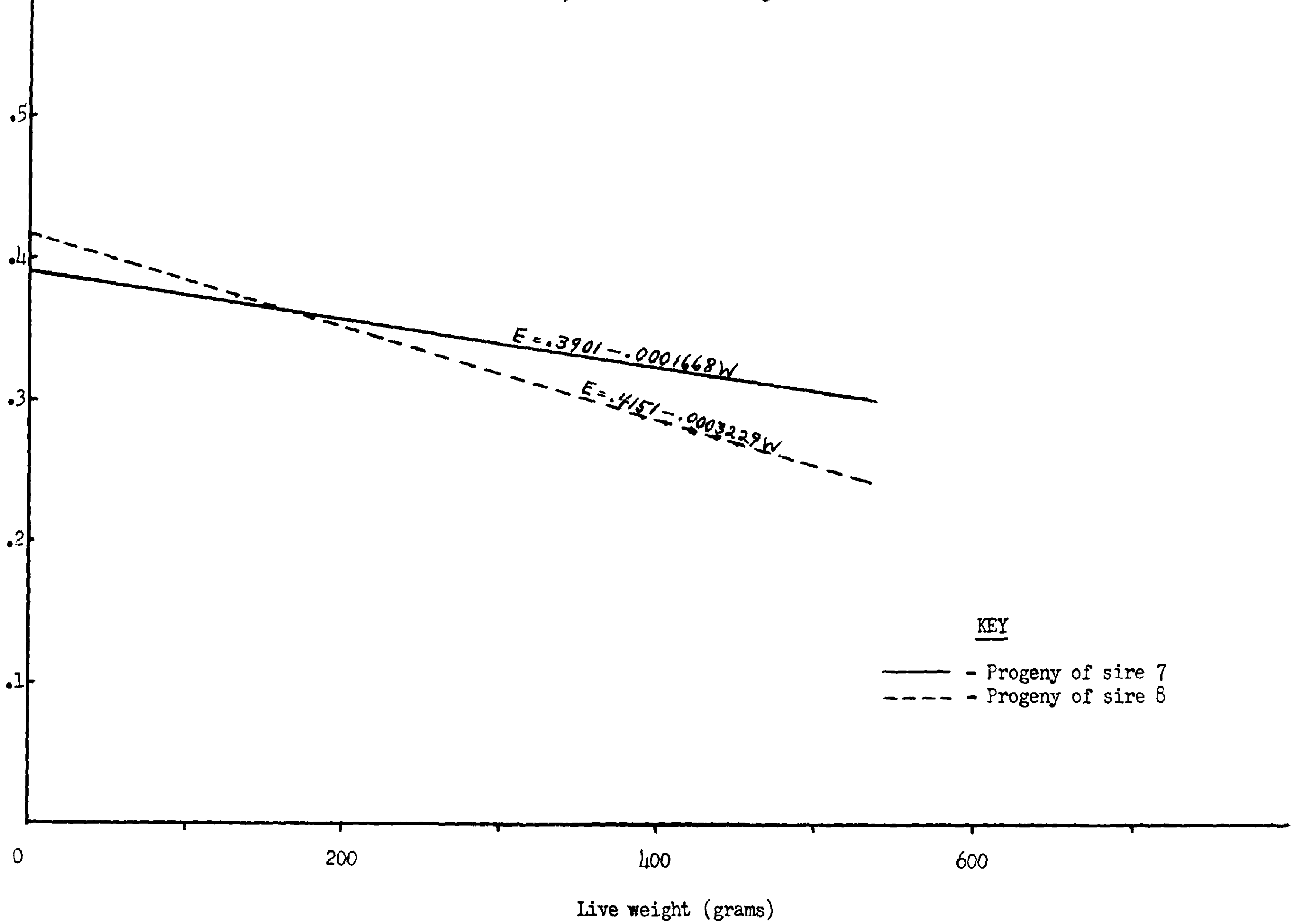
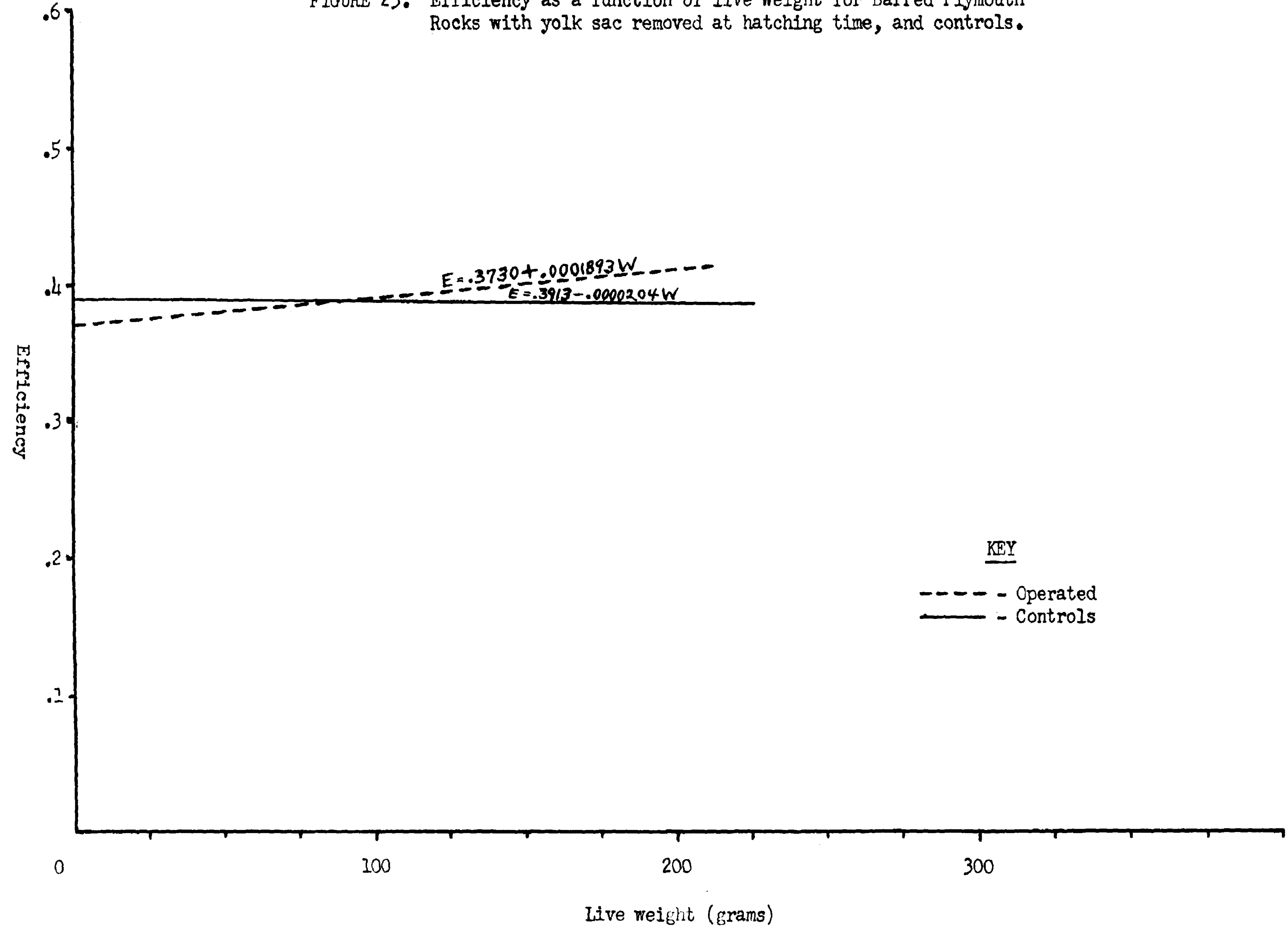


FIGURE 23. Efficiency as a function of live weight for Barred Plymouth Rocks with yolk sac removed at hatching time, and controls.



DISCUSSION

The fact that animals vary in their ability to utilize feed is an old observation verified in this study. Full brothers may differ materially in their gross efficiency, and one rather expects that they differ unless they have an identical gene complex in addition to identical environmental conditions. For example, two individuals, identical in every other respect, would certainly have a different efficiency provided they differed in rate of feathering, in their fattening ability, or in their temperament. Even a seemingly small variation in thyroxin production might result in a wide variation in efficiency. Even if we discover the individual with the greatest physiological efficiency in feed utilization, it does not imply that we have the individual with the most profitable gain. One individual may be a less efficient user of feed in the physiological sense, but if it has the ability to consume large quantities of feed it may actually, from the producer's standpoint, be more profitable than the more efficient one. The capacity to consume considerable quantities of feed is very important in determining the economy of gain, but unfortunately it is not possible to segregate capacity from efficiency. The more an individual eats the more it will grow, and the more it grows the larger the successive portions of feed intake. Consequently, it seems logical that the ideal way, theoretically, to study variations in feed utilization efficiency is to keep the animals away from droppings and give each individual the same amount of feed and water and then compare the body weight. It would be necessary to analyze the animal body at the end of the experiment, and possibly analyze the excrete for digestable nutrients.

As may be seen throughout this work, the efficiency of feed utilization is an extremely complicated problem. Besides all of the physiological and environmental conditions that affect efficiency in utilizing feed, we have the question of how to compare and present the data that we have collected. A study of efficiency of feed utilization is most generally based on the concept of gross efficiency or on the gain per unit of feed consumed. As mentioned before, gross efficiency is probably the most important single item, but it is certainly not the only one. Simply comparing weight as a function of feed consumption does not take time into consideration and therefore does not always give a true comparison. On the other hand, units of feed per unit of gain is probably the simplest means of comparing efficiency, but since it does not take into consideration body weight, rate of gain, nor time, it too presents a warped picture. The law of diminishing increment or the instantaneous growth rate as expressed by the linear equation $E = C - kW$ is probably the most satisfactory of the three methods discussed here. This equation determines the initial efficiency and the rate of decrease in efficiency. It considers feed consumption, gain in live weight, and body weight but it disregards the factor of time. For accuracy it is absolutely necessary that the test periods are of short duration, frequent observations be made, and the body weights be reasonably uniform for the groups compared.

It is understood, of course, that this equation $E = C - kW$ shows the efficiency only at any one particular instant and not for any long time. That is, we can say the efficiency at 500 grams is .3124 but for any other weight there will be a different efficiency value. Consequently, the efficiency value expressed by the equation $E = C - kW$ does not tell us how much feed was required to attain 500 grams, but merely how much increase in weight we obtain for a unit of feed at that particular weight.

Unfortunately it is not mathematically sound to use the accumulative feed consumption in calculating the values in the equation $E = C - kW$, but if it were, it would give us a truer picture of what we mean by efficiency from a practical point of view. Practically, we are interested in how many units of feed it takes to produce a unit of chicken, whereas, scientifically we are anxious to know how many units of gain we obtain per unit of feed or more specifically what use a particular animal makes from one unit of feed. The author has attempted to plot efficiency as a function of accumulative feed consumption and the results are interesting. The data conformed much more closely to a straight line and the decrease in efficiency was much less. This is to be expected, of course, because all the data accumulated to that point are used for each weekly calculation. Consequently, there is a tendency for the weekly fluctuations to be smoothed out and the deviations to be less. The definite advantage of using efficiency as a function of accumulative feed consumption rather than feed consumption for the weekly period, would be that one could read off the graph the actual efficiency to that point instead of at that point. These data are omitted in this thesis as well as several efficiency indexes that the author has attempted to develop, because they have not reached perfection.

It should also be pointed out that it was found impossible to extrapolate efficiency values from the equation $E = C - kW$. Although it is supposed to be a linear relationship, it is subject to slight changes from week to week, and these small changes when extended beyond the actual observed data may result in enormous differences at the weights beyond those observed.

In general, the faster a chicken grows the more efficient its utilization of feed on a live weight basis. For example, male A20 attained a body weight of 997 grams at 9 weeks on 2566 grams of feed, or 2.74 units of feed per unit of gain, while male A4 reached 922 grams body weight on 2739 grams of feed, or 3.13 units of feed per unit of gain. Consequently, male A20 attained a heavier weight on less feed than male A4 and therefore made more economical use of his feed. A large portion of the difference, undoubtedly, is due to the fact that the former reached this weight in 9 weeks while the latter required 12 weeks. Even though the maintenance requirements were identical for the two individuals, the fast-growing individual would actually require less feed for maintenance due to the shorter time. On the other hand, it is noted in Table XVIII that at 11 weeks the units of feed per unit of gain are identical for the two birds involved, but one male weighed almost twice that of the other. Consequently, the time being the same, the slow-growing bird must have had a lower maximum growth efficiency, or a lower maintenance efficiency (higher maintenance requirement) or both.

The New Hampshires studied were more efficient in their utilization of feed than the Barred Plymouth Rocks. It is granted that the New Hampshires grow faster than the Barred Plymouth Rocks, but in addition the Barred Plymouth Rocks are slower feathering. Consequently, this slower feathering may result in more heat loss and therefore more feed required for maintenance. It is also interesting to note that the Barred Plymouth Rocks are generally regarded as slower growing, slower feathering, less viable and in general somewhat inferior to some of the other standard breeds. The opinion is put forth that the presence of the barring gene or some factor linked with it might account for this slightly below-average performance. If this be the case, does this barring factor interfere with efficiency of feed utilization? The evidence presented shows that if the barring factor is influential in decreasing feed utilization efficiency, there are certainly other factors involved. If this were the major factor in determining feed utilization efficiency, then one would expect that Barred Plymouth Rock males with two barring factors would be less efficient than Barred Plymouth Rock females, and the crossbred males should have efficiencies identical with those of the crossbred females. Actually, the males were slightly more efficient than the females, showing that if the barring factor affects efficiency it is only in a secondary and minor capacity.

It is impossible with the present data to even suggest how many factors are involved in the inheritance of the efficiency of feed utilization. That there are a great many is undisputed, and that there are inherent differences in feed utilization are conclusively shown. It is also shown that in some cases the progeny of sons and daughters had the same efficiency as those of their parents while in other cases it deviated from that of the parents. This is expected, for complicated factors like egg production and hatchability also show considerable variation in transmitability.

SUMMARY

Observations were made on 942 Barred Plymouth Rocks, 199 New Hampshires, 813 chickens secured from Barred Plymouth Rock x New Hampshire and the reciprocal crosses, 21 Single Comb White Leghorns, and 35 Cornish crossbreds reared in batteries and fed a uniform all-purpose mash. The majority of these chickens were on experiment for either eight or twelve weeks, although some were removed from the test earlier and others remained as long as twenty weeks. Some groups consisted of full and half sisters, others were groups of full sibs, while many were grown in individual cages from hatching time to 12 weeks of age. Weekly, and in some cases bi-weekly, weights and feed consumption were recorded. Data were collected during every month from October 1938 to October 1941, and from September 1946 to April 1947.

The data were analyzed by plotting live weight as a function of feed consumption, efficiency as a function of live weight, and by calculating the units of feed required per unit of gain. The linear equation $E = C - kW$ was used for calculating efficiency as a function of live weight. The efficiencies of the progenies of various sires were compared, as well as the efficiencies of the progenies of a number of dams. Comparisons were also made between purebreds and crossbreds, between New Hampshires and Barred Plymouth Rocks, between fast-growing and slow-growing individuals, between chickens reared to the same weight at the same age, and between chickens reared to a definite age and to a definite weight regardless of age.

CONCLUSIONS

1. There is a definite inherent difference in feed utilization efficiency between individuals that cannot be explained on the basis of body weight, rate of gain, or time. There was a significant difference between the slope of the line in the regression of efficiency on live weight for the progenies of sire 7 and sire 8. At 536 grams of live weight the progeny of sire 7 required 24.3 per cent less feed than those of sire 8.
2. Male chickens were slightly more efficient than females in utilizing their feed. At 500 grams or at the lower weights the difference is not very marked, but the difference in efficiency progressively increases in favor of the males until at 1500 grams body weight the New Hampshire males required 40.2 per cent less feed than the New Hampshire females.
3. The "k" value for males is somewhat lower than that for females, indicating either a lower maintenance requirement for males, or a more rapid decrease in efficiency in females due to a lower mature weight.
4. Fast-growing individuals utilize their feed more efficiently than slow-growing individuals. At 1750 grams body weight the fast-growing males required 16.3 per cent less feed than the slow-growing males, and the fast-growing females required 55.0 per cent less feed than the slow-growing females at the same weight. At 1750 grams body weight the fast-growing males required 169.3 per cent less feed than the slow-growing females.
5. The crossbred chickens were more efficient in their feed utilization than the purebreds sired by the same male. At 500 grams body weight

the crossbreds required 13.1 per cent less feed than the purebreds, and at 1000 grams it amounted to 27.1 per cent.

6. Inbreeding had a detrimental effect upon the efficiency of feed utilization. Daughters of New Hampshire sire 18 when mated to New Hampshire sire 17 produced progenies which were more efficient than the progenies secured from the daughters of New Hampshire sire 18 backcrossed to sire 18, even though there was no difference in the efficiency of the progenies of these two sires when mated with nonrelated dams.

7. The strain of New Hampshires studied was more efficient in utilizing feed than the Barred Plymouth Rocks studied.

8. At 400 grams live weight, the difference between the most efficient and the least efficient Barred Plymouth Rock progenies was 1.02 units of feed per unit of gain or 30.8 per cent less feed required by the progeny of sire 4B1 over those of sire 4B.

9. At 400 grams live weight, the difference between the most efficient and the least efficient Barred Plymouth Rock X New Hampshire crossbred progenies was 1.04 units of feed per unit of gain or 32.8 per cent less feed required by the progeny of sire 4B over those of sire 1.

10. Data collected up to twelve weeks of age and compared at 500 grams live weight by the equation $E = C - kW$ appear to be as satisfactory as rearing chickens to almost maturity.

11. In general, efficiency is a negative function of weight and expressible by the equation $E = C - kW$. This equation is probably the best method available at present for comparing individuals or groups of individuals as to feed utilization efficiency.

12. Extrapolation is not recommended when using the equation $E = C - kW$, but comparisons should be made at or below the maximum weight for the groups studied.

13. The simple regression line of live weight against feed consumption gives a fairly good fit to the observed data up to 500, 900, or even 1200 grams body weight but beyond that it is no longer a linear relationship.

14. Units of feed required per unit of gain is not a satisfactory measure of efficiency, unless comparisons are made at both the same age and the same weight.

15. Considerable variation was found to exist among the progeny of various sires, both from the standpoint of growth and efficiency.

16. The mode of inheritance of feed utilization efficiency is a very complicated phenomenon and would probably require several years to solve.

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