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Factors Affecting the Growth of Range Cattle in Semi-Arid Regions.*

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INTRODUCTION.

THE investigation reported in this paper deals with the comparative growth under range conditions of first generation offspring obtained by crossing cows of nondescript breeding with purebred bulls of five different beef breeds. The experiment was conducted at the Messina Ranching Station located in a semi-arid region of the Union of South Africa. Extensive areas in this region, which lies between 22° and 26° south latitude, are devoted almost exclusively to cattle raising.

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The cattle common to this part of the country originally consisted of several fairly distinct types of indigenous cattle, but in recent years blood of the European breeds as well as that of the Afrikander has been introduced into most of the herds, and interbreeding between different native types has occurred freely with the result that the cattle population at present consists of a heterogeneous mixture, showing some evidence of the presence of a small, but varying percentage of improved blood.

These cattle are relatively small and slow maturing as compared with the improved beef breeds. They lack beef conformation, being relatively long-legged, flat-ribbed and drooping in the rump. However the typical native cattle are extremely hardy and capable of subsisting on scant pastures. Moreover, they possess a high degree of tolerance to tick infestation and a resistance to tick-borne diseases.

No definite information is available on the origin of the indigenous types of African cattle, but it is generally accepted that they originated from a mixture of the Longhorn cattle (*Bos primigenius*) and the Zebu types (*Bos indicus*). The distinguishing characteristics of these species are still observed in various types of the present-day native cattle in the form of horn gigantism and hump respectively. Several distinct types of indigenous cattle have been described in detail by Groenewald and Curson (1933), Bisschop and Curson (1933), and others.

Attempts to improve the type and productiveness of these animals by means of grading up with purebred bulls of both dairy and beef breeds have not been conspicuously successful. Although the first generation obtained from such matings usually showed improvement in type and conformation over their dams, loss of constitutional vigour, failure to develop properly and increased mortality invariably have followed one or two further topcrosses with purebred bulls.

Since the reasons for the deterioration in size and constitution must be sought largely in the severe climatic conditions of this locality, the following brief description of the topography and vegetation is given of the experiment station where the investigation was carried out. The conditions at this station are fairly typical of the country. A granite formation dominates the entire area and the topsoil is shallow and exceedingly poor. The country is rough and hilly in most parts. The rainfall is low,—the mean annual precipitation for the years 1928-1932 was 14·20 inches—and there is practically no opportunity for growing supplementary forage crops. The greater part of the area lies at an elevation of 1,500 to 3,000 feet above sea level. The summers are extremely hot, shade temperatures of 100° F. to 110° F. being frequently recorded. Killing frosts rarely occur but the nights are chilly throughout the winter months.

The main characteristics of the pasture land are the scrub growth which forms a monotonous covering (see Appendix, figure 25) and the annual grasses. The dominant scrub types over most of the area are the Mapane (*Capaifera mopane*) and the species belonging to the family *Celastrasseae* but in the more fertile sections several species of Acacia are prominent. The remainder of the vegetative covering is composed of annual grasses intermixed with a small and varying percentage of perennial grass. On the poorest soil types and in overgrazed sections annual weeds are fairly prominent but on the hilly situations the perennial grasses are more abundant. It is therefore evident that a large proportion of the pasture has to establish itself annually.

Enneapogon mollia is the most commonly occurring grass. Other prominent annuals are *Aristida adsceniosis*, *Tragus racemosus*, and *Schmidtia bulbosa*. As regards perennial grasses the following are the most important economically: *Digitaria eriantha*, *Pannicum maximum*, *Eragrostis atherstonii* and *Pennisetum cenchroides*.

The comparatively small perennial grass growth is largely due to the low annual rainfall and unfavourable soil conditions. Although the soil is composed largely of decomposed granite there is apparently no serious mineral deficiency as determined by chemical analysis of samples of soil and of the vegetation.

OBJECTS OF THE INVESTIGATION.

At the time the investigation was started the main objects in view were to determine the degree to which native cattle could be successfully graded up under practical range conditions by the continued use, in successive generations, of purebred bulls. For this purpose it was proposed to make a comparative study of the five major beef breeds found in the country by breeding these to unimproved cows and on their progeny for several generations.

A secondary object was to determine the most suitable practice of herd and pasture management. However, this phase of the investigation suffered a severe setback after the work had been in progress for two years owing to an outbreak of foot-and-mouth disease in the adjoining territories with consequent necessary quarantine restrictions.

The present study is concerned with the growth of the first generation animals obtained from this scheme of breeding.

REVIEW OF LITERATURE.

The various aspects of the subject of growth are comprehensively reviewed in recent publications by Robertson (1923), Robbins and co-authors (1928), Brody and Associates (1926), (1927), and Hammond (1932). Growth in dairy cattle has been extensively studied but comparatively few systematic investigations on the growth of range beef cattle have been reported.

Moulton and associates (1921) investigated the growth of beef steers on different planes of nutrition from birth to 1,440 days of age. Their results indicate that animals fed to the limit of their appetites show a remarkably uniform increase in weight up to the age of 1,200 days. Animals fed on a plane of nutrition to furnish maximum growth without fattening show a similar curve except that the rate of gain is slower. Animals fed scantily to the extent where growth was actually retarded show a more irregular curve with a perceptibly slower average rate of growth. However, it was found that the scantily fed animals reached the same wither height as the full fed ones at the age of four years. The authors concluded that a greater underweight than underheight resulted from the feeding of poor rations. They also note that growth is more rapid at the earlier ages.

Hogan and Fox (1923) present growth curves for beef steers fed in such a manner as to secure as rapid growth as practicable under ordinary conditions. These curves show a uniformly straight line up to the age of two years when the downward trend, indicating a decreasing growth rate, commences.

Clawson (1926) in a study of the weight of range cattle on pasture found that the younger animals made larger percentage gains than the older ones and that the rate of gain was most rapid in the early part of the season and gradually slowed down in the autumn. These observations were made during a period of four years from June to September.

In his studies on type in beef calves Hultz (1927) found very marked changes in body proportions or " type " during a six months feeding period. He also states that the most important measurements for the determination of type are depth of chest, paunch girth and height at withers.

In a comprehensive review of the growth studies on dairy cattle at the Missouri Agricultural Experiment Station, Brody (1927) states " weight and girth are apparently affected to nearly the same *relative* extent by conditions of undernutrition . . . one reason is that the measurement of circumference of chest includes not only the skeletal growth but also the flesh around the chest . . . The height at withers measurement does not measure fleshiness ". He concludes that the measurements which approach their mature values at relatively rapid rates are but slightly influenced in their growth by environmental conditions as compared with the influence of the same conditions on those which approach their mature values at a relatively slow rate as compared with weight.

Lush (1928) has shown that certain measurements, noticeably those of width, are greatly affected by degree of finish or fatness apart from growth. Eckles and Swett (1919) found no relation between size at birth and rate of growth or size at maturity. They also state that gestation has no effect on growth whereas lactation and nutrition have pronounced effects on body weight. These factors also influence the rate of growth in wither height to some extent but have no effect on the height attained at maturity. They observed that the rate of growth in skeleton is the same for such widely different breeds as Holsteins and Jerseys up to 24 months of age. Espe, Cannon and Hansen (1932) also observed a pronounced effect of lactation on growth in weight in dairy cattle.

Brody and Ragsdale (1921) found evidence of two post-natal cycles in the growth of Holstein and Jersey heifers, the maximum growth velocity in the first cycle occurring at four and a half to five months and the second, an ill-defined maximum at 20 months.

Hammond (1920) collected data from the records of the Smithfield Club of stock exhibited at Fat Stock shows and studied the relative growth of various breeds and crosses of cattle. He analyzed the weights for animals at different ages but these cannot be considered as normal growth since exhibition stock are usually fed and managed exceptionally well. However, he observed definite breed and sex differences for the breeds studied.

In his studies on the growth of the lowland cattle of Eastern Prussia, Hansen (1925) found that the younger the animals were the greater was the rate of growth in all directions. The measurements of width increased most rapidly, followed by measurements of length and finally measurements of height. He found that growth of various measurements ceased between the ages of three and four years. He also observes that the plane of nutrition of the animals during the early stages of development is very important.

Ashton (1930) in presenting growth measurements of various European breeds of cattle makes the following interesting observation: "It would seem that in general the various European breeds of cattle vary in volume or size according to the quality or nature of the soil where they are born and reared. . . . The Brittany, truly a dwarfed breed in every respect, owes its extremely small size to the natural lack of both calcium and phosphorus in the geological formation of those parts of Brittany where the breed was evolved."

The importance of minerals, especially phosphorus, in the normal growth of range cattle on phosphorus-deficient pastures, was investigated by du Toit and Bisschop (1929) in an extensive series of experiments. Cows of the nondescript unimproved type were bred to four different breeds of bulls. The herds were kept under natural range conditions except that certain groups were fed small amounts of bonemeal daily. Regular weights were taken but only two sets of body measurements were taken at two different ages on a number of half-bred heifers of different breeding in each group. The following conclusions were drawn in regard to the growth of these animals:

"The influence of bonemeal on the *rate of growth* of calves is remarkable. At birth there is no difference between 'bonemeal' calves and 'control' calves; at six months there is a difference of 48 lb. (or 14·5 per cent.) in favour of the former group; and at two and a half years the difference is 243 lb. (or 32·2 per cent.)."

In regard to the effect of bonemeal feeding on skeleton growth the authors state: "There is a marked difference in favour of cows receiving bonemeal in respect to length of body, width of chest, heart girth and width between hook bones. The skeletal development of bonemeal-fed calves is also superior in every way to the control calves."

It was also observed that the increase in weight of the young stock showed a definite seasonal trend depending upon the condition of the pastures, consequent upon the rainfall. Growth usually received a check during late winter to early summer, i.e. from July to December.

In regard to breed differences it was found that the Sussex half-breds were heavier at six months than all other breeds (Afrikander, Red Poll, Friesland) and that they retained this lead throughout the period of the experiment. The Red Poll half-breeds weighed considerably less than the other groups at six months but soon overtook the Afrikander and Friesland. The latter groups showed approximately the same rate of increase.

The most extensive investigation on the growth of range cattle under conditions of yearlong grazing is that conducted by Lush and co-workers (1930). This investigation covered a period of nine years during which an extensive series of body measurements in addition to live weights were taken. The following breeds and crosses were included in the study: Herefords, first cross high grade Brahman-Hereford, and backcrosses of the latter to the Hereford. The conclusions drawn from this study may be summarized as follows:—

The most rapid rates of increase in weight occurred from mid-April to mid-July, after which they gradually decreased until mid-January to early March when actual losses were recorded. The growth curves show a definitely seasonal trend and variations from the typical rates of growth are directly connected with rainfall and pasture conditions.

Measurements greatly influenced by degree of fatness were affected to a greater extent by seasonal changes than measurements of the head and of the long bones .

Breed and sex differences were relatively unimportant but quarter-blood Brahmans were slightly heavier than half-bred Brahmans or high grade Herefords. Steers were slightly heavier than heifers at all ages up to 30 months.

In regard to the effect of adverse conditions on ultimate size the authors conclude as follows: " The evidence indicates rather clearly that the skeletal growth is really slowed down in parts of the body by the winter period of scanty feed. Whether mature size is permanently stunted at all by winter periods of feed shortage or is only postponed to a later age than would be the case with cattle well fed the year round is not clear. These data and the data from the experiments at other stations lead us to believe that very little if any of such permanent stunting occurs."

PLAN OF EXPERIMENT.

In 1928 two hundred cows of the unimproved type were purchased from farmers in the surrounding country and these were transferred to the experiment station near Messina, Northern Transvaal. Selection of the cows was confined to such factors as freedom from disease or visible defects; a fairly good frame and reasonable thriftiness but no special attention was paid to the breeding of the animals. Some showed evidence of an infusion of Afrikander blood while others showed the presence of either Friesland, Shorthorn or Hereford blood in earlier generations. The average type of these cows is illustrated in Appendix figures 26 and 27.

Two bulls of each of the following breeds were acquired: Hereford, Shorthorn, Sussex, Aberdeen-Angus, and Afrikander, as representing the five major beef breeds used extensively in South Africa. The Afrikander is a breed developed from indigenous strains of cattle and has been fully described by Bosman (1924), Reinecke (1927) and du Toit and Bisschop (1929). The information on the origin of the breed is fragmentary. However, all available information tends to show that it was developed from the large framed cattle of the Hottentots, a tribe of African native which inhabited the coastal regions of the Cape at the time of the advent of the white man in the early eighteenth century. The Hottentot cattle were considered a distinct type differing widely from that of the cattle owned by the Bantu tribes. Epstein (1933) has recently endeavoured to show the similarity in many respects of the present day Afrikander to the early Hottentot cattle and he concludes that there can be little doubt that this breed traces back ultimately to the *Bos indicus* of Asia. It is reasonably certain that the European breeds of cattle played very little or no part in the formative period of the Afrikander since it had already become established as a breed at the time of the first importation of Eurpean cattle towards the end of the eighteenth century. On the other hand, evidence of a Zebu (*Bos indicus*) origin is displayed in the characteristic hump and sloping rump. Although the Afrikander Cattle Breeders' Society was only established in 1912 and the registration of animals only dates from that time, the breed had been bred pure for many generations at the time of the outbreak of the Anglo-Boer War in 1899 and many notable herds were in existence at that time. As the result of the war most of these herds became scattered and valuable breeding records became lost so that the pedigrees of the present-day Afrikanders generally cannot be traced further back than the beginning of the present century. As a breed the Afrikander may be described as medium of size and inclined to be narrow and shallow of body. It is somewhat leggy, judged from the standpoint of a beef animal, but it shows very fine, clean bone. It is relatively slow in development and both sexual maturity and maximum body growth are attained at a later age than is commonly found in the British breeds of beef cattle. The colour is red, ranging from light to deep cherry red and the coat is short and sleek. The breed is noted for its hardiness, rustling ability and resistance to ticks and tick-borne diseases.

The selection of the bulls was carried out in co-operation with the respective breed Societies in order to ensure that the animals would be representative of the average type of ranching bull. They were medium priced bulls and cannot be considered representative of the best of their respective breeds. The type of these bulls may be observed in the illustrations in Appendix figures 28 to 32. They were immunized against Redwater (Piroplasmosis) and gall sickness (Anaplasmosis) before being introduced into the area.

The cows were branded and divided at random into five groups of equal numbers and each group was bred to bulls of one of the breeds mentioned above. It was planned to breed each group of cows to all five breeds of bulls in rotation in successive years.

Management.—In view of the dense bush and the absence of adequate fencing it was extremely difficult to keep the herds apart during the breeding season and to prevent animals from straying. Consequently all herds were rather closely herded by day and kraaled* at night.

During the breeding season the groups were kept separate and the bulls were allowed to run with their respective herds every day from late afternoon until the following morning, for a period of approximately 10 weeks. The breeding season was restricted with the object in mind of limiting the calving season to the months of April, May and June. At the conclusion of the service period the groups were combined into two large herds which were allowed to graze on the various sections of the station in rotation.

All calves were ear-tagged at birth and branded some time after weaning. The males were castrated (bloodlessly) by means of the Burdizzo Pincers before they were three months old. Weaning occurred at an average age of eight months. After weaning the calves were run in one herd until they were 18 months old when the steers and heifers were separated.

No supplementary feeding was practised at any time during the year except in the case of the bulls. These received small supplements of cottonseed meal, crushed maize and at odd intervals a small allowance of hay during the service period. Salt and bonemeal were fed at irregular intervals. Generally the animals showed no craving for salt, due to the high sodium chloride content of the drinking water which was obtained from boreholes.

In view of the fact that this part of the country was heavily infested with ticks and due to the prevalence of Anaplasmosis, Piroplasmosis and Heartwater all cattle were dipped regularly at weekly intervals during the summer months and bi-weekly during the winter months.

EXPERIMENTAL DATA AND METHODS.

Commencing in January 1931, all calves were weighed regularly at bi-monthly intervals from birth. The calves born in 1929 and 1930 were weighed at birth and again at weaning time. Thereafter they were also weighed at bi-monthly intervals. The foundation cows were weighed only once a year when their calves were weaned. At the first weighing in January 1930, they were weighed on three consecutive days and the average of the three weights recorded. For all other animals only single weights were recorded.

In January 1931, a system of taking body measurements was adopted. All half-bred steers were measured at bi-monthly intervals up to May, 1933. Measuring of the females was discontinued approximately three months prior to freshening. The method employed in taking measurements was as follows: A group of animals was placed in a pen and the individual to be measured was driven into a crush pen where it was secured with cross beans. A concrete platform

* Confined in a small enclosure or coral.

had been constructed on the floor of the pen to ensure that the animal would stand at the same level with all four feet. An attempt was made to stand the animal in a natural position but this was extremely difficult in some instances, especially in the case of the young stock as some animals were extremely wild. Linear measurements were taken with a " Deriaz " measuring stick graduated in inches, and circumference measurements were taken with a tape measure similarly graduated.

These operations were usually carried out at the middle of the month but as numbers grew the process occupied several days. The following body measurements were taken:—

Height at withers—the vertical distance from the ground to the highest point over the withers.

Height over hips—the vertical distance from the ground to the highest point midway between the hooks.

Depth of chest—the smallest vertical distance behind the shoulders.

Depth of flank—the vertical distance between the highest point in the rear flank and the top of the body just in front of the hook bones.

Width of chest—the greatest width of the chest immediatley behind the shoulders.

Width at thurls—the horizontal distance between the hip points.

Width at hooks—the horizontal distance between the lateral points of the hooks.

Width of loin—the horizontal distance between two corresponding points midway between the anterior point of the pelvis and the last rib.

Length of pelvis—the distance between the anterior point of the hooks and the pin bones on the posterior.

Length of body—the distance from the shoulder point to the pin bone taken parallel with the axis of the body.

Heart girth—the smallest circumference of the body immediately behind the shoulders.

Paunch girth—the greatest circumference of the body perpendicular to the navel or sheath.

Flank girth—the smallest circumference of the body at the rear flank, immediately in front of the hooks.

Width between pin bones.

The last mentioned measurement proved to be very inaccurate owing to the difficulty in locating the pin bones exactly, especially in the well-fleshed or fat animals. Consequently these figures have been discarded and this body measurement is not being used in this study. For the same reason other measurements taken from the pin bones to some other point, e.g. length of pelvis and length of body are subject to greater error than the rest of the measurements. In addition the measurement of length of body is also affected by the standing position of the animal. The same also applies to height at withers. All other linear measurements are not subject to these sources of error to any marked extent and are therefore reasonably accurate. Measurements of circumference are affected by the tautness with which the tape is drawn around the body and since it is difficult to judge this accurately these measurements are also subject to an appreciable error in this respect. In addition, these measurements, especially paunch girth, are greatly affected by the " fill " of the animals.

All body measurements of the individual animals were taken at the same time and recorded in a form provided with columns under the respective headings. Subsequently the observations for each body measurement were arranged according to year of birth, breed and sex.

The relevant data for three groups of animals, born in 1929, 1930 and 1931 respectively, are used in the present study. It should be noted that all the animals are half-breds of the different breeds of bulls used but occassionally they will be referred to simply as " Herefords ", " Shorthorns ", " Aberdeen-Angus ", etc., in the following pages for the sake of brevity.

ANALYSIS OF RESULTS.

In the following section the results are analysed from the standpoints of general growth and breed and sex differences. In the analysis of the latter the method of analysis of variance introduced by Fisher (1933) has been used. This method is particularly well adapted to a study of this nature in view of the relatively small number of observations involved and the disproportionate frequencies in the sets. The computations were made on a Monroe Calculating machine after the method of Wallace and Snedecor (1931). The test of significance is effected by a direct comparison of the mean squares through the use of Snedecor's (1934) table for values of F for the corresponding degrees of freedom. These values bear a close relation to those of Z in Fisher's Table VI (1933). This relationship may be expressed as follows:—

$$\frac{\text{Variance I}}{\text{Variance II}} \ldots\ldots = \text{F (Snedecor's notation).}$$

$$\text{Log}_e \text{ Variance I} - \log_e \text{ Variance II} \ldots = \log_e \text{F.}$$

$$\text{Log}_e \text{ Variance I} - \log_e \text{ Variance II} \ldots = 2\text{ Z (Fisher's notation).}$$

$$\text{Log}_e \text{ F} \ldots\ldots = 2\text{ Z.}$$

$$\text{F} \ldots\ldots = e^2 \text{ Z.}$$

The standard errors of the mean differences have been derived directly from the standard deviation of the observations from their respective breed means as follows:—

$$\text{Standard Error} = \text{S.D.} \sqrt{\frac{1}{n_1 - 1} + \frac{1}{n_2 - 1}}$$

in which S.D. is the standard deviation *within* groups and n_1, n_2 are the numbers of animals respectively in the groups compared.

Live Weights.

The average weights of all half-breds born in 1929, 1930 and 1931 respectively are shown in Appendix Tables XXIII to XXV. The weights are compared according to year of birth, breed and sex. For purposes of comparison the average weights of the dams of the 1929 group are also included.

The average birth weights of all animals classified according to sex are shown in the following table.

Table I.

Average Birth Weights in Pounds of all Half-breds.

Sex.	No.	Sex Ratio.	Breed.					
			Hereford.	Shorthorn.	Sussex.	Afrikander.	Ab.-Angus.	Average.
		%						
Males........	176	52·87	68·2	67·8	70·9	63·2	57·7	65·0
Females.....	157	47·13	63·2	60·7	66·3	57·9	56·7	60·8
Average...	—	—	65·8	63·3	68·7	60·0	57·2	63·1

These figures do not differ materially from those reported by du Toit and Bisschop (1929) for range cattle of similar breeding but they are appreciably lower than those reported by Lush and co-workers (1930) for Hereford and Hereford-Brahman crossbred range cattle.

The difference between the sexes is highly significant as shown in Table II. The value of $F = 15 \cdot 06$ may be compared with that corresponding with Fisher's ·01 probability which is 6·72 for the corresponding degrees of freedom. Likewise the differences between breeds are highly significant for both sexes. The corresponding values of F designated as highly significant are 3·43 and 3·45 for males and females respectively. In the lower half of the table the breeds are arranged in descending order in respect of birth weight and mean differences with their respective standard errors given between the different breeds. It will be observed that the ranking of the breeds is the same for both sexes. In the case of the males both Sussex and Herefords proved significantly heavier than the Afrikanders and the Aberdeen-Angus, while the Shorthorns and the Afrikanders are significantly heavier than the Aberdeen-Angus. In the case of the females the Sussex are significantly heavier than all breeds except the Herefords. The latter are significantly heavier than both Afrikanders and Aberdeen-Angus.

TABLE II.

Analysis of Variance of Birth Weights.

Classification.	Source of Variation.	Degrees of Freedom.	Sums of Squares.	Mean Squares.	Standard Deviation.	F.*
Sex..........	Total..........	332	33,356·32	—	—	—
	Between sexes..	1	1,452·00	1,452·00	—	—
	Within sexes...	331	31,904·32	96·39	9·8	**15·06**
Breed:						
(*a*) Males...	Total..........	175	25,140·77	—	—	—
	Between breeds	4	9,885·02	2,471·25	—	—
	Within breeds..	171	15,255·75	89·21	9·4	**27·71**
(*b*) Females.	Total..........	156	12,445·69	—	—	—
	Between breeds	4	1,676·70	419·18	—	—
	Within breeds..	152	10,768·99	70·85	8·4	**5·91**

MEAN DIFFERENCES.

		Hereford.	Shorthorn.	Afrikander.	Ab.-Angus.
Males.........	Sussex.........	2·69±2·3	3·14±2·5	**7·76±2·2**	**13·20±2·1**
	Hereford.......	—	0·45±2·5	*5·07±2·2*	**10·51±2·2**
	Shorthorn......	—	—	4·62±2·4	**10·06±2·4**
	Afrikander.....	—	—	—	**3·44±2·1**
Females......	Sussex.........	3·12±2·3	*5·63±2·5*	8·33±2·2	**9·64±2·1**
	Hereford.......	—	2·51±2·5	*5·21±2·2*	**6·52±2·2**
	Shorthorn......	—	—	2·70±2·4	4·01±2·4
	Afrikander.....	—	—	—	1·31±2·1

* NOTE.—Significant differences (P = ·05) are given in italics and those highly significant (P = ·01) are given in black type. This system is followed throughout in subsequent tables.

Growth in Body Weight.—Live weights are used most commonly to depict growth in animals. There are several methods of constructing growth curves from such data. The usual method is to plot the actual weights against age or time. This gives the absolute growth curve as shown in Appendix figures 9 to 11 in which the weights of the different breeds for each sex have been plotted against age. These charts show the general trend of the weights of each breed of the different groups for both sexes separately and indicate the seasonal fluctuations in the weights. However they do not convey a correct picture of the relative rate of growth. Several other methods may be used. Minot (1908) originally suggested the "Simple Interest" method which may be represented by the formula $R = \frac{W_2 - W}{W_1}$ where R is the relative rate of growth and W_1 and W_2 represent successive weights. Brody (1927) suggested two different equations for relative growth rate at different ages: First, for growth preceding the inflection at puberty, represented by the formula $K = \frac{d\ W/dt}{W}$, and second, for the phase of growth following the inflection the following formula is proposed $K = \frac{d\ W/dt}{(A-W)}$ where W is weight at the given instant, (A-W) growth yet to be made, and *k* proportionality constant or relative rate of growth.

However, the formula proposed by Fisher (1921) appears to be the best adapted to the study of relative growth rates and this method has accordingly been used in the present study. In Fisher's formula $R = \frac{\log_e m^2 - \log_e m_1}{t_2 - t_1}$ where m_1 and m_2 are successive weights and $t_2 - t_1$ represents the length of the interval between weighings. R is the relative growth rate.

Figure 1 shows the relative (instantaneous) growth rates expressed in percentage from weaning of steers and heifers of all breeds in the 1929 group.

It will be observed that there is little change in the relative rate of growth between the sexes until the age of 34 months. From this age up to the age of 42 months the steers show an appreciably greater relative increase (or smaller loss) in weight than the heifers. The former age coincides with the time that the heifers first came into lactation. Upon weaning of their calves the former were 42 months of age and the relative rate of increase again rises to that of the steers. At the age of 46 months there is a further decrease in the growth rate of the heifers. At this age they came into lactation again. This situation is also clearly brought out in Figure 2 in which the average bi-monthly weights are plotted in semi-log paper. These curves show the relative growth of the sexes throughout the period and bring out the divergence in the lines after the age of 32 months is reached.

It is of course well known that steers are normally heavier than heifers at maturity but this sharp divergence must be ascribed partly to the effect of lactation on the females. Eckles and Swett (1919) and also Espe, Cannon and Hansen (1932) found that while gestation had no effect on growth rate, lactation exercised a pronounced influence. When the females are divided into two groups on the basis of whether or not they had been in lactation the following results are obtained:—

TABLE III.

Effect of Lactation on Body Weight.

Group.	Number.	Weight.	
		July, 1931.	January, 1933.
Lactating	26	709	790
Non-lactating	21	705	903
DIFFERENCE	—	4	—113

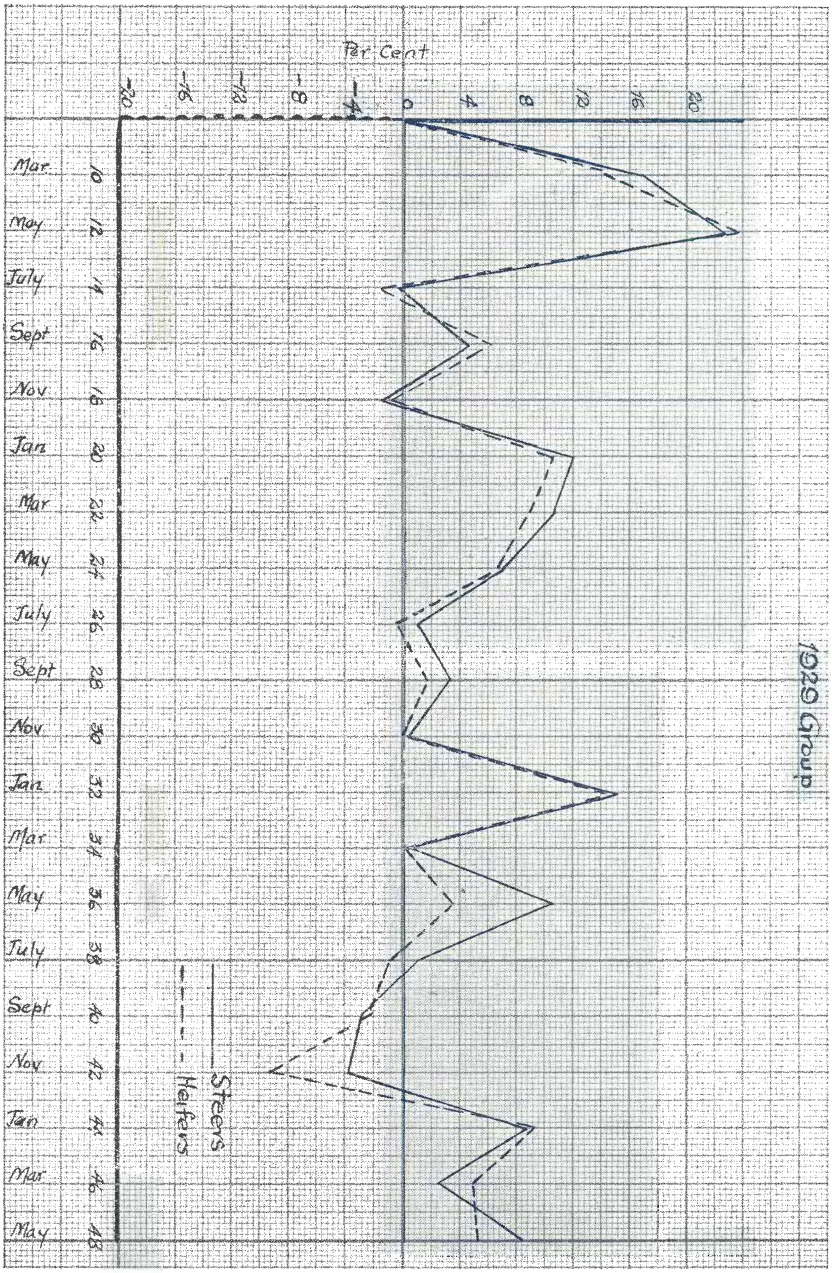

Fig. 1.—Percentage growth rates. Live weights of 1929 steers and heifers.

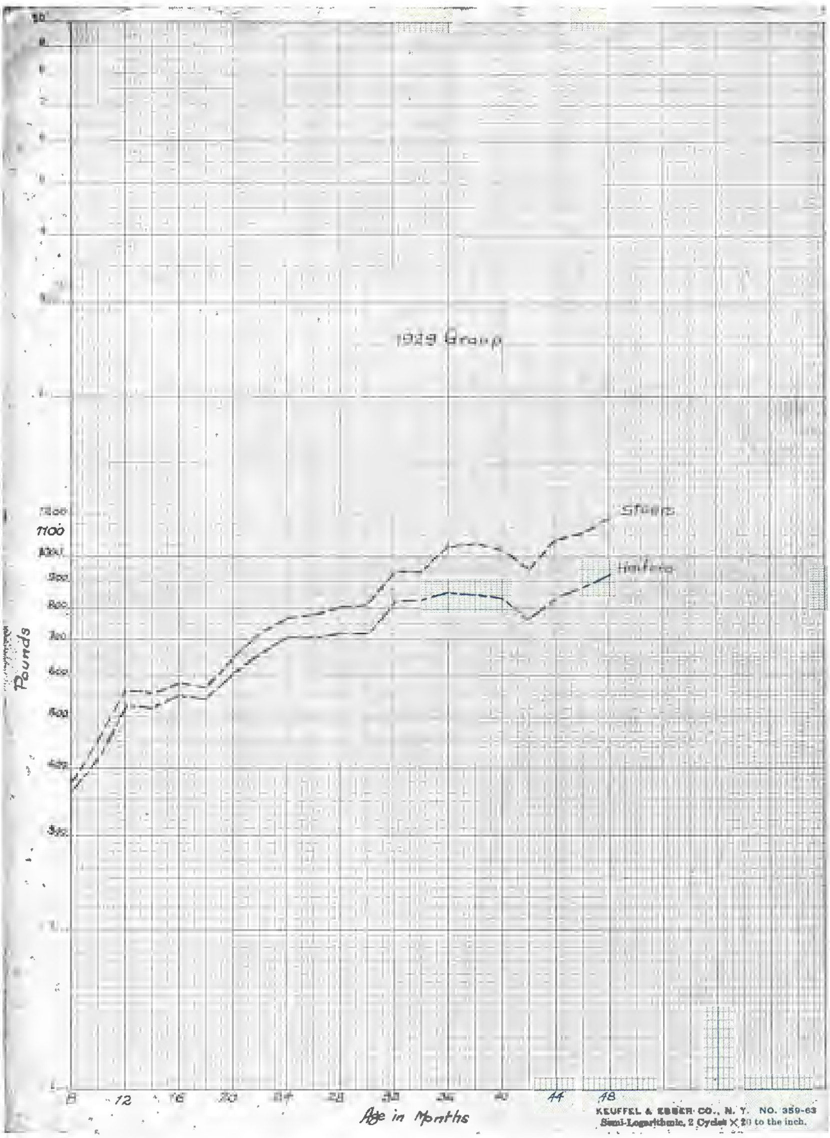

Fig. 2.—Relative growth. Live weights of 1929 steers and heifers.

When the difference in the last column is tested for significance by the method of analysis of variance a value $F = 21 \cdot 64$ is obtained, which is highly significant. The difference in the heights at withers of the above groups in January 1933, was similarly tested. Although the non-lactating group showed the higher average height the difference is only on the borderline of significance ($F = 2 \cdot 61$). Lactation evidently retarded growth in height to some extent especially in view of the fact that the animals were still immature.

Breed Differences.

Appendix Tables XXIII to XXV show the average weights for the different breeds grouped according to year of birth. Appendix figures 9 and 10 show the average trend of the changes in weight, from weaning up to the ages of 51 months and 39 months respectively, for the 1929 and 1930 groups, while the average trend of the weights of the 1931 group from birth up to 27 months of age is indicated in Appendix figure 11. It will be observed that all breeds follow more or less the same course and it would appear that environmental factors, such as climatic conditions and feed supply, have the same general effect on all breeds. This point will be further discussed in a later section.

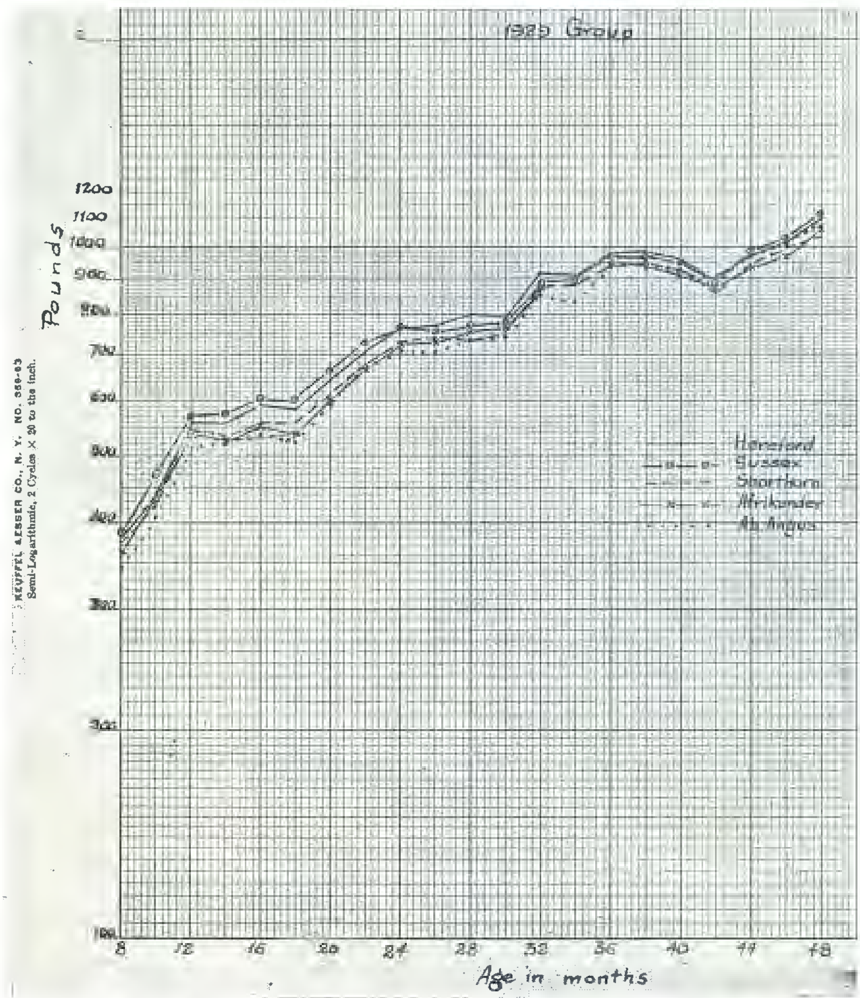

Fig 3.—Relative growth of the 1929 group. Live weight.

Figure 3 shows the relative growth of the steers of the different breeds of the 1929 group, and Figure 4 the relative rate of increase in weight on a percentage basis. With the exception of the Aberdeen-Angus, which show a higher relative rate of increase at the age of

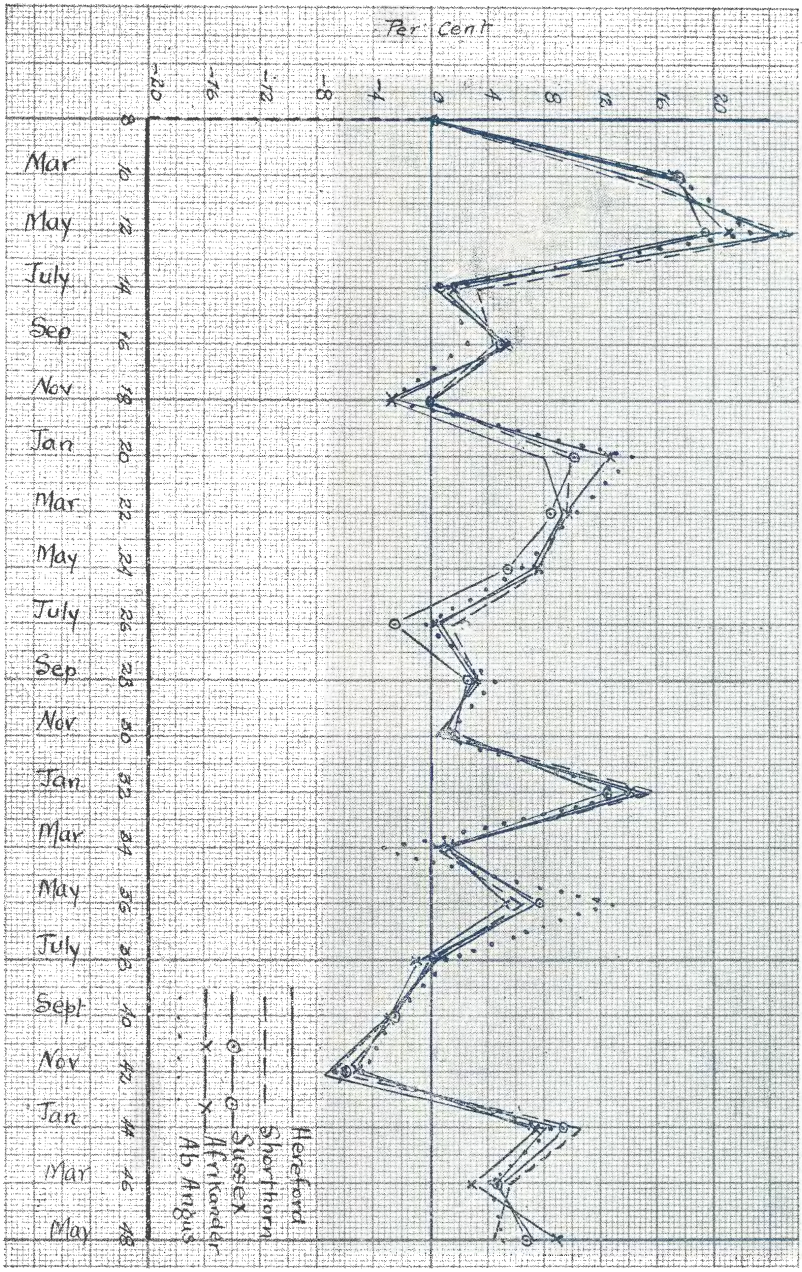

Fig. 4.—Percentage growth rates of the 1929 group. Live weight.

36 months, the breeds maintain their relative positions throughout the period and generally speaking there is practically no difference between any of these breeds in this respect. However, the differences in absolute weights between breeds in all three groups are not inconsiderable.

The differences are analysed separately for the sexes in Tables IV-VI.

TABLE IV.

Analysis of Variance of Final Weights. 1929 Half-breds.

	Source of Variation.	Degrees of Freedom.	Sums of Squares.	Mean Squares.	Standard Deviation.	F.
Steers........	Total..........	49	499,966·6	—	—	—
	Between breeds	4	180,774·6	45,193·6	—	—
	Within breeds..	45	319,192·0	7,093·2	84·2	**6·37**
Heifers.......	Total..........	44	403,850·5	—	—	—
	Between breeds	4	93,416·0	23,354·0	—	—
	Within breeds..	40	310,434·5	7,760·86	88·1	**3·01**

MEAN DIFFERENCES.

		Afrikander.	Shorthorn.	Sussex.	Ab.-Angus.
Steers........	Hereford.......	**115±35·8**	**125±42·7**	**153±37·8**	**158±34·4**
	Afrikander.....	—	10±42·7	38±37·8	43±34·4
	Shorthorn......	—	—	28±44·3	33±40·6
	Sussex.........	—	—	—	5±34·4
		Shorthorn.	Hereford.	Ab.-Angus.	Afrikander.
Heifers.......	Sussex.........	84±45·4	**132±44·0**	**132±49·0**	**137±45·4**
	Shorthorn......	—	48±37·7	48·0±42·5	53±39·4
	Hereford.......	—	—	0·0	5±37·7
	Ab.-Angus.....	—	—	—	5±42·5

The value of F=6·37 in the case of the steers is highly significant. The corresponding value for the one per cent. probability being F=3·77 for 45 degrees of freedom. In the tests of significance of mean differences in the lower half of the table the breeds have been arranged in descending order of their mean weights.*

The Herefords prove to be significantly heavier than all other breeds while no heterogeneity is demonstrated among the other breeds. The conclusion is reached that the high value obtained for F is due entirely to the extraordinary high average weights attained by the Hereford half-breds, namely 1,312 pounds at 48 months of age as compared with 1,197, 1,187, 1,159 and 1,154 for the Afrikander, Shorthorn, Sussex and Aberdeen-Angus half-breds respectively.

* This system is followed in all subsequent tests of significance of mean differences between breeds.

In the case of the females heterogeneity between breeds is likewise demonstrated, the value F = 3·01 being above the 5 per cent. point. However in this case the Sussex are significantly heavier than all breeds while the differences between the rest of the breeds are not significant. A possible explanation for the high average weight of the Sussex as compared with the Herefords may be sought in the fact that only 50 per cent. of the former freshened during the previous year as against 83 per cent. in the case of the latter. Similarly, the low average weight of the Afrikander half-breds may be accounted by the high calving percentage of 83 per cent. as compared with 50 per cent. for each of the remaining breeds.

TABLE V.

Analysis of Variance of Final Weights. 1930 Half-breds.

	Source of Variation.	Degrees of Freedom.	Sums of Squares.	Mean Squares.	Standard Deviation.	F.
Steers........	Total..........	53	451,761	—	—	—
	Between breeds	4	65,232·9	16,308·2	—	—
	Within breeds..	49	386,528·1	7,888·3	87·7	2·06
Heifers.......	Total..........	52	286,968	—	—	—
	Between breeds	4	56,828	14,207	—	—
	Within breeds..	48	230,140	4,794·6	69·2	*2·96*

MEAN DIFFERENCES.

		Sussex.	Afrikander.	Ab.-Angus.	Shorthorn.
Steers........	Not significant.				
Heifers.......	Hereford.......	1·0±32·9	43±26·4	*69±29·6*	*88±31·6*
	Sussex.........	—	42±31·4	*68±33·4*	*87±35·8*
	Afrikander.....	—	—	26±27·9	45±29·0
	Ab.-Angus.....	—	—	—	19±32·8

In the 1930 steers the differences between the breeds are not significant. However, the Sussex and the Hereford half-breds are again appreciably heavier than the other breeds. It will be observed that the value of F = 2·06 borders on significance, the value corresponding to the 5 per cent. point being F = 2·56.

In the 1930 females the difference is significant. In this case the Herefords and the Sussex are significantly heavier than the Aberdeen-Angus and the Shorthorn while the differences between the latter are not significant.

The animals of the 1931 group were only 20 months of age on the average when the final weights were taken. The difference between breeds is highly significant for both sexes, the values for F being above the one per cent. probability. In the case of the steers the Herefords and the Sussex are again significantly heavier than the remaining three breeds. The mean differences between all other breeds are not significant.

In the case of the females all breeds are significantly heavier than the Afrikanders while the differences between the rest of the breeds are not significant.

TABLE VI.

Analysis of Variance of Final Weights. 1931 Half-breds.

	Source of Variation.	Degrees of Freedom.	Sums of Squares.	Mean Squares.	Standard Deviation.	F.
Steers........	Total..........	63	278,400	—	—	—
	Between breeds	4	73,935·27	18,483·82	—	—
	Within breeds..	59	204,464·73	3,465·50	58·8	**5·32**
Heifers.......	Total..........	52	187,566	—	—	—
	Between breeds	4	63,976	15,994	—	—
	Within breeds..	48	123,590	2,574·8	50·7	**6·21**

MEAN DIFFERENCES.

		Sussex.	Afrikander.	Shorthorn.	Ab.-Angus.
Steers........	Hereford.......	10±22·8	*62±22·5*	**75±25·4**	**82±22·5**
	Sussex.........	—	*52±21·3*	*65±24·2*	**72±21·3**
	Afrikander.....	—	—	13±25·1	20±22·5
	Shorthorn......	—	—	—	7±25·1
		Shorthorn.	Hereford.	Ab.-Angus.	Afrikander.
Heifers.......	Sussex.........	9±26·2	10±21·0	35±23·3	**88±21·0**
	Shorthorn......	—	1±24·7	26±26·7	**79±24·7**
	Hereford.......	—	—	25±21·7	**78±19·2**
	Ab.-Angus.....	—	—	—	*53±21·7*

It is concluded from the analysis of variance of the weights taken at different ages on the three groups of cattle that the breeds may be classified into two major weight groups namely, Hereford and Sussex in one group and Shorthorn, Afrikander and Aberdeen-Angus in the second group. While the differences in average weight between breeds within each of these groups are not significant, the breeds in the first group are significantly heavier than those in the second group.

Seasonal Influence on Live Weight.

No evidence of the peculiar cyclic nature of growth in weight as described by Brody and Ragsdale (1921) is shown by the growth curves of any of the three groups. This is possibly due to the extreme effects produced by the seasons of the year which would tend to mask the expression of such cycles especially in the older animals. The absolute growth figures indicate the same general trend and seasonal fluctuations for all groups. Referring again to Figure 4 which shows the relative percentage growth rate of all animals in each of the five breeds for the 1929 group from weaning up to 4 years of age, it will be observed that the highest percentage increase occurred at the age of 12 months, the next peak is between 20 and 22 months, the third at 32 months and the fourth at 44 months. These ages coincided with the following months of the year respectively: May 1930, January-March 1931, January 1932, January 1933. The ages at which relative growth was the least (actual losses being recorded in most instances) are as follows: 18 months, 26 months, 34 months, and 42 months. These ages coincided with the following months respectively: November 1930, July 1931, March 1932, November 1933.

The fluctuations in relative growth rate between periods of greatest and smallest gains respectively is very considerable and clearly demonstrates the influence of season on the weights of cattle at any age from weaning up to maturity. The fluctuations in the growth of the 1930 and the 1931 groups exactly coincide in a vertical plane with those described above. Thus in the 1930 group the peaks occur in January-March 1931 (age 8-10 months), January 1932 (age 20 months), January 1933 (age 32 months). Likewise in the 1931 group the peaks occur in January 1932 (age 8 months), and January 1933 (age 20 months).

It is therefore apparent that growth in live weight is strictly seasonal under the conditions obtaining in the locality where these cattle were raised. Most rapid growth occurs during the late summer and early autumn months while growth is retarded to a great extent during late winter and early spring. Rainfall rather than season *per se* is the cause of these fluctuations. The rainfall is limited and strictly seasonal. The heaviest precipitation usually occurs from November to February. The monthly rainfall for the five-year period during which this experiment was in progress is given in Table VII.

TABLE VII.

Monthly Rainfall in Inches.

	1928.	1929.	1930.	1931.	1932.	1933.
January	1·64	3·07	3·72	0·16	2·56	10·88
February	2·08	5·88	0·30	0·60	4·21	—
March	0·43	0·89	1·60	1·43	5·77	0·90
April	—	—	1·80	1·35	1·47	—
May	—	0·10	0·40	—	0·06	—
June	—	0·05	—	—	—	—
July	—	—	—	1·10	—	—
August	0·16	0·02	—	—	—	—
September	—	—	0·08	—	—	—
October	0·11	0·65	—	1·66	0·71	—
November	1·77	4·68	2·69	2·94	1·30	—
December	2·43	1·94	4·22	1·45	3·11	—
TOTAL	8·62	17·68	14·81	10·69	19·19	11·78*

* 6 months total.

The rainfall for the 4-month period November to February inclusive was 12·15; 9·64; 7·67; 11·16; 15·24 inches, as compared with 0·80; 1·71; 5·88; 5·54; 8·31 inches for the remaining 8-month period for the years 1928 to 1933 respectively. These figures show more clearly the reason for the relatively large percentage increases each year. It will be observed that there was practically no precipitation during the period extending from May to October hence the retardation in growth of body weight up to November.

That this is the general situation in the semi-arid regions of South Africa in the summer rainfall area is fully borne out by the results obtained by du Toit and Bisschop (1929) in which they invariably observed an actual loss in weight in young growing cattle during the period July to November as compared with uniformly substantial increases during the period December to May.

Similar results have also been obtained by Lush and co-workers (1930) for range cattle in Texas. They record actual losses in weight from mid-January to mid-March (corresponding with the season July to November in the present study) and the greatest increase in weight from mid-April to mid-July (corresponding with the season December to March).

These results are in strong contrast to those obtained with cattle kept on a uniform level of nutrition throughout the year as reported by Moulton and associates (1921) and Hogan and Fox (1923) for beef steers and by Brody and Ragsdale (1923), (1925) for dairy cattle. Under these conditions the animals show a uniform, although slightly decreasing rate of growth throughout the year from birth up to the age of three years or over.

Returning to Appendix Table XXV, attention is drawn to the similarity between the final weights of the 1929 half-bred heifers and those of their dams. The average weights of the Shorthorn, Sussex and Afrikander half-breds are slightly higher than the averages of their respective dams, while those of the Hereford and Aberdeen-Angus half-breds are slightly lower than those of their dams. These differences are small, however, and it must be concluded that the half-bred females show no significant improvement in body weight over their dams. The steers, on the other hand, are uniformly heavier than their dams but it is difficult to determine accurately whether or not this is due to normal sex differences as no data are available on the weights of steers of the unimproved type. The question arises as to whether the use of pure-bred beef bulls on the native cows has resulted in any marked improvement in weight of the offspring over that of their native dams. Any possible effect of lactation on the weights of the half-bred offspring must be ruled out since the weights of the dams represent the average of weights taken in January in three successive years just at the time when their calves were weaned. Several possible explanations suggest themselves but discussion of these must be deferred until the body measurements have been examined.

Body Measurements.

Growth in Body Measurements.

As pointed out in a previous section the measurements were discontinued in the case of the heifers shortly after they had been bred so that completed figures are available only for the steers.

Furthermore, these measurements were only initiated in the beginning of 1931 consequently no data are available for the 1929 group up to the age of 20 months, nor for the 1930 group prior to the age of 8 months. However, the animals of the 1931 group were measured at bi-monthly intervals from birth up to the age of 24 months so that there is sufficient overlapping of the measurements at different ages in the different age groups to enable one to estimate with a fair degree of accuracy the nature of the continuous relative growth in body shape.

The relative growth of different parts of the body is presented graphically in Figures 5 and 6. Figure 5 shows the average linear measurements of all 1931 steers from 2 months up to 24 months of age. Figure 6 shows the same measurements for all 1929 steers from the age of 24 months up to 48 months. All body measurements were plotted on the same logarithmic scale consequently these curves also show the relationship of the different body parts to each other.

All measurements show fairly rapid growth in the pre-weaning stage. At the age of 8 months there is a slight downward deflection of the curves. This deflection becomes more marked at the age of 12 months. From this point the curves straighten out indicating a continuous but decreasing rate of growth up to the age of 24 months. Figure 6 shows the relative growth in the older animals. The various body measurements occupy the same relative position in the diagram as in the case of the younger group. Practically the same relative growth is shown throughout the period up to the age of 48 months when the measurements ceased.

Seasonal Influence on Body Measurements.

Although some measurements, notably those of width (between hooks, between thurls; chest and loin width) show some irregularity, in no case are such excessive fluctuations observed as in the case of body weight (see Figure 3). The curves representing body length, hip height and wither height respectively, are particularly smooth. In Figures 7 and 8, which represent the percentage growth rates of the 1931 and 1929 groups respectively, the measurements have been divided into those which show the greatest and those showing the least seasonal fluctuations respectively. The former comprise the following measurements in descending order of the degree of fluctuation: width of chest, width of loin, width at thurls, width at hooks, and length of pelvis. The second group includes depth of flank, width of chest, length of body, height over hips and height at withers. The former group of measurements occupy the lower half of the respective diagrams and the latter occupies the upper half.

Figure 7 shows at a glance the course of the percentage growth rates in the young animals. The growth rate for all measurements in the upper half of the diagram diminishes rapidly until the age of 14 to 16 months. It remains fairly constant during the succeeding four months except in the case of flank depth which shows rather wide fluctuations, and thereafter again shows an upward trend. The same general trend is observed for the measurements in the lower half of the diagram. In the latter, however, the fluctuations are much greater and such measurements as width of chest and width of loin actually show substantial negative growth rates at the age of 14 months.

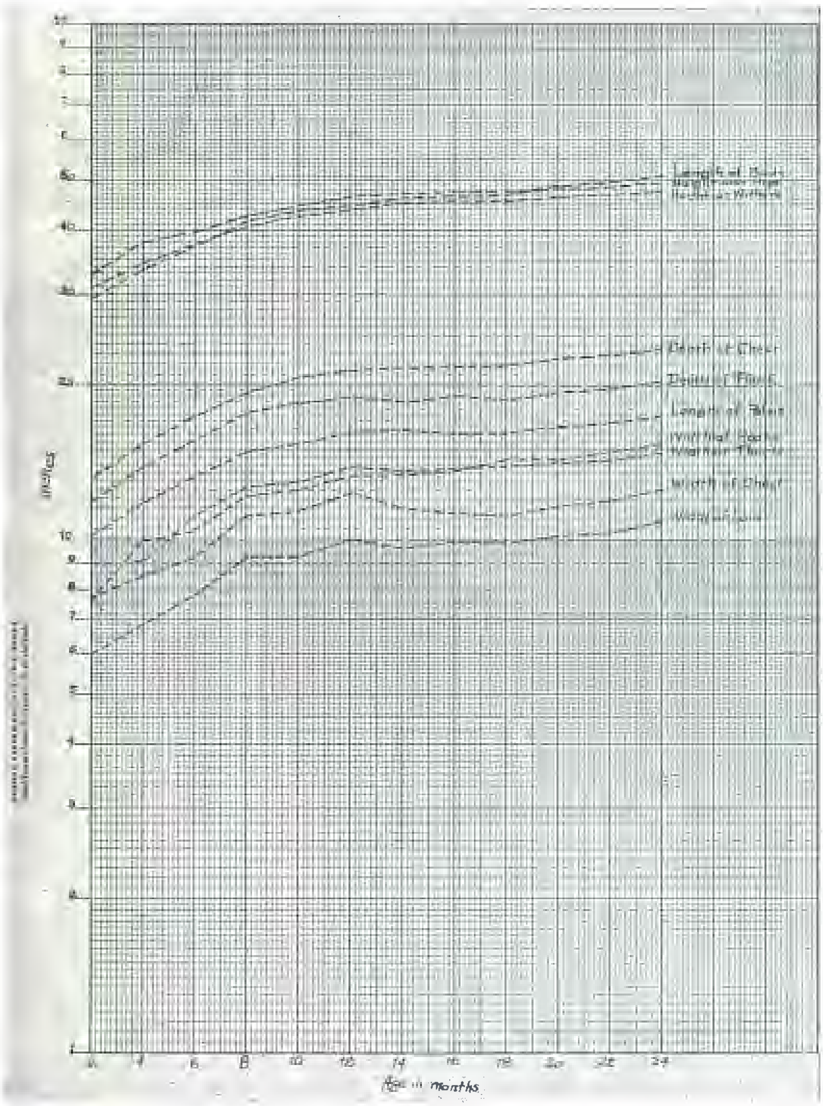

Fig. 5.—Relative growth in various body dimensions. 1931 steers.

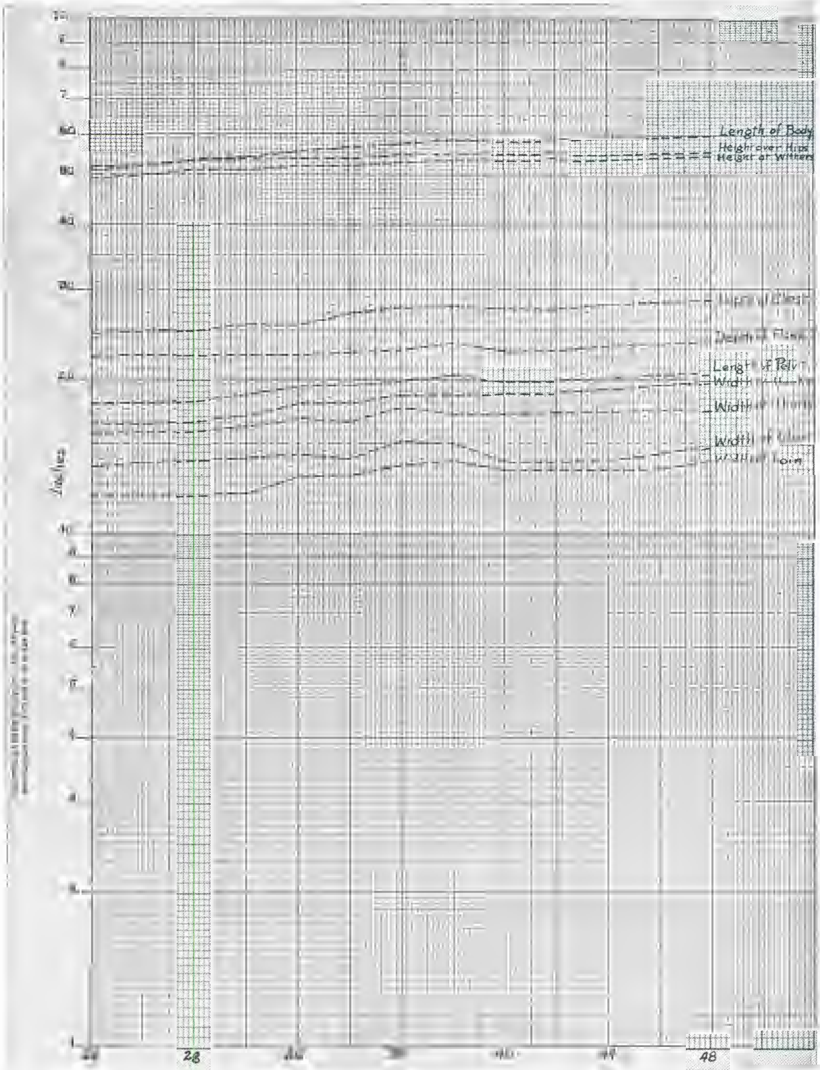

Fig. 6.—Relative growth in various body dimensions. 1929 steers.

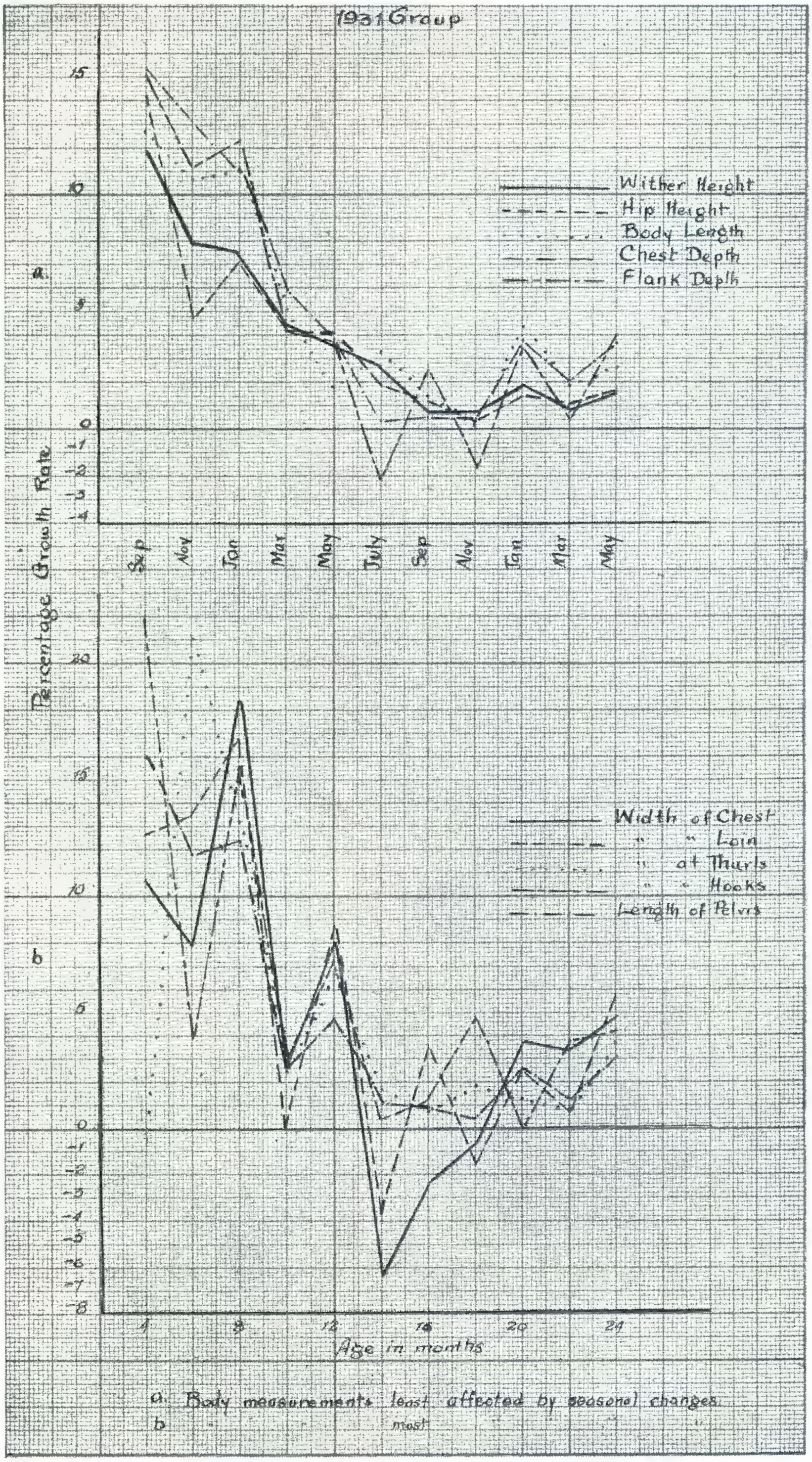

Fig. 7.—Percentage growth rates of various body dimensions. 1931 steers.

Figure 8 shows the corresponding measurements for the older group of steers. The measurements in the upper half of the diagram show a relatively constant, although slightly diminishing, rate of growth. Those in the lower half show wide fluctuations from month to month and tend to diminish at a greater rate with increasing age. Substantial negative values are again observed in the case of the latter.

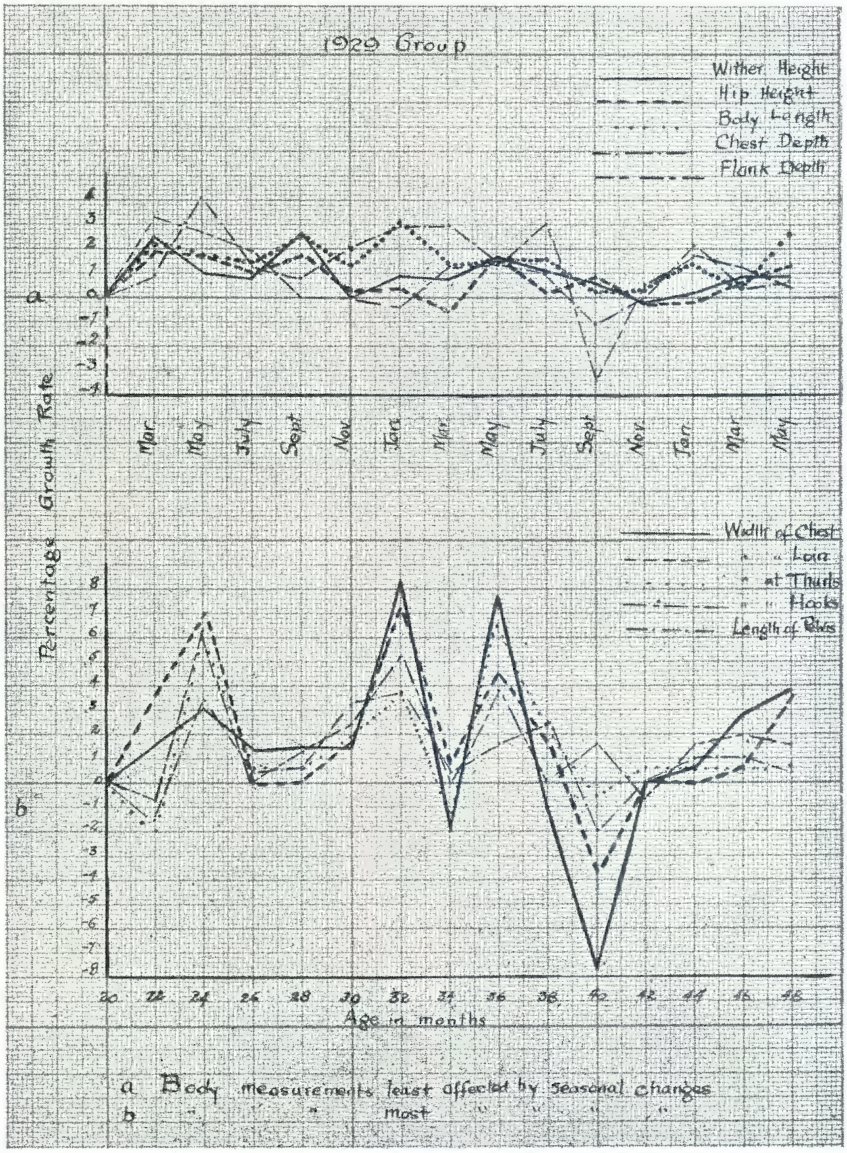

Fig. 8.—Percentage growth rates of various body dimensions. 1929 steers.

The ages at which the rate of growth in body measurements was highest correspond exactly with those observed for the greatest increase in weight as shown in Figure 4. Similarly, the points of smallest or negative growth rate coincide with those at which losses in weight occur. These fluctuations must therefore be attributed largely to seasonal influences. As pointed out by Lush (1928) certain body measurements are greatly affected by the degree of fleshing or fatness in the animals.

It can be reasonably assumed that the seasonal fluctuations in the rate of growth in respect to both weight and body measurements are due primarily to the alternating periods of abundance and scarcity in the feed supply. The production of forage in this region is largely dependent upon frequent precipitation in view of the temporary nature of the grasses which consist predominantly of annual species. Under conditions of a uniformly optimum feed supply such fluctuations in growth do not occur as pointed out by Moulton and co-workers (1921), Hogarty and Fox (1923) and Lush and co-workers (1930). Even if no permanent stunting in ultimate size of the animals occurs, interference with the normal development of the animals results and such interference undoubtedly influences the age of maturity. It is generally held that the native cattle in the semi-arid region of South Africa are late maturing. Our own observations confirm this view and it is suggested that this phenomenon is indirectly the result of inadequate nutrition and that the presence of natural selection in favour of a type of animal that can subsist on a low plane of nutrition is stronger than man's artificial selection for beef conformation.

Breed Differences.

The measurements of the steers are presented graphically in Appendix Figures 12 to 24. The three groups of curves in each diagram have been so arranged that a perpendicular line intersecting the horizontal axes of all three at any point represents the same date (month and year) so as to give a comparative picture of seasonal influences on the various body measurements of different breeds at different ages. It will be observed that the course of the absolute measurements is very similar for all breeds indicating that the breeds are affected by conditions of environment such as feed supply, more or less to the same extent. In the younger age groups the relative differences in certain body measurements between the breeds appears at a comparatively late stage in the development of the animals. The differences between breeds in the different age groups of steers are analyzed in the following section.

Referring to Table VIII it is seen that no heterogeneity is demonstrated in either the 1931 or the 1930 group. In fact the variance within breeds is greater than that between breeds in either group. This may be due to age differences in the animals within the groups although it should be pointed out that the calving season was controlled within certain limits and the extreme range in ages between individual animals is generally less than two months. However the values of $F = 1 \cdot 55$ and $F = 1 \cdot 22$ are insignificant. On the other hand, in the 1929 group the difference between breeds is highly