SOME EFFECTS OF SOIL VARIATIONS ON THE NUTRITIVE VALUE OF FORAGES FOR CATTLE

by

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INTRODUCTION

There has long been evidence that forages produced on different types of soil in the same general area give significantly different results when fed to animals. Cattlemen in Kansas have often believed that cattle grazing on limestone pastures gain more than those on sandstone pastures. It is not known, however, whether the limestone and sandstone pastures differ in yield or nutritive value of the grasses, in fertility of the soil, or in some other factor or factors that may be involved.

Studies have been conducted on the yield and chemical composition of forages and pasture herbage, the effects of soil, climatic, and site differences, and the effects of fertilization and management practices on the nutritive value of forages. There are many other factors that may be involved in these studies. Some of these factors may not yet be known. The review of literature includes the more important work that has been done related to this study.

REVIEW OF LITERATURE

Fraps and Fudge (1940) found that fertilization of pastures can increase the protein and phosphoric acid content of the grasses, as well as the yield; that soils which contained relatively high percentages of nitrogen, active phosphoric acid and active lime produced young grass which contained higher percentages of protein, phosphoric acid, and lime than were found in grass produced on soil which contained lower amounts of these constituents. Vandecaveye and Baker (1944) concluded on the basis of experimental results that the nitrogen, phosphorus, potassium and calcium content of forage crops are affected markedly by differences in soil types. Fraps and Fudge (1940) working on forage grasses of the East Texas Timber country found the correlation between protein in the grasses at a young stage of growth and nitrogen of the soils on which they grew, high for carpet grass, big bluestem, and little bluestem. There was a high correlation between the phosphoric acid content of all the grasses and the total phosphoric acid of the soil. And the correlation between the lime content and the active lime of the soil was high for big and little bluestems, broomsedge, and carpet grass.

Numerous studies have been conducted on the chemical composition of forage classes and plant species within these broad groups (Clarke and Tisdale, 1945; Hart et al, 1932). In many respects there is no general agreement. The chemical composition reported for the same plant group or plant species by various authors differs so greatly as to make any real significance in composition highly controversial. These variations result from differences in stages of maturity, soil conditions, or general climatic conditions, as well as difference in collection technique and analytical procedure.

It has been found that season of growth varies among different species, such as cool-weather and warm-weather species. These may be decidedly different in chemical composition at a given date because of the stage and duration of normal dormancy (Savage and Heller, 1947).

Some of the differences between species may be ascribed to relative amounts of leaf and stem normally produced. Leaves are materially higher in protein and minerals than are stems, and the leaf-stem ratio varies with stage of growth (Stapledon, 1947). However, carefully planned investigations (Dutoit et al, 1935; and Ferguson, 1931) have shown that different species or even varieties grown on the same soil and under the same climatic conditions display appreciable differences in nutritive content even when harvested at comparable stages of development.

Daniel and Harper (1934) found that certain species of forage were normally high in calcium and phosphorus even when grown on soils containing relatively low amounts of these minerals and plants normally low in calcium and phosphorus revealed a low content of these minerals when grown on rich soils.

Some investigators (Archibald et al, 1932; Dutoit et al, 1935; Stoddart and Greaves, 1942) have found that marked changes in chemical composition take place from early growth until maturity. With advancing maturity, protein and phosphorus contents decrease, crude fiber and nitrogen-free extract (NFE) increase, and little or no change occurs in per cent calcium. It has been found that chemical changes in the plant resulting from advanced growth stages, are greater than those arising from any other factor (Archibald et al, 1932; Stoddart and Greaves, 1942).

It has been found that the diet may be affected by season, vegetation composition, and intensity of grazing (Cook et al, 1950; Stapledon, 1947). Stapledon suggested that both the nutritive value and palatability are greatly influenced by soil conditions, manuring, liming and fertilizing with phosphorus, and nitrogen tends to increase these effects.

In general, high feeding value in pasture forage is associated with high levels of carotene, protein, and phosphorus. If these constituents are not present in the forage in amounts adequate to meet the nutritive requirements of grazing animals, the forage will not be of high quality, even though relative amounts and qualities of the other constituents are adequate.

No chemical analysis, however complete, will determine the feeding value of a forage. This can be determined by feeding trials with experimental animals. Chemical analysis, however, does serve to reveal specific deficiencies of essential constituents in forages and provides a reasonably accurate indication of their nutritive value.

The chemical composition and nutritive value of range forage and of pasture plants in general have been shown to vary greatly in relation to stage of plant maturity, seasonal conditions, rainfall, altitude, leaching, and a number of other factors. Most range and tame grasses are high in protein, phosphorus, and carotene in the early growth stages. As the plants mature these constituents decrease and the quality of the forage progressively declines.

Hopper and Nesbitt (1930) found that protein and phosphorus decreased in native range grasses from Western North Dakota with advancing plant maturity, while crude fiber increased. Sarvis (1941) found crude protein and phosphorus in native and tame grasses at Mandan, North Dakota to be high in early growth stages and low at plant maturity.

McCreary (1939) found the nutritive value in Wyoming range grasses after maturity in the fall to be so low that they had a feeding value apparently but little better than that of oat straw.

According to Beath and Hamilton (1952), grasses, whether native or introduced follow a definite pattern during their annual growth. Crude protein is highest in the initial stages of growth, decreasing gradually until fall. The percentage of crude fiber increases with advance of the season and decreases with increase of rainfall. Phosphorus varies directly as the crude protein. The perennial green plants do retain carotene, crude protein, and other desirable foodstuffs during the autumn and winter months; these are the chemical indications of their high feeding value.

Crude protein and phosphorus have received the most consideration in chemical studies of range grasses. McCreary (1939) found the phosphorus content of pasture grasses to be higher in the early summer than in the fall and to vary directly with crude protein content. Baker et al (1947) found crude protein and phosphorus in native Nebraska hays to decrease as maturity of the grasses increased and hays having higher protein content producing greater gains when fed to wintering calves.

Hart et al (1932), from a study of California's annual grass ranges, concluded that the dry matter in this type of range forage varies from a protein rich concentrate during the early vegetative stages to that of a poor roughage during a drought period.

All studies of range forage do not indicate serious nutritive deficiencies in the mature forage. Stanley (1938) in summarizing results of a grazing trial with Hereford cows and calves, concluded that the nutritive qualities of an Arizona grassland range were adequate for the year-long maintenance of a cattle breeding unit. Esplin et al (1937) concluded from a study of Utah's winter ranges that the mineral supply of the forage plants was adequate for the requirements of sheep.

Several more recent studies of the chemical composition of forage have included carotene analysis. Apparently carotene in the grasses shows the same general seasonal decrease as do protein and phosphorus. Langham et al (1943) found that in buffalo grass and blue gramma the moisture, protein, and phosphorus and carotene dropped rapidly as the plants approached maturity. Keirstead (1945), using the data of the above investigators, obtained high correlations of carotene and crude protein for buffalo grass and blue gramma grass.

Hathaway et al (1945) determined the carotene content of 24 native Nebraska grasses at approximately monthly intervals from June to November and concluded that most of the grasses contained enough carotene content to supply the needs of range cattle until late November.

McMillen et al (1943) found gains of yearling Herefords on Oklahoma short-grass range to be high when protein and carotene were high in the forage. Savage and Heller (1947), after a five study of cattle gains and chemical composition of native range grasses at Woodward, Oklahoma, concluded that the trends in monthly gains of yearling steers were fairly direct in their positive relationship to change in the content of protein, phosphorus, ash, and moisture in the grass. Carotene content of the range grasses was extremely high during the spring period, but decreased successively thereafter in a trend similar to that observed for protein. The carotene content of the blood plasma of yearling steers showed a direct but delayed relation to that contained in the forage. Watkins and Knox (1950) found that average range forage carotene and average blood plasma carotene of Hereford cows agreed quite closely when plotted. They concluded that vitamin A deficiency of cattle on southern New Mexico grassland range would occur only in case of prolonged drought or extremely abnormal conditions.

Savage and Heller (1947) reported that cattle having access to a considerable quantity of the cool weather grasses in winter in addition to the dry-range forage, and others confined solely to a reseeded pasture of a cool-weather grass, made much more winter gain with less protein concentrates than comparable cattle grazed entirely on the dormant range. They also reported that the trend in the content of carotene in the blood plasma of yearling steers showed a direct but delayed relation to that contained in the forage. An increase in the carotene content of the forage, caused by the revival of growth in March, was reflected in an April increase of this constituent in the blood.

Kik (1943) reported that big bluestem (Andropogon furcatus) was too low in crude protein content for use in animal experimentation without supplementation. Little bluestem (Andropogon scoparius) paralleled big bluestem in protein content.

Stoddart (1943) in an investigation with a single species in Utah found time of collection, soil type and nature of site to be the principal factors affecting chemical composition. The variability of crude fiber proved to be higher than that of protein, phosphorus or calcium. These latter results are not in accord with the findings of Clarke and Tisdale (1945) but the discrepancy may be due to the difference in material used. Data presented by Kik (1943) for samples of little bluestem in Arkansas showed less variability for crude fiber than for other constituents except total ash.

Greaves (1938) concluded that phosphorus content was a good indication of the nutritive value since protein and crude fat varied directly with phosphorus content while crude fiber varied inversely.

Several digestibility trials agreed in finding that the nutritive value of range grasses is highest in the leaf stage and declines with growth development, reaching a minimum value in the cured stage.

The research project reported herein was conducted to study some effects of soil variations on the nutritive value of forages for cattle.

EXPERIMENTAL PROCEDURE

Thirty-nine choice Hereford heifer calves purchased from the Williams Ranches in Lovington, New Mexico were used in this study. The heifers had been spayed before the start of the experiment to eliminate the possibility of their being bred during the study. They were divided into two lots of approximately the same average weight. Twenty of the heifers were wintered on native sandstone pasture and 19 on native limestone pasture. The predominant species in both pastures was native bluestem grass. The pastures were located within eight miles of each other in Ellsworth County, Kansas. Both lots of heifers received 1½ pounds of cottonseed cake daily as protein supplement during the winter period. On days when the pastures were completely covered with snow, alfalfa hay was fed to the heifer calves.

At the end of the winter period it was necessary to place the cattle on different limestone and sandstone pastures. The pastures used during the grazing period were approximately 20 miles apart and were as similar as possible. However, the frequency and quantity of rainfall had differed in that particular season. Rainfall was inadequate on both pastures during the grazing period.

Due to the drought conditions of the pastures in that year (1956), the cattle were returned to Manhattan at the end of the pasture season. They were put on drylot for the following winter season and they received prairie hay grown on either limestone or sandstone soil in Woodson County, Kansas. To determine the effect of additional phosphorus on their weight gains on drylot, one half of the heifers in each group received 4 grams of supplemental phosphorus per day. All of the cattle received 1½ pounds of soybean meal per head per day during the winter period.

During all phases of the study the animals were weighed periodically. At the end of the wintering period the sandstone and limestone cattle were weighed once at the Union Pacific stockyards in Brookville, Kansas. And during the grazing season the cattle were weighed in June, August, and October when they were returned to Manhattan, Kansas. The sandstone cattle were weighed at the Union Pacific stockyards in Brookville, Kansas and the limestone cattle at a ranch two miles southeast of Sylvan, Kansas.

Early in the grazing season all the cattle were sprayed with 50 per cent wettable D.D.T. to kill ticks and flies.

Blood samples were collected from a representative group of the animals at indicated intervals. Soil, water, and forage samples were also collected periodically throughout the different phases of the study. Analysis of blood, forage, soil, and water samples were carried out by the Department of Chemistry, Kansas State College.

On March 11, 1957, the animals were started on a full feed fattening ration consisting of milo grain, soybean oil meal, and either limestone or sandstone hay fed free-choice. They were fed to choice slaughter grade until June 8, 1957, when they were about two years of age. Further blood and forage studies were carried out and carcass studies at the time of slaughter. The cattle were sold at the Kansas City yards to Swift and Co. in Kansas City, Kansas.

EXPERIMENTAL RESULTS

Phase 1. Wintering on Pasture

The cattle grazing on the limestone pasture gained an average of 63 pounds in this entire period; whereas those on the sandstone pasture only gained an average of six pounds. The difference between the gains of the two groups of cattle was highly significant (at the 1 per cent level) as shown in Table 1[1]. Average daily

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[1] All tables in the appendix.

gain per head was 0.49 lbs. for the limestone cattle and 0.05 lbs. for the sandstone cattle. At the end of this 131-day-period (Dec. 5, 1955 to April 15, 1956) the limestone cattle weighed an average of 616 pounds, and the sandstone cattle an average of 564 pounds.

The pastures during those months were fairly dry, although there were spots with cool-weather species of grass. The predominant species were little bluestem (Andropogon scoparius), buffalo grass (Buchloe dactyloides), and big bluestem (Andropogon gerardi). An average proximate analysis of samples of grass species commonly growing on both pastures is shown in Table 4. Samples were taken from about six different areas on each pasture. The grass was cut an inch from the ground.

A look at Table 4, under winter pasture, shows that the limestone grasses were higher in dry matter, protein and ash content than the sandstone grasses. Ether extract, crude fiber, and nitrogen-free extract contents were comparably equal. Calcium and phosphorus contents were somewhat higher for the limestone grasses than the sandstone grasses.

Table 5 shows the soil and water analyses of the limestone and sandstone pastures. Under winter pastures, the limestone soil analysis indicated a slightly higher organic matter content of 3.2 per cent than that of the sandstone, 2.86 per cent. The pH value for the limestone soil was 7.13, and for the sandstone, 6.45. This indicated the limestone soil was more alkaline than the sandstone soil. Available phosphorus for the limestone was 31 pounds per acre, which is about 10 pounds more than the sandstone's 21.33 pounds. Exchangeable potassium contents did not differ much for both pastures.

The water analysis under winter pastures in Table 5, shows that water from wells on the limestone pasture were higher in mineral content than the pond water on the sandstone pasture. Values for total hardness, calcium and chlorine contents were very much higher for the water of the limestone pasture than that of the sandstone pasture.

On March 14, 1956, blood samples were collected from five heifers of each group of cattle. A look at Table 3 will not show much difference between the calcium and phosphorus levels of the blood of the two groups of cattle.

Phase 2. Pasture Season

During this 176-day period, from April 15, 1956 to October 8, 1956, the limestone cattle gained an average of 180 pounds and the sandstone cattle gained an average of 193 pounds. Statistical analysis indicated that the difference between gains of the two groups of cattle was not significant, as shown in Table 1. Average daily gain per head was 1.02 pounds for the limestone cattle and 1.10 pounds for the sandstone cattle. Both groups of cattle made the larger gains in the months of June through August, after which time the cattle on the sandstone pasture started to loose weight. The cattle on the limestone pasture began to look smoother and showed more quality than those on the sandstone pasture. At the end of the period the limestone cattle weighed an average of 796 pounds, and the sandstone cattle, weighed an average of 757 pounds.

On July 12, 1956, forage, soil, and water samples were again collected from each pasture. Table 4 shows the analysis of forages in the summer pastures. This time only little bluestem (Andropogon scoparius) was sampled from five different areas on each pasture. It was observed that the limestone pasture had more grass, especially little bluestem and buffalo grass, than the sandstone pasture.

The data presented in Table 4 under summer pasture indicates only slight differences in the chemical composition of the limestone and sandstone forage. The average percentages of dry matter, protein, ash, and phosphorus were comparatively equal for both pastures. Calcium content was somewhat higher for the limestone forage than for the sandstone forage.

In Table 5 the soil analyses show some differences between the limestone and the sandstone soils. Average organic matter contents were about the same, 2.86 per cent for the limestone and 2.42 per cent for the sandstone. Average pH value was again higher for the limestone soil, 7.8, than for the sandstone, 6.28. The limestone soil had an average of 18 pounds per acre of available phosphorus as compared to 14.8 pounds per acre for the sandstone soil. However, the sandstone soil had an average of 447 pounds per acre of exchangeable potassium as compared to 347.2 pounds for the limestone soil. It was easier to collect soil samples from the limestone pasture than from the sandstone pasture, because the limestone soil was not as hard as the sandstone soil. This would indicate a difference in soil texture.

The water analysis in Table 5 under summer pasture shows higher average values for total hardness, contents of phosphorus, calcium, and chlorine[1].for the sandstone water than that for the limestone water. Sodium content was about twice more for the limestone than for the sandstone source.

On November 13, 1956, blood samples were collected from ten heifers in each group. Table 3 shows that the calcium contents were almost equal, 11.31 mg per cent for the limestone, and 11.37 mg. per cent for the sandstone cattle. Phosphorus content was somewhat higher for the limestone cattle, 7.58 mg per cent, than that of the sandstone cattle, 6.98 mg. per cent.

Phase 3. Wintering On Drylot

This 151-day period began on October 8, 1956 and ended on March 8, 1957. The limestone cattle made an average total gain of 145 pounds and the sandstone made 113 pounds. The difference was highly significant statistically as shown in Table 1. Average daily gain per head was 0.99 pounds for the limestone and 0.76 pounds for the sandstone cattle. Both groups of cattle made the larger gains in the months of November, December, and January. After that time they did not gain at all and they even lost a little weight. At the end of the period, the average weight of the limestone cattle was 941 pounds, that of the sandstone cattle was 870 pounds.

Table 4 shows the chemical analysis of the limestone and sandstone prairie hay that was fed to the cattle during the wintering period. The data did not show much difference in the chemical composition of two kinds of hay except in phosphorus content where

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[1] This water from a city well was trucked to the sandstone pasture due to the summer drought.

the limestone hay was about 0.5 per cent higher than the sandstone hay.

Ten heifers in each group were bled on March 13, 1957. Analysis of blood samples as shown in Table 3 showed no difference in the calcium contents but a somewhat higher phosphorus content for the limestone group.

Value of Added Phosphorus on the Wintering Ration. This was a 100-day period, from November 28, 1956 to March 8, 1957. Table 2 shows the data obtained from this period. Average total gains for the limestone lots were 74 pounds for the control and 79 pounds for the phosphorus lot; for the sandstone lots, 80 for the control and 79 for the phosphorus lot. Statistical methods showed no significant differences. Average daily gains were about 0.8 pounds for all the lots. It should be noted that the added phosphorus was fed to one of the limestone and sandstone lots during the last 100 days of the wintering period.

Data for average daily ration and feed consumption per 100 pounds gain are also included in Table 2. Feed consumption per 100 pounds gain was lower for the phosphorus lots than for the controls.

An analysis of the soybean oil meal fed is given in Table 4. The only difference between the soybean meals of the two lots of each group (sandstone and limestone) was phosphorus content. The control had 0.7 per cent in the meal, and the P lot, 1.1 per cent. It was mentioned previously that phosphoric acid was fed mixed with soybean oil meal. No harmful or ill effects were observed from feeding phosphoric acid as a source of phosphorus. The cattle ate the feed mixture readily. Description of the hay analysis

(Table 4) has already been given. Blood phosphorus of the sandstone phosphorus lot, with 7.36 mg. per cent was 1 mg. per cent higher than that of the limestone phosphorus lot, with 6.3 mg. per cent blood phosphorus. There were no marked differences in blood calcium.

Phase 4. Fattening Phase

This was the last phase of the experiment, a 92-day period which started on March 8, 1957 and ended on June 8, 1957. Average total gain for the limestone cattle was 128 poonds and for the sandstone, 149 pounds as shown in Table 1. The difference was highly significant statistically in favor of the sandstone cattle. Average daily gain for the limestone cattle was 1.35 pounds, for the sandstone cattle, 1.65 pounds.

Value of Added Phosphorus to the Fattening Ration. Supplemental phosphorus feeding was continued through the fattening period. Table 2 presents the data obtained from this phase of the experiment. For the limestone lots, average total gain for the control was 115 lbs., for the P lot, 133 lbs.; for the sandstone lots, 160 lbs. for the control, and 144 lbs. for the P lot. Calculation of the least significant difference (L.S.D.) showed that the control lot of the sandstone group made a significantly greater gain than the other lots. For the limestone group average daily gain was 1.25 pounds for the control and 1.44 pounds for the P lot; for the sandstone group, 1.74 pounds for the control, and 1.57 pounds for the P lot. Periodical gains were normal for the control lots of each group. The gains of the phosphorus lots in each group dropped in the month of April. This might have resulted from the cattle going off feed while gradually increasing their fattening ration. Some heifers showed signs of bloat or actually bloated. They were treated by veterinarians. The control lots of the limestone and sandstone groups gave the most trouble with mild or severe bloats. One important factor that might have affected some of the cattle adversely was the heavy rains that fell in April. Since the cattle were in open pens, the ground became wet and muddy and the cattle refused to lie down. Some of them even lost their appetite. At the end of the period the final average weights were: for the limestone cattle, 1,048 lbs. for control, 1,091 lbs. for P lot; for the sandstone cattle, 1,025 lbs. for control, and 1,014 lbs. for P lot.

The average daily ration and feed consumption per hundred pounds of gain are given in Table 2. The amount of feed consumed per hundred pounds of gain was less for the limestone phosphorus lots, but more for the sandstone phosphorus lots.

Milo feeding was started out at 4 pounds per head per day and was gradually increased by one half pound everyday for about 20 days when the cattle could eat as much as 18 pounds per head per day. Daily hay consumption went down to about 10 pounds per head compared to 17 to 18 pounds per head in the wintering period. Soybean oil meal was maintained at 1½ pounds per head per day.

Blood Analysis

Data for analysis of blood for the fattening period is shown in Table 3. Samples were collected on May 29, 1957. The average calcium content of the limestone lots was 10.45 mg. per cent (10.66 mg. per cent for control and 10.20 mg. per cent for P lot); of the sandstone lots, 10.98 mg. per cent (10.66 mg. per cent for control and 11.31 mg. per cent for P lot). For the limestone lots the average phosphorus content was 10.66 mg. per cent (10.3 mg. per cent for control and 11.02 mg. per cent for P lot); for the sandstone lots, 9.38 mg. per cent (9.51 mg. per cent for control and 9.26 mg. per cent for P lot).

Final Analysis

Average total gains for the whole experiment were, 513 pounds for the limestone cattle and 466.5 pounds for the sandstone cattle. Statistically the difference was significant (at the 5 per cent level). The final average weights were, 1,070 pounds for the limestone cattle and 1,020 pounds for the sandstone cattle (Table 1).

At the end of the fattening period all the cattle were trucked to the Kansas city market (Missouri) where they were sold to the highest bidder. Swift and Company bought the twenty sandstone cattle for $ 21.50 per cwt., 17 limestone cattle for $ 22.50 per cwt., and two cowy-looking limestone cattle for $ 20.00 per cwt.

Carcass Data

Table 6 presents the yield and carcass data. Average hot carcass weights for the limestone cattle were: 639 lbs. for control and 655 lbs. for P lot, and for the whole group, 647 lbs. For the sandstone cattle average carcass weights were 588 lbs. for control, 587 lbs. for P lot, and for the whole group, 588 lbs. The limestone carcasses weighed 59 pounds heavier than the sandstone carcasses and dressing per cent was 3 per cent higher for the limestone group. Average dressing per cent for the limestone carcasses was 60.5 per cent, and for the sandstone carcasses, 57.6 per cent.

Finish was based on the thickness of the carcass and distribution of fat. In general, the limestone carcasses had a better quality and finish than the sandstone carcasses. Most of the limestone carcasses had a modest degree of marbling, while the sandstone carcasses had only a small amount of marbling.

Carcass grades for the limestone group (Table 6) were mostly in the good plus to choice plus range. The sandstone carcasses had a lower range, mostly from good minus to choice minus. There was one limestone and one sandstone carcass that graded a standard plus, and one sandstone carcass with a commercial plus.

Conformation equivalents[1] ranged from good to choice plus (Table 6) for the limestone carcasses, whereas for the sandstone carcasses they ranged from a lower good to choice minus.

Added phosphorus showed no apparent effect on carcass yields, grades, and quality of the limestone and sandstone carcasses.

The limestone carcasses were observed to have more color or a yellowish tinge on their fat than the sandstone carcass. The kidneys appeared to be cleaner for the limestone group than for the sandstone, whose kidneys were unevenly layered with fat. The sandstone carcasses also had thinner fat covering on the ribs than the

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[1] This refers to the general conformation of the carcass.

limestone carcasses.

An interesting observation on all the carcasses was the presence of a scar on the side where the cut was made during the spaying operation. This scar did not hurt any major wholesale cuts at all.

Two carcasses had bruised flanks which might have been caused by improper handling of the cattle in transit or in the packing plant.

DISCUSSION

During the first phase of the experiment (wintering on pasture) the limestone cattle made about half a pound daily gain per head, whereas the sandstone cattle hardly gained at all. These gains did not meet the expected daily gain of one pound for wintering weanling calves on pasture as set by the National Research Council (1950). Although gains are usually lower for heifers than for steers of comparable grade and weight, the low gains of the heifers could possibly be attributed to the adverse conditions of the pastures during that year. Due to drought conditions of the previous years, the pastures had been affected to some extent. The chemical analysis of the forage samples taken from the pastures during that season indicated a low crude protein content especially for the sandstone forage. According to the N.R.C., less than 8 per cent total crude protein in the dry matter of dry range forage or poor roughage low in digestibility is deficient for all classes of cattle. However, the cattle were supplemented cottonseed cake at 1½ pounds per head daily. Crude protein content of the supplement was 41 per cent. This increased the crude protein consumption of the cattle by 0.615 pounds per head daily. This amount plus that contained in the forage consumed would be more than the recommended allowance (N.R.C.). The calcium and phosphorus contents of the pasture forages were high during the wintering phase of the experiment, based on the N.R.C. recommended allowances. The higher protein and phosphorus contents of the limestone forage might be due to the higher organic matter content, pH value and available phosphorus of the limestone soil. Fraps and Fudge (1940) found a correlation between calcium and phosphorus in the soil and plants only for certain species. Watkins (1943) reported that soils high in phosphorus generally produced plants high in phosphorus, but some species were more efficient than others in obtaining phosphorus from the soil and showed a high content even on soils low in available phosphorus.

Water analysis showed a higher mineral content for the water on the limestone pasture than that on the sandstone pasture. It was mentioned that there were small areas on the limestone pasture with green grass. Chemical analysis of this cool-weather species (in appendix) gave 14 per cent crude protein content which was much higher than the average chemical analysis of the common species of grass on both pastures. This high-protein content of part of the forage could be a factor in favor of the limestone pasture. In this phase of the experiment the significantly higher gains made by the cattle on the limestone pasture might have been the result of a higher yield or a higher nutritive value of the pasture. The fertility of the soil on that pasture might have had some effect on the nutritive value of the forages.

Blood analyses of the cattle taken during this period did not reveal any marked difference in calcium content, but the phosphorus content was somewhat higher for the sandstone than that of the limestone cattle. It should be noted, however, that this was only the first phase of the experiment and no reason could be given for any changes in the blood analysis at this time.

During the pasture season the average daily gains of the limestone and sandstone cattle were close to the N.R.C. expected daily gain of 1.2 pounds for normal growth of 800-lb. heifers or steers. There was no statistically significant difference between the total gains of the two groups of cattle. Whether this was the result of the similar chemical composition of the forage samples from the two pastures, could be questioned. The samples might not be representative of what the animals actually ate, even if they were collected from several areas around the pasture. Gains of the two groups of cattle were normal until August of that year (1956) when the pastures became too dry because of the small amount of rainfall.

The average chemical composition of the summer forage samples did not appear to vary much from that of the winter forage samples. Only little bluestem grass was sampled in the summer and it was approaching maturity. Mixtures of grass specieas were sampled in the winter. It was mentioned that samples of cool-weather species of grass were taken in the winter along with samples of bluestem and the other common grass species.

Comparing only little bluestem samples, crude protein content of the summer samples was about double that of the winter samples, and ether extract was a little higher for the summer samples. The contents of ash, calcium, and phosphorus were higher for the summer grasses than the winter grasses. Crude fiber varied inversely with the more valuable chemical constituents in the forage. In general, the larger the quantity of fiber in the grasses, the lower their palatability and nutritional quality.

Soil analysis in this phase of the experiment was similar to that of the winter season. The amount of available phosphorus and exchangeable potassium decreased. Organic matter content was slightly lower for this season.

Water analysis showed a higher mineral content for the water that was trucked from a city well to the sandstone pasture than the water on the limestone pasture. The sandstone water had a much higher value for total hardness ($CaCO_3$), phosphorus (P_4), calcium, and chlorine, but a lower value for sodium and potassium than the limestone water.

The blood picture during this phase of the experiment might be indicative of the effects of differences in chemical composition of the forages growing on each pasture. Calcium contents were about the same for the limestone and sandstone cattle but phosphorus content was somewhat higher for the limestone cattle. Knox, et al. (1941) found a high correlation between the inorganic phosphorus in the blood plasma and the phophorus intake of range cattle;

blood calcium did not prove to be of value as measure of calcium intake.

Although there was no statistically significant difference in the total gains of the limestone and sandstone cattle in this phase of the experiment, the limestone cattle looked smoother and showed more finish than the sandstone cattle.

Variation in fertility of the limestone and sandstone soils might have effected the differences in chemical composition of the forages. However, the differences in chemical composition were probably not great enough to cause any significant increases in weight gains either of the limestone or of the sandstone cattle. The problems of forage sampling, animal behavior, soil and climatic factors are all involved in a study of this type.

In the second wintering period, all the cattle were moved to Manhattan and were fed in drylot on native prairie hay from limestone and sandstone pastures in Woodson County, Kansas. It was decided that existing factors on pasture could be better controlled in drylot. The cattle were also supplemented with one and a half pounds of soybean meal per head daily. Later in the wintering period, one half of the cattle in each group were fed added phosphorus in the form of phosphoric acid mixed with the soybean oil meal.

Average daily gains based on N.R.C. expected daily gain of 0.7 pound per head for wintering yearling cattle, were normal for both the limestone and sandstone cattle. The highly significant total gain of the limestone cattle over the sandstone cattle could not be mainly the result of a variation in chemical composition of the two kinds of hay, since analysis of hay samples indicated no appreciable differences in chemical composition except for phosphorus. Limestone hay had a higher phosphorus content than sandstone hay. Only representative samples were collected at the time when hay was being fed to the animals.

The fact that there appeared to be a difference in the quality of the limestone and sandstone hay fed earlier in the period might explain why the limestone cattle gained more than the sandstone cattle. This difference in gain was only evident earlier in the period. The first bales of sandstone hay fed appeared inferior in quality to the limestone hay, since the sandstone hay was contaminated with weeds and unpalatable material which the animals refused to eat. All such material was discarded. However, the cattle were still given all the hay they could consume.

The fact that there was no difference in the gains of the limestone and sandstone lots (when added phosphorus was being fed), was not the result of phosphorus feeding. This is true because the limestone and sandstone control lots displayed the same trend of periodical gains as the phosphorus fed lots. Most of the lots showed a sharp decrease in gains during periods of adverse weather conditions. Thus, the weather was one important factor that affected the gains of the cattle during the wintering period.

In the case of the added phosphorus, there was no effect on weight gains. Daily gains for all the lots were about 0.8 pound which was normal, based on N.R.C. (1950) expected daily gain for wintering yearling cattle on drylot. The amount of feed consumed per 100 pounds gain was less for the phosphorus fed lots. Richardson, et al. (1956) observed an increased feed efficiency when phosphoric acid was fed as a source of phosphorus for cattle. They also observed no (statistically) significant increase in rate of gain.

Blood analysis for the wintering on drylot period again indicated no marked difference in calcium levels, but a somewhat higher phosphorus level for the limestone cattle. The higher phosphorus content of the limestone hay might have effected this slight difference. The sandstone phosphorus lot seemed to have a higher blood phosphorus level than the sandstone control. Whether this had been the effect of the added phosphorus would still be doubtful.

In the fattening period the highly significant (statistically) gain of the sandstone cattle over the limestone cattle could be attributed to a number of factors, some of which may have affected the limestone cattle adversely.

While gradually increasing the amount of milo for fattening, the cattle of the limestone control lot went off feed and the amount of grain fed had to be cut down for this lot. This same lot had the most trouble with mild or severe bloat. Consequently, feed consumption decreased to some extent. It cannot be said that the cattle were brought to full-feed too rapidly, since the other lots gave no trouble at all. But due to differences in cattle behavior, it would be possible that this lot was affected. Koch, et al. (1956) reported cases of mild bloat and cattle going off-feed when bringing them to full feed of milo gain rapidly (at the rate of one and two pounds increase per head daily).

Adverse weather conditions (continuous rain) seemed to have affected the limestone cattle more than the sandstone cattle. This would again be a question of differences in animal behavior. Some of the limestone cattle showed signs of loss of appetite and lack of vigor. In general, the sandstone cattle were easier to put on full-feed than the limestone cattle.

One important factor that should be mentioned is the fact that cattle that make small weight gains in the winter tend to recover and gain more in the following summer. The sandstone cattle gained significantly less than the limestone cattle during the previous wintering period.

Since the chemical analyses of the limestone and sandstone hay were quite similar except in the matter of phosphorus, the two kinds of hay could not have effected any difference in cattle gains of the two groups. However, it was observed later in the fattening period that portions of the limestone hay were also inferior in quality to the sandstone hay. These portions were coarse and could be lower in feeding value.

Added phosphorus had no significant effect (statistically) on weight gains of the limestone and sandstone cattle. It was observed that the limestone lot not receiving phosphoric acid had the most number of cases of mild or severe bloat and going off-feed. A few of the sandstone control cattle also showed signs of bloat. It is not known whether added phosphorus can prevent to some extent bloating or cattle going off-feed in a fattening program. The limestone lots were switched to the pens of the sandstone lots and vice versa, but there was no advantage in doing this.

Feed consumption was about the same for all lots. Feed conversion or feed efficiency was higher for the phosphorus lot of the limestone cattle, but lower for that of the sandstone phosphorus lot. No explanation could be given for this.

Blood calcium levels for the limestone and sandstone group were about the same. Blood phosphorus level was 1.3 mg. per cent higher for the limestone than for the sandstone group.

At the end of the fattening period the limestone cattle still weighed heavier than the sandstone cattle, in spite of their higher gains in this period. The limestone cattle also looked smoother and showed more quality than the sandstone cattle. Final total gains of the limestone cattle averaged 46.5 pounds more than those of the sandstone cattle. Statistical analysis indicated the difference was significant (5 per cent level).

Variation in the nutritive value of the limestone and sandstone forages was apparently one factor that brought about the differences in weight gains of the cattle. There were some differences in chemical composition but they were not large. It cannot be concluded, however, that variation in soil fertility of limestone and sandstone soils effected the differences in chemical composition and nutritive value of the forages because of other factors already mentioned. A series of consecutive trials would be necessary to confirm the results of this study.

In general the limestone cattle gave higher carcass yields, finish and quality than the sandstone cattle. Carcass quality includes grade, conformation, degree of marbling, size and firmness of ribeye muscle. The carcasses of the limestone cattle had a characteristic yellow tinge on their fat, which the sandstone carcasses did not have. One desirable characteristic of the sandstone carcasses, however, was the thin fat covering on the ribs.

In view of the fact that all the cattle came from the same herd and were closely related, it appears that variation in chemical composition and nutritive value of the limestone and sandstone forages may have been responsible for the differences in yield and quality of carcasses of the cattle eating either the limestone forage or the sandstone forage.

SUMMARY

In the first wintering phase of the experiment (December 5, 1955 to April 15, 1956), the cattle grazing on limestone pasture gained an average of 63 pounds, and the cattle grazing on sandstone pasture an average of six pounds. The difference was highly significant (1 per cent level). All the cattle received one and a half pounds of cottonseed cake per head daily in this period.

In the following pasture season (April 15, 1956 to October 8, 1956) average gains were 180 pounds for the limestone cattle and 193 pounds for the sandstone cattle. The difference was not significant statistically.

Average gains for the wintering period on drylot (October 8, 1956 to March 8, 1957) were 149 pounds for the limestone cattle and 114 pounds for the sandstone cattle. The difference was highly significant (1 per cent level). Most of these differences in gain were made in the early part of the period, when the limestone cattle were eating what appeared to be a better quality hay than the sandstone cattle. Added phosphorus gave no significant increase in gains of the limestone or the sandstone cattle, but increased feed efficiency to some extent.

For the fattening period (March 8, 1957 to June 8, 1957) average gain for the sandstone cattle was 149 pounds, and for the limestone cattle, 128 pounds. The difference was highly significant (1 per cent level). The sandstone cattle were easier to put on full-feed than the limestone cattle. The limestone lot not receiving phosphoric acid had the most number of cases of mild or severe bloat and most of the cattle in that lot went off-feed. Added phosphorus had no effect on weight gains, and only increased feed efficiency of the limestone cattle. The lots not receiving phosphoric acid showed signs of mild and severe bloat. 1 The soybean meal-phosphoric acid mix was readily consumed by the animals and no ill effects were noted.

During the whole two-year trial, average total gains were 513 pounds for the limestone cattle and 466.5 pounds for the sandstone cattle. The difference was statistically significant (5 per cent level).

Analyses of blood throughout the whole trial indicated no marked difference in calcium levels, but a slightly higher phosphorus level for the limestone cattle than for the sandstone cattle. Added phosphorus slightly increased blood phosphorus levels of the limestone and sandstone cattle.

Average carcass yield for the limestone cattle was 60.5 per cent, and for the sandstone cattle, 57.6 per cent. In general, the limestone carcasses graded higher, had more finish and quality, and a slightly higher degree of marbling than the sandstone carcasses.

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APPENDIX

Table 1. Average weight, total gain, and daily gain of spayed heifers eating forage grown on limeston or sandstone soils.

Soil type	Limestone	Sandstone
Number of animals	19	20
Average initial weight, lbs.	553	558
Phase 1 - December 5, 1955, to April 15, 1956 (131 days)	Pasture	Pasture
Average weight, April 15, 1956	616	564
Average total gain, lbs.	63**[1]	6
Average daily gain, lbs. per head	0.49	0.05
Phase 2 - April 15, 1956, to October 8, 1956 (176 days)	Pasture	Pasture
Average weight, October 8, 1956	796	757
Average total gain, lbs.	180	193
Average daily gain, lbs. per head	1.02	1.10
Phase 3 - October 8, 1956, to March 8, 1957 (151 days)	Dry lot	Dry lot
Average weight, March 8, 1957	941	870
Average total gain, lbs.	145**	113
Average daily gain, lbs. per head	0.99	0.76
Phase 4 - March 8, 1956, to June 8, 1957 (92 days)	(Fattening Phase) Dry lot	Dry lot
Average weight, June 8, 1957	1,070	1,020
Average total gain, lbs.	128	149**
Average daily gain, lbs, per head	1.35	1.65

1 Analysis of variance: ** = significant at the 1 % level.

Table 1a. Summation of all phases of the trial.

	Limestone	Sandstone
Average total gain (December 5, 1955, to June 8, 1957), lbs.	513*[1]	466.5
Average weight, lbs. (June 8, 1957)	1,070	1,020

1 Analysis of variance: * = significant at the 5 % level.

Table 2. Value of added phosphorus for spayed heifers wintered and fattened on prairie hay from limestone or sandstone soils.

Soil type	Limestone		Sandstone	
Treatment	Control	Plus P	Control	Plus P
Number of animals	9	10	10	10
Av. initial wt., lbs.	861	869	787	798
Wintering phase, November 28, 1956, to March 8, 1957 (100 days)				
Av. total gain, lbs.	74 ±7.1[1]	79 ±8.9	80 ±5.0	79 ±8.4
Av. daily gain, lbs. per head	0.74	0.79	0.80	0.79
Av. hay consumed per day, lbs.	17	18	17	17
Soybean meal per day, lbs.	1.5	1.5	1.5	1.5
P from H_3PO_4[3], per day, gms.	0	4	0	4
Lbs. feed per 100 lbs. gain:				
Prairie hay	2,297	2,279	2,266	2,152
Soybean meal	202.5	190	200	190
P from H_3PO_4[3], gms.	0	540	0	540
Fattening phase, March 8, 1957, to June 8, 1957 (92 days)				
Av. total gain, lbs.	115	133	160*	144
Av. daily gain, lbs. per head	1.25	1.44	1.74	1.57
Av. final wt., lbs.	1,048	1,091	1,025	1,014
Av. hay consumed per day, lbs.	9.5	10	11	11
Av. milo consumed per day, lbs.	14.7	15.7	15.7	15.7
Soybean meal per day, lbs.	1.5	1.5	1.5	1.5
P from H_3PO_4[3], per day, gms.	0	4	0	4
Lbs. feed per 100 lbs. gain:				
Prairie hay	760	694	633	701
Milo	1,176	1,088	903	1,000
Soybean meal	144	111	103.5	114.7
P, gms.	0	278	0	254.8

1 Standard error of the mean.

2 Analysis of variance: *, significant at 5 % level; **, significant at 1 % level.

3 Phosphoric acid mixed in soybean meal.

Table 3. Average blood analysis of cattle on limestone or sandstone forage.

	Date taken	Limestone (mg. %)		Sandstone (mg. %)	
Calcium	3/14/56	11.44 ±0.16[1]		11.26 ±0.10[1]	
	11/13/56	11.31 ±0.27		11.37 ±0.20	
	3/13/57	11.45 ±0.31		11.44 ±0.12	
	5/29/57	10.45 ±0.32		10.98 ±0.74	
		Control	Plus P	Control	Plus P
		10.69 ±0.08	10.20 ±0.23	10.66 ±0.67	11.31 ±0.67
Phosphorus	3/14/56	7.68 ±0.12		8.00 ±0.18	
	11/13/56	7.58 ±0.28		6.98 ±0.21	
	3/13/57	7.74 ±0.25		6.84 ±0.33	
	5/29/57	10.66 ±0.84		9.38 ±1.17	
		Control	Plus P	Control	Plus P
		10.30 ±0.80	11.02 ±0.95	9.51 ±0.94	9.26 ±1.5

1 Standard error of the mean.

Table 4. Analysis of forage grown on limestone or sandstone soils and of soybean oil meal.

	Winter pasture		Summer pasture		Prairie hay		Soybean
	Limestone	Sandstone	Limestone	Sandstone	Limestone	Sandstone	oil meal
	%	%	%	%	%	%	%
Dry matter	94.6	93.4	93.3	93.4	94.6	94.4	93.2
Protein (N X 6.25)	7.1	4.7	6.1	5.7	5.1	4.9	49.69
Ether extract	1.8	1.6	2.3	2.2	1.9	2.2	1.55
Crude fiber	29.6	31.1	29.4	30.5	34.6	34.1	5.47
Nitrogen free extract	42.0	45.0	48.3	48.9	46.5	47.1	30.05
Ash	14.1	11.0	7.1	6.2	6.5	6.2	6.44
Calcium	0.9	0.4	0.8	0.5	0.56	0.6	0.44
Phosphorus	0.5	0.2	0.1	0.1	0.105	0.06	Control 0.70 Plus P 1.10

Table 5. Soil and water analyses from limestone and sandstone areas.

Water analysis	Limestone		Sandstone	
	Winter pasture	Summer pasture	Winter pasture	Summer[1] pasture
	(ppm)[2]	(ppm)	(ppm)	(ppm)
Total hardness ($CaCO_3$)	567.0	140.0	87.3	408.0
Phosphorus	0.03	0.5	0.01	1.2
Calcium	108.0	26.0	15.7	57.0
Sodium	14.0	167.0	8.7	82.0
Potassium	5.0	13.5	6.8	10.0
Chlorine	24.0	23.0	2.2	97.0
Soil analysis:				
Organic matter content (%)	3.2	2.86	2.27	2.42
pH value	7.13	7.18	6.45	6.28
Available phosphorus, lbs. per acre	31.00	18.0	21.33	14.8
Exchangeable potassium, lbs. per acre	476.7	347.2	491.0	447.0

1 Water from town well trucked to summer pasture due to drought.
2 ppm = parts per million.

Table 6. Dressing per cent and carcass data.

Lot	Limestone			Sandstone		
	Control	Plus P	Whole group	Control	Plus P	Whole group
Av. carcass wt., lbs.	639	655	647	588	587	588
Av. dressing per cent[1]	61	60	60.5	57	58	57.5
Finish[2]:						
Av. thickness	3	3	3	4	4	4
Av. distribution	4	4	4	4	4	4
Av. degree of marbling[3]	5	6	6	7	7	7
Av. size of ribeye[4]	5	5	5	5	5	5
Av. degree of firmness[5]	3	4	4	5	4	5
Carcass grade:						
Choice (plus)	1	2	3	0	0	0
Choice	4	3	7	0	0	0
Choice (minus)	2	0	2	1	2	3
Good (plus)	2	3	5	4	4	8
Good	1	0	1	0	2	2
Good (minus)	0		0	4	1	5
Standard (plus)	0	1	1	1	0	1
Commercial (plus)	0	0	0	0	1	1
Confirmation equivalent:						
Choice (plus)	0	1	1	0	0	
Choice	3	3	6	0	0	
Choice (minus)	5	2	7	2	0	2
Good (plus)	2	1	3	3	5	8
Good	0	2	2	5	5	10

1 Dressing per cent or yield was determined by dividing hot carcass weight by average final weight taken in Manhattan.

2 Thickness: Based on thick = 2; moderate = 3; modest = 4; slightly thin = 5. Distribution: Based on uniform = 2; moderately uniform = 3; modestly uniform = slightly uneven = 5; uneven = 6; very uneven = 7.

3 Based on moderately abundant = 3; slightly abundant = 4; moderate = 5; modest = 6; small amount = 7; slight amount = 8; traces = 9.

4 Based on modestly large = 4; slightly small = 5; small = 6.

5 Based on firm = 2; moderately firm = 3; modestly firm = 4; slightly firm = 5; soft = 6.

Table 7. Analysis of blood samples taken March 14, 1956.

Description	Calcium (mg. %)	Phosphorus (mg. %)
Limestone		
R 17	11.14	7.8
R 31	11.71	7.8
R 47	11.60	7.9
L 79	11.75	7.2
L 85	10.99	7.7
Average	11.44 ±0.35[1]	7.68 ±0.28
Sandstone		
R 8	11.15	7.4
L 17	11.25	8.5
L 14	11.28	8.1
L 22	11.61	8.1
R 96	10.99	7.9
Average	11.26 ±0.23	8.0 ±0.40

1 Standard error of the mean.

Table 8. Analysis of blood samples taken November 13, 1956.

Description	Calcium (mg. %)	Phosphorus (mg. %)
Limestone		
L 79	12.3	9.63
R 47	11.5	7.08
L 85	11.5	6.61
L 39	11.5	7.68
R 31	11.2	7.20
L 7	11.4	6.84
L 89	12.4	8.36
L 75	9.5	6.89
L 91	11.4	7.76
L 17	10.4	7.76
Average	11.31 ±0.84[1]	7.58 ±0.90
Sandstone		
L 10	11.8	6.69
L 65	10.3	5.37
R 96	11.6	6.45
R 8	11.5	7.32
L 14	11.5	7.52
R 56	12.4	7.08
L 22	10.5	7.16
L 17	10.9	7.44
RR 16	11.4	7.44
R 93	11.8	7.32
Average	11.37 ±0.64	6.98 ±0.66

1 Standard error of the mean.

Table 9. Analysis of blood taken March 13, 1957.

Lot (Description)	Calcium (mg. %)	Phosphorus (mg. %)
Sandstone Control		
RR 16	10.94	7.94
L 65	11.37	6.15
R 93	11.13	6.02
R 8	11.86	5.53
R 96	11.94	5.86
Average	[illegible]	6.30
Sandstone Plus P		
L 22	11.06	7.87
R 17	11.12	7.28
R 56	11.17	5.88
L 10	11.93	7.87
L 22	11.36	7.99
Average		7.36
Sandstone Average	11.44 ±0.12[1]	6.84 ±0.33
Limestone Control		
L 91	11.36	7.22
R 31	10.59	8.40
L 85	11.24	7.99
L 7	11.60	7.80
L 75	14.07	6.86
Average		7.65
Limestone Plus P		
L 39	11.47	7.57
L 89	11.47	8.58
L 79	10.68	7.65
L 17	11.02	7.17
R 47	10.98	8.14
Average		7.82
Limestone Average	11.45 ±0.31	7.74 ±0.25

1 Standard error of the mean.

Table 10. Analysis of blood taken May 29, 1957.

Lot (Description)	Inorganic Phosphate (mg. %)	Calcium (mg. %)
Sandstone Control		
L 65	9.64	10.32
R 8	8.91	9.69
R 93	8.91	11.50
R 96	11.29	11.32
RR 16	8.80	10.47
Average	9.51 ±0.94[1]	10.66 ±0.67
Sandstone Plus P		
L 10	10.95	10.24
L 14	7.40	11.28
L 17	11.11	12.07
L 22	8.56	10.74
R 56	8.26	12.20
Average	9.26 ±1.50	11.31 ±0.67
Sandstone Average	9.38 ±1.17	10.98 ±0.74
Limestone Control		
L 7	10.45	10.40
L 75	10.10	10.77
L 85	8.88	10.77
L 91	10.89	10.45
R 31	11.16	11.07
Average	10.30 ±0.80	10.69 ±0.08
Limestone Plus P		
L 39	9.42	10.10
L 79	11.40	9.89
L 89	10.70	10.59
R 17	12.17	10.20
R 47	11.40	10.23
Average	11.02 ±0.95	10.20 ±0.23
Limestone Average	10.66 ±0.84	10.45 ±0.32

1 Standard error of the mean.

Table 11. General soil fertility test on samples taken February 25, 1956.

Sample number	Organic matter content (%)	pH value	Available phosphorus lbs./acre	Exchangeable potassium lbs./acre
Sandstone I	1.8	6.5	20	330
Sandstone II	2.6	6.45	150	550
Sandstone III	2.4	6.4	42	550
Average	2.27	6.45	70.67	476.67
Limestone I	2.6	7.4	29	373
Limestone II	4.0	7.2	15	550
Limestone III	8.0	6.8	20	550
Average	3.2	7.13	21.33	491

Table 12. General soil fertility test of samples taken July 12, 1956.

Sample number	Organic matter content (%)	pH value	Available phosphorus lbs./acre	Exchangeable potassium lbs./acre
Sandstone I	2.8	6.3	14	420
Sandstone II	2.5	6.1	14	410
Sandstone III	2.8	6.4	14	470
Sandstone IV	1.7	6.3	16	475
Sandstone V	2.3	6.3	16	460
Average	2.42	6.28	14.8	447
Limestone I	2.8	7.8	18	275
Limestone II	2.5	7.8	17	320
Limestone III	3.0	7.8	18	390
Limestone IV	3.0	7.8	19	351
Limestone V	3.3	7.8	18	400
Average	2.86	7.8	18	347.2

Table 13. Analysis of samples of water taken February 25, 1956.

Description	Total Hardness ppm $CaCO_3$	P_4 ppm	Ca ppm	Na ppm	K ppm	Cl ppm
Sandstone 1 (West Spring)	29	0.01	4	4	0.5	9
Sandstone 2 (East Spring)	63	0.09	11	6	1	8
Sandstone 3 (Water from Pond)	170	0.07	32	16	19	49
Average	87.3	0.057	15.67	8.67	6.83	2.2
Limestone (Well Water)	567	0.03	108	14	5	24

Table 14. Analysis of samples of water taken July 12, 1956.

Description	Total Hardness ppm $CaCO_3$	P_4 ppm	Ca ppm	Na ppm	K ppm	Cl ppm
Limestone 1 (South Windmill)	24.0	0.5	6	260	17	23
Limestone 2 (North Windmill Well)	256	None	46	75	10	23
Average	140	0.5	26	167.5	13.5	23
Sandstone tank (Hauled in)	408	1.2	57	82	10	97

Table 15. Chemical analysis of samples of grass from limestone and sandstone pastures (Ellsworth, Kansas - 2/25/56).

Description of Sample	Protein (NX6.25) %	Ether Extract	Crude Fiber	Moisture %	Ash %	N-Free Extract %	Carbohydrate %	Calcium %	Phosphorus %
Limestone:									
Little Bluestem L-1	3.63	1.58	33.28	4.24	9.29	47.98	81.26	0.61	0.03
Buffalo Grass L-1	4.81	1.27	25.86	6.43	24.87	36.76	62.62	2.78	0.06
Mostly Annual Browe L-2	7.94	1.93	26.36	6.84	14.76	42.17	68.53	0.68	0.12
Sas L-2	3.75	2.24	42.81	3.59	6.24	41.37	84.18	0.24	0.06
Mostly Annual Browe L-3	8.19	1.66	26.71	6.59	15.95	40.90	67.61	0.44	1.07
L-3 S-3	14.19	2.36	22.66	4.46	13.78	42.55	65.21	0.53	1.39
Average	7.09	1.84	29.61	5.35	14.14	41.96	71.57	0.88	0.46
Sandstone:									
Little Bluestem S-1	3.56	1.53	33.09	6.64	6.62	48.56	81.65	0.33	0.19
Mostly Afu S-2	4.75	1.95	29.62	6.86	11.00	45.82	75.44	0.46	0.58
Sas S-2	3.63	1.73	37.23	6.32	7.03	44.06	81.29	0.21	0.05
Buffalo Grass S-2	7.31	1.45	24.00	6.56	19.58	41.10	65.10	0.43	0.10
Sas S-3	3.44	1.50	37.21	6.26	6.08	45.51	82.71	0.26	0.08
Little Bluestem S-3	3.69	1.43	31.92	6.92	6.06	49.98	81.90	0.30	0.04
Buffalo Grass S-3	6.81	1.50	24.80	6.53	20.98	39.38	64.18	0.52	0.14
Average	4.74	1.58	31.12	6.58	11.05	44.91	76.04	0.36	0.17

Table 16. Chemical analysis of samples of little bluestem, *Andropogon scoparius*, taken from limestone and sandstone pastures (Ellsworth, Kansas - 7/12/56).

Description of Samples		Protein (NX6.25) %	Ether Extract %	Crude Fiber %	Moisture %	Ash %	N-Free Extract %	Carbo-hydrates %	Calcium %	Phosphorus %
Limestone	1	6.06	2.17	29.24	6.86	7.67	48.00	77.24	0.84	0.07
"	2	5.94	2.41	30.47	6.65	6.96	47.57	78.04	0.72	0.07
"	3	6.13	2.34	29.63	6.60	6.66	48.64	78.27	0.71	0.07
"	4	6.19	2.27	28.94	6.59	7.20	48.81	75.75	0.78	0.08
"	5	6.19	2.27	29.14	6.64	7.23	48.53	77.67	0.84	0.10
Average		6.10	2.30	29.42	6.67	7.14	48.31	77.39	0.78	0.08
Sandstone	1	5.56	2.32	31.48	6.51	5.77	48.36	79.84	0.55	0.06
"	2	5.81	2.18	30.64	6.44	6.59	48.34	78.98	0.53	0.07
"	3	6.44	2.10	29.80	6.72	5.76	49.18	78.98	0.53	0.08
"	4	5.50	2.11	29.97	6.60	6.01	49.81	79.78	0.57	0.06
"	5	5.31	2.07	30.56	6.60	6.82	48.64	79.20	0.52	0.06
Average		5.72	2.16	30.49	6.57	6.19	48.86	79.35	0.54	0.07

Table 17. Chemical analysis of prairie hay taken from limestone and sandstone pastures in Woodson County, Kansas, May 2, 1957.

	Protein (NX6.25) %	Ether Extract %	Crude Fiber %	Moisture %	Ash %	N-Free Extract %	Carbo-hydrates %	Cal-cium %	Phos-phorus %
Limestone:									
Sample 1	5.31	1.95	35.65	5.12	6.50	45.47	81.12	0.59	0.11
Sample 2	4.88	1.87	33.55	5.64	6.54	47.52	81.07	0.53	0.10
Average	5.10	1.91	34.60	5.38	6.52	46.50	81.10	0.56	0.11
Sandstone:									
Sample 1	5.00	2.24	33.75	5.29	6.32	47.40	81.15	0.60	0.06
Sample 2	4.75	2.12	34.37	5.94	6.07	46.75	81.12	0.61	0.06
Average	4.88	2.18	34.06	5.61	6.19	47.07	81.13	0.61	0.06

SOME EFFECTS OF SOIL VARIATIONS ON THE NUTRITIVE VALUE
OF FORAGES FOR CATTLE

by

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Thirty-nine choice Hereford heifers calves were used to study some effects of soil variations on the nutritive value of forages for cattle. The heifers were spayed and were divided into two lots of approximately the same average weight. Twenty heifers grazed on native sandstone pastures, and nineteen on native limestone pastures through the winter and summer of the first year. All the pastures were in Ellsworth County, Kansas. The predominant grass species in the two kinds of pastures was native bluestem (Andropogon scoparius).

During the wintering period (December 5, 1955 to April 15, 1956) the limestone cattle gained an average of 63 pounds, and the sandstone cattle, an average of six pounds. The difference was highly significant (1 per cent level). All the cattle received one and a half pounds of cottonseed cake per head daily in this period.

In the following pasture season (April 15, 1956 to October 8, 1956) average gains were 180 pounds for the limestone cattle and 193 pounds for the sandstone cattle. The difference was not significant statistically. However, the limestone cattle looked smoother and showed more quality than the sandstone cattle.

Due to drought conditions of the pastures in that year the cattle were returned to Manhattan to be wintered and fattened on drylot for the second year of the study. Prairie hay from limestone and sandstone pastures in Woodson County, Kansas was fed to the cattle plus one and a half pounds of soybean meal supplement per head daily. To determine the effect of additional phosphorus on weight gains, one half of the heifers in each group received 4 grams per head daily of supplemental phosphorus in the form of phosphoric acid during part of the wintering period and through the fattening phase.

Average gains for the wintering period on drylot (October 8, 1956 to March 8, 1957) were 145 pounds for the limestone cattle and 113 pounds for the sandstone cattle. The difference was highly significant (1 per cent level). Most of these differences in gain were made in the early part of the period when the limestone cattle were eating what appeared to be a better quality hay than that of the sandstone cattle. Added phosphorus gave no significant increase in gains of the limestone and sandstone cattle, but increased feed efficiency to some extent. For the fattening period (March 8, 1957 to June 8, 1957) average gain for the sandstone cattle was 149 pounds, and for the limestone cattle, 128 pounds. The difference was highly significant (1 per cent level). The sandstone cattle were easier to put on full-feed than the limestone cattle. The limestone lot not receiving phosphoric acid had the most number of cases of mild or severe bloat and most of the cattle in that lot went off-feed. Added phosphorus had no effect on weight gains, and only increased feed efficiency of the limestone cattle. The lots not receiving phosphoric acid showed signs of mild and severe bloat. The soybean meal-phosphoric acid mix was readily consumed and no ill effects were noted.

During the whole two-year trial, average total gains were 513 pounds for the limestone cattle and 466.5 pounds for the sandstone cattle. The difference was statistically significant (5 per cent level).

Analysis of winter forage showed higher crude protein, calcium, and phosphorus contents for the limestone pasture than for the sandstone pasture. There were no appreciable differences in chemical analysis of summer forages. (Only little bluestem, *Andropogon scoparius*, was sampled for summer analysis). Analysis of limestone and sandstone hay showed no marked differences in chemical composition except phosphorus content which was higher for the limestone hay.

Soil analyses showed a higher fertility test for the limestone soils than for the sandstone soils. Analyses of water from limestone and sandstone pastures varied in the winter and summer due to differences in source of water.

Analyses of blood throughout the whole trial indicated no marked difference in calcium levels, but a slightly higher phosphorus level for the limestone cattle than for the sandstone cattle. Added phosphorus slightly increased blood phosphorus levels of the limestone and sandstone cattle.

Average carcass yield for the limestone cattle was 60.5 per cent, and for the sandstone cattle, 57.6 per cent. In general, the limestone carcasses graded higher, had more finish and quality, and a slightly higher degree of marbling than the sandstone carcasses.