THE EFFECTS OF IMPROVED PASTURES UPON MINERAL METABOLISM AND GROWTH OF BEEF STEERS

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Introduction

It has been stated that better animal nutrition should begin at the grass roots. Certainly good pastures have come to be recognized as one of the fundamental requirements of a sound livestock program in all of the major livestock producing areas. Pastures provide a cheap source of forage because they require little attention during the growing season and are harvested by the animal. Good pastures also supply the animal with minerals and vitamins in a more satisfactory manner than can usually be attained with any other type of feed.

Soil fertility is one of the major problems in the production of good pastures. As a result of annual cropping, grazing, leaching and erosion, much of the land used for pastures today is low in fertility and deficient in many nutrients. Phosphorus is lacking in many pasture soils and in many cases is the limiting factor for the growth of pasture plants, particularly legumes.

The problem of low pasture fertility is important in Oklahoma. Approximately two million acres of pasture land in southeast Oklahoma is low in fertility and low in available phosphorus. Much of this land is old abandoned crop land which supports only sparse vegetation of low quality. Livestock men have noted that the cattle that are not fed a phosphorus containing mineral, and grazing the herbage produced on these low phosphate soils do not gain as rapidly and do not appear as thrifty as cattle produced in other parts of the state where the soils contain an abundance of available phosphorus.

These observations suggested that the value of fertilizing such soils and the improvement of such pastures be studied.

Review of Literature

Most of the food of animals comes from plants. The plant in turn is dependent upon the soil for its nutrients. Sick soils mean sick plants, which lead to sick or unthrifty and poor producing animals. The herbivorous animal cannot be healthy or be an efficient producer without receiving nutritious forage; and the forage, to have the proper quality, must come from productive soil containing the needed elements. For many years there has been a continued removal of nutrients from our crop, hay, and pasture lands until the reduced mineral content has resulted in much land and many pastures that support only poor species of plants of low quality. Animals grazing this deficient forage and not receiving supplementary food eventually show unthriftiness and malnutrition.

Referring to the depletion of pastures by the removal of milk, meat in the form of beef, and other animal products, Orr (1929) remarked, "Accompanying the visible movement of milk and beef there is a slow invisible flow of fertility from the soil." He stated that a nine hundred pound beast taken from the farm takes with it more than 13 pounds of calcium and 6½ pounds of phosphorus. A thousand gallons of milk removed from the farm some 12 pounds of calcium and 10 pounds of phosphorus.

Phosphorus has been called the master key to agriculture. Its importance in general farming is indicated by the fact that low crop production is due more often to a lack of phosphorus than to a deficiency of any other element. Phosphorus is important in the body of the animal. Maynard (1947) called attention to the fact that phosphorus is found in large amounts in the mineral matter which gives rigidity and strength to the framework of the body. Approximately eighty per cent of the body phosphorus is found in the bones and in the teeth. The element is present in all cell nuclei. It is essential for vital activity and especially for cell division. Phosphorus is concerned in the chemical processes involved in sugar oxidation, in the activation of certain enzymes, and in the production of buffering acids in the body. Maynard further stated that phosphorus constitutes 0.15 to 0.20 per cent of the soft tissues of the body. The ash of mammalian bone contains about 17 per cent of this element. Hogan and Nierman (1927) gave the average phosphorus content of the body of a steer as 0.74 per cent, and stated that most of the body phosphorus is in the skeleton.

Calcium is another one of the more important biological elements, and is necessary for the growth of all animals and all green plants. According to Maynard (1947), calcium is the principle element which gives rigidity and strength to the framework of the animal body. Approximately 99 per cent of the body calcium is present in the bones and teeth. The remaining 1 per cent is widely distributed throughout the organs, soft tissues, and fluids. The ash of bone contains 36 per cent calcium. Sherman (1932) pointed out that upon the presence of the right amounts and proportions of calcium ions depend the normal properties and behaviour of the fluids and soft tissues of the body, such as the blood, the muscles, and the nerves. Together with sodium and potassium, calcium is essential for the steady working of the heart and for normal activities of the muscles. It is necessary for the clotting of blood, and to some extent is concerned in the maintenance of acid-base equilibrium. In connection with the production of animal products, the skeleton acts as a store of calcium which may be mobilized at times when the assimilation of calcium is inadequate to meet the needs of the body. This robbery of the skeleton may have serious and even disastrous results.

The occurence of many disorders in animals is often attributed to a deficiency of either calcium or phosphorus. It is difficult to attribute a deficiency specifically to calcium or phosphorus because of their intimate relationship. There are certain factors which play important roles in the functioning and metabolism of calcium and phosphorus. Vitamin D must be available to the animal. Rupel, Bohstedt and Hart (1933); and Huffman and Duncan (1935) reviewed the effects of vitamin D in relationship to calcium and phosphorus metabolism. This vitamin regulates the metabolism of calcium and phosphorus in the body and is associated with the normal formation of bones and teeth. Vitamin D plays an important part in the absorption of calcium and phosphorus from the intestine and in their consequent deposition in bone tissue. No amount of the vitamin will compensate for a marked deficiency of calcium or phosphorus in the diet. The vitamin may be present in the food either as the vitamin itself or in the form of a precursor. Exposure to the action of radiant energy (ultra-violet light) converts the precursor into the active vitamin. In the same way ultra-violet radiation of sunlight activates the precursor present in the animal's skin. The animal grazing during the summer is not likely to suffer from a vitamin D deficiency even though the ration contains little or none.

In their review of literature relative to calcium and phosphorus, Schmidt and Greenberg (1935) pointed out that calcium and phosphorus are also under the physiological controlling influence of the parathyroid glands. These glands cooperate with the intestines, kidneys and skeleton in keeping the serum calcium and phosphorus within narrow limits. If the ration is deficient in either of the elements the parathyroids mobilize a supply from the skeletal reserves. If the parathyroids are removed or if they fail to function properly, the level of serum calcium falls and tetany occurs. On the other hand hyperactivity of the glands may cause an excessive loss of calcium and phosphorus from the skeleton resulting in soft and porous bones.

In early work it was assumed that since the ratio of calcium to phosphorus was 2 to 1 in bone and 1.25 to 1 in milk, that somewhere in this range was the optimum at which calcium and phosphorus should occur in the ration. Work in regard to the ratio of calcium to phosphorus in the ration is not in complete agreement. Meigs et al. (1926) pointed out that an excess of calcium to phosphorus in the ration of dairy cows may interfere with phosphorus assimilation. They claimed that 2 parts of calcium to 1 part of phosphorus constituted an excess. In contrast Bethke, Kick, and Wilder (1932) showed that for optimum growth and formation of bone, a calcium phosphorus ratio of 2 to 1 in a chick ration gave best results. An increase in the ratio of these elements from 1 part calcium to 5 parts phosphorus or 5 parts of calcium to 1 part of phosphorus caused a progressive decrease in bone growth and in calcification. Maynard (1947) stated that while a 1 to 2 or 2 to 1 ratio of these elements is probably optimum, adequate nutrition can occur outside of these ranges.

Investigations by Bauer, Aub and Albright (1929) regarding the deposition of calcium and phosphorus salts in bone formation have shown that two enzymes appear to be involved, namely: phosphorylase and phosphatase. They showed that the bones served not only as structural elements, but also as storehouses for calcium and phosphorus which may be mobilized at times when the assimilation of these minerals is inadequate. All workers are in agreement that calcium and phosphorus exist in the bone in a ratio of 2 to 1 but that the inorganic composition is not constant, and may vary with the specie and with age.

There are voluminous accounts of soil deficiencies and their relation to animal nutrition. Orr (1929) has reviewed the pasture research in the British Empire relating to the composition of herbage and the health of the animals. Reviews pertaining to the United States have been made by Maynard (1939); Beeson and LeClerc (1941); and Browne (1938).

A deficiency of calcium in the ration of cows affects the health of animals. Calcium deficiency was reported by the Florida Agricultural Experiment Station (1933), when rations fed Jersey cows over a period of years were low in calcium content. Several of the cows withdrew mineral reserves from their skeleton to such an extent that many of them suffered broken hips and ribs. The leg bone from one of these cows with a newly broken pelvis had an average breaking strength of 335 pounds. Following the addition of bone meal to the ration, minneral matter was restored to such an extent that the heavy leg bone had an average breaking strength of more than 3,000 pounds.

Symptoms of phosphorus deficiency include the chewing of wood, bones or other substances, stiffness of the legs, swollen joints, emaciation and usually poor unthrifty appearance. In the case of cows there is usually a lower production of calves. Phosphorus deficiency has been reported from at least twenty states in the United States,as well as from Canada, the British Isles, many sections of Europe, South America, Australia, and from New Zealand, South Africa, and from Asia. Various names have been used for these abnormal conditions: "creeps" in Texas, "stiffs" and "sweeny" in Florida, "styfsiekte" in South Africa, and "cripples" or "peg-leg" in Australia. Bone chewing has been known to lead to other serious diseases such as "loin disease" in the Gulf Coast Region of Texas. Schmidt (1926) described the disease in cattle as manifesting itself by a sudden and complete breakdown of the organs of locomotion. Theiler (1928) from South Africa pointed out that cattle in advanced stages of aphosphorosis ate carcass debris containing toxins produced by the organism Clostridium botulism bovis resulting in a disease known as "lamsiekte" which usually proved fatal. Following a visit to Texas, Theiler stated that the symptoms of "loin disease" and "lamsiekte" were similar. He cured the disease by feeding the animals three ounces daily of sweet bone meal. He also found that the feeding of bone meal caused the cattle to stop craving bones, and made for better growth and larger animals at maturity. Extreme deficiencies of phosphorus or calcium are usually detected immediately, but the more numerous borderline cases are often not recognized. In such cases a deficiency may have resulted in decreased growth and an unthrifty condition even when no obvious symptoms were visible. It has been reported by Orr (1929) that on phosphorus and calcium deficient pastures, sheep and cattle of Wales do not grow to full size, but remain stunted. Horses pastured on the mineral-deficient soils of the Falkland Islands became smaller with each generation, gradually reverting to the size of ponies.

The calcium and phosphorus requirements of animals as estimated by different investigators vary considerably. Maynard (1947) stated that data available as a whole was incomplete and in many cases so variable that it would be hazardous to draw conclusions from them as to what the actual requirements are for a given specie over its entire growth period. It is agreed that the requirements decrease with age, per unit body weight and also per unit of dry matter intake. The calcium requirements markedly exceed those for phosphorus in early life, but the difference becomes less as maturity is approached.

Beeson and co-workers (1941) reported a three-year study, involving 112 head of steer calves fed various levels of phosphorus. They produced a phosphorus deficiency in steer calves fed rations containing 0.11 to 0.15 per cent phosphorus which provided an average daily phosphorus intake from 1.04 to 1.63 grams of phosphorus per hundred pounds of live weight. The feeding of 2.00 grams of phosphorus daily or providing a ration with 0.18 per cent or more phosphorus met the needs of steer calves. Knox, Benner and Watkins (1941) stated that the minimum level of phosphorus necessary in forage for range cattle is between 0.11 and 0.12 per cent. They suggested that the theoretical minimum of calcium should not go below 0.23 per cent in the forage. Weber and others (1941) estimated that fattening calves require more than 11 grams of calcium per day.

Black and others (1943) found that rations which contained 0.13 per cent phosphorus and 0.23 per cent calcium provided the minimum amounts of these elements for Texas range cattle.

Mitchell and McClure (1937) estimated that the phosphorus necessary for fattening beef steers ranges from 0.34 per cent of the ration for a 300 pound steer to 0.18 per cent of the ration for a 1000 pound steer. They estimated from slaughter data that a 500 pound growing steer required 12.4 grams of phosphorus daily and a 500 pound fattening steer required a daily intake of 16.7 grams. They stated that the quantity of calcium required in the ration for fattening steers ranged from 0.17 per cent to 0.48 per cent, which is comparable to 14.0 grams per day for a 1000 pound steer and 0.48 grams for a 300 pound steer.

Archibald and Bennet (1935) found that dairy heifers made average growth on rations supplying 1.8 grams phosphorus daily per 100 pounds of live weight during their first year of life. Rations containing 1.7 grams of phosphorus per 100 pounds daily produced normal growth during the third year. They concluded that these amounts were not optimum, but were close to the minimum. They suggested that hay containing less than 0.20 per cent phosphorus and consumed in normal amounts will not supply sufficient phosphorus.

Maynard, Graves and Smith (1932-1934) found that fattening yearling steers showed definite phosphorus deficiencies with a daily intake of 1.96 grams of phosphorus per 100 pounds of live weight, and that steer calves became phosphorus deficient when ingesting 1.62 grams of phosphorus daily per 100 pounds. They felt that 2 grams of phosphorus daily per 100 pounds of live weight would meet yearling steer and calf requirements.

Watkins (1933) using digestion and mineral balance trials, showed that 500 pound steers ingesting 11.03 grams of feed phosphorus had a negative phosphorus balance, but the steers receiving 14.7 grams of feed phosphorus, furnished either by natural feeds or by disodium phosphate, showed uniformily positive phosphorus balance. He also found that growing steers, 18 months of age, could not satisfy their needs with a daily intake of 8.5 grams of phosphorus.

Lindsey, Archibald and Nelson (1931) found that an intake of 5.97 grams of calcium per 100 pounds of live weight resulted in normal development of dairy heifers and that equally satisfactory growth was secured with 3.17 grams. Forbes, French and Letenoff (1929) conducted a maintenance balance study with 1000 pound beef steers and found that an intake of 10.84 grams daily was necessary to produce a positive phosphorus balance. Theiler, Green and Du-Toit (1927) found that 4.99 grams of calcium per day was not enough for range cattle.

A lack of adequate calcium or phosphorus in the ration has been shown to have a detrimental effect upon the general well being of farm animals. Data by Morrison (1948) and Fraps (1944) showed that forage which contained less than 12 per cent protein was only about 56 per cent digested, but when the forage contained more than 12 per cent protein the digestibility was 75 per cent. Beeson (1941) found that rations were not utilized as efficiently when low in phosphorus as those containing higher amounts of this element. Steer calves fed low phosphorus rations required 30 per cent more feed per pound of growth and gained 37 per cent slower than calves fed a ration containing sufficient phosphorus. Maynard and co-workers (1936) pointed out that a phosphorus deficiency is a limiting economic factor in beef production. Work of Eckles, Becker and Palmer (1932) showed that milk flow of cows was eventually reduced by lack of phosphorus in the feed. They stated that in extreme conditions a shortage of phosphorus became a limiting factor in the economical utilization of feed and in growth of cattle. They concluded that cows on a low phosphorus diet required 20 per cent more digestible nutrients to maintain body weight than cows receiving adequate phosphorus in their diet. Early work by Theiler, Green and DuToit (1924) showed that a lack of phosphorus in the diet of beef cattle caused a lack of appetite and poor feed utilization.

Weber, McCampbell, Hughes and Peterson (1943) showed that the addition of ground limestone to a fattening ration, deficient in calcium, increased gains, gave more efficient utilization of feed, produced cattle of higher slaughter grade and produced bones with greater breaking strength and of higher ash content. Kansas workers, Hall, Mackintosh and Voil (1944) demonstrated that beef from low phosphorus steers was inferior in palatability, keeping quality and shrinkage loss.

The calcium and inorganic phosphorus content of the blood of cattle is considered a reliable measure of the adequacy of these minerals in the ration. Maynard (1947) stated that the inorganic calcium and phosphorus levels of the blood plasma are important indicators of the state of nutrition of these elements. Maynard further stated that whole blood contained from 35 to 45 mg. of phosphorus per 100 ml., most of which was in the cells. The phosphorus level of healthy animals lies between 4 and 9 mg. per 100 ml. of plasma depending upon the age and species involved. He pointed out that the level is higher at birth than at maturity.

The development of methods for the analysis of blood has given research workers a very useful tool in ascertaining the general nutrition, metabolism, and disease of animals. Workers are generally agreed that the calcium content of the blood of cattle is ordinarily quite constant. They have stated that an excessive amount of calcium in the diet, however, may render some of the phosphorus unavailable. Meigs (1919) was able to reduce the inorganic plasma phosphorus of dairy cattle by feeding rations low in the element, but was unable to increase to any extent the calcium in the plasma by feeding calcium in the ration. His results indicated that in cattle over two months of age, the plasma calcium is little altered by pregnancy, lactation or by feeding rations rich in calcium. Halverson and co-workers (1917) found that the content of blood calcium of dairy cows was not materially affected by feeding calcium in the feed, and that it was kept nearly constant by the enormous calcium reserve stored in the bones.

There have been numerous reports by research workers relative to the inorganic phosphorus levels of blood plasma, but not all workers are in agreement. Savage and Heller (1947) reported a four year study in the Southern Great Plains area and found average inorganic blood plasma levels for yearling steers, grazing forage sufficient in phosphorus and calcium, to be 10.74 mg. calcium, 5.84 phosphorus. In contrast to this Heller (1947) reported that frequently the plasma phosphorus levels for cattle grazing phosphorus deficient forage in eastern Oklahoma ranged from 2.5 to 4.0 mg. per 100 cc. Black and associates (1943) showed that steer calves up to two years of age on a low phosphorus diet had nearly as high plasma phosphorus levels and gained as well as steers receiving a phosphorus supplement. Only during two months did the phosphorus plasma levels of the non-supplemented groups go below the 4 mg. level where they felt that a phosphorus deficiency may occur. Cows grazing the same range and receiving no phosphorus supplement showed aphosphorosis, with plasma levels consistently below 4 mg. and frequently below 3 mg. per cent. They stated that aphosphorosis could be diagnosed by inorganic plasma phosphorus determinations, even before physical symptoms were manifested. Beeson, Bolin, Hickman and Johnson (1941) in their three year study of phosphorus requirements for beef steers produced definite phosphorus deficiencies in steer calves fed rations containing 0.11 to 0.15 per cent phosphorus. After sixty days the average plasma phosphorus level for the steers on the phosphorus-low ration was lowered from a normal of 6.47 mg. to what they called an abnormal low of 3.59 mg. Knox, Benner and

Watkins (1941) in their study of seasonal calcium and phosphorus requirements of range cattle found that cows grazing New Mexico ranges and receiving a mineral supplement of dicalcium phosphate averaged 2 to 3 mg. of inorganic phosphorus per 100 ml. of plasma in the winter and spring, and from 3.00 to 4.5 mg. in the summer. Cows in the non-mineral lot showed lower plasma values for phosphorus throughout the entire year with the exception of the months of May and June when the plasma phosphorus level was higher in the non-mineral lot, apparently due to greater consumption of weeds by the cattle receiving no phosphorus supplement.

Becker, Neal and Shealy (1933) showed that the blood of steers and heifers grazing on ranges where cattle had depraved appetites possessed 2/3 more inorganic phosphorus than did cows that were suckling calves. The following table shows comparative plasma values as reported by these workers.

No. Animals	Kind of Animals	Av. Inorganic P. per 100 ml. Plasma
42	Nursing cows	2.87
16	Dry cows	3.80
8	Steers and heifers	4.91

Maynard, Greaves and Smith (1932) fed a group of forty yearling steers a ration of beet by-products, alfalfa and salt (a ration low in phosphorus). Steers on this ration showed evidences of phosphorus deficiency. The gains were small and the steers showed symptoms of malnutrition. Their hair coat was lusterless and their appetites were sluggish. Characteristic pica was manifested by an abnormally large consumption of salt and by gnawing of wood. Steers on this ration had inorganic plasma phosphorus levels ranging from 2.41 to 3.01 mg. per 100 ml. The addition of bran, bone meal, or cottonseed meal to the ration resulted in higher plasma phosphorus levels; the range being 4.12 to 5.41 mg. Calcium levels were similar for all groups of steers and ranged from 10 to 13 mg. per 100 ml. of plasma.

Jones and Mullen (1926) observed a tendency for the inorganic phosphorus in the blood plasma of cattle to rise when bone meal or raw phosphate rock was added to the ration, but decreased when the phosphate supplements were withdrawn.

Palmer, Cunningham and Eckles (1930) studied the variations in the inorganic phosphorus of the blood of dairy cattle. They concluded that exercise caused marked changes in the plasma phosphate of cattle. Feeding had small, but significant effects on the inorganic phosphate. The values rose within the first hour and apparently did not return to normal until after about three hours. Normal water drinking by cattle had no effect on the plasma phosphate. Robinson and Huffman (1926) noted similar fluctuations for the blood of beef cattle.

Theiler, Green and DuToit (1928) stated that 5 mg. of inorganic phosphorus per 100 ml. of blood was the normal value for cattle fed on phosphorus sufficient rations.

Palmer and Eckles (1927) studied mature lactating cows raised in a phosphorus deficient area of Minnesota. They reported a range of 1.28 to 2.99 mg. of inorganic phosphorus per 100 ml. of blood plasma for cows fed a hay-oats ration without a mineral supplement. The total plasma calcium ranged from 10.97 to 16.02 mg. per 100 ml. which they considered normal. When sodium phosphate was fed, inorganic phosphorus levels ranged from 3.82 to 6.57 mg. and calcium values were from 10.51 to 13.11 mg.

Bones are useful in the animal body first to act as a support and to give shape to the body; second to protect some of the vital organs; and third to act as a storehouse for calcium and phosphorus which might be drawn upon later as the animal finds need for them.

Voit (1880) found that the skeleton of pigeons and puppies became weakened and porous on rations low in calcium. Weiske and Wildt (1873) found that with lambs fed rations low in calcium and phosphorus, the ratio of the two minerals in the compact part of the bone remained the same as in the normal bone, but that the percentage of calcium and phosphorus was reduced. McCollum and Simmonds (1921) stated that in rachitic bone, all of the processes of growth and the maintenance of equilibrium of the bone are abnormal. Osteoid tissue is not calcified as it is formed in the trabeculae or by the periosteum so that the bone becomes soft. The animals attempt unsuccessfully to compensate for this weakness due to the lack of mineral salts by producing abnormal amounts of osteoid tissue, especially at points subject to stress and strain. This overproduction of osteoid and cartilage caused irregular enlargements of the bones and their consequent weakness resulted in bowing and fracture. In studies of bone growth, Hammett (1925) found that the humerus and femur bones decreased in water content and increased in ash content as the animal grew older. The calcium and phosphorus in the bones increased as the animal grew older, but the percentage of phosphorus decreased.

Henderson and Weakley (1930) found that feeding rations that were low in calcium or phosphorus or in both of these mineral elements to dairy heifers resulted in bone changes as shown by chemical analysis, breaking strength and appearance. The femurs and humeri of the animals fed a normal ration were dense at the ends and hard in the shaft. The walls of the shaft were thick and the amount of marrow was only 8.2 per cent of the weight of the bone. The femurs and humeri, however, of the low mineral animals were spongy and soft at the ends. The shaft, while hard, was not as thick as the normal bone and there was a large amount of marrow. At the time of slaughter it was found that there was a slight enlargement at the costochondral junction of ribs in the low mineral group. The breaking strength of the low calcium group was approximately 25 per cent less than that of the bones of the mineral fed group. A longitudinal medial section about 3/16 inch thick was taken from the femurs and humeri for analysis. The ribs were sampled by taking about two inches in length from near both ends and from the middle of each. Analyses showed the average amount of ash in the dry extracted bone was less for those cattle fed rations low in calcium or phosphorus. They further stated that their results would indicate that a study of bones of growing animals is a good index of the cattle's mineral sufficiency.

Work by Eckles and Gullickson (1932) indicated that aphosphorosis in cattle produced marked effects upon the mineral composition of bones. In the fresh bone, the primary effect was the marked reduction in ash and its replacement by lipid material. This effect was magnified when the moisture was driven off and the lipids were extracted. The aphosphorotic bones, especially the femurs, humeri and rib bones were characterized by a low total ash with a lower $Ca_3 (Po_4)_2$ and a higher $Ca Co_3$ content than present in normal bones. Examination of bones of "stiffs" or "sweeny" (phosphorus deficient) cattle in Florida by Becker, Neal and Shealy (1933) showed them to have thin shaft walls and less calcification than present in normal long bones. Vertebrae could be sawed, cut with a knife or broken more easily than bones of cattle slaughtered from other areas. The ribs were very flexible and easily broken. Upon autopsy of a mature cow, the dorsal border of the scapulae were found to be more cartilagenous (less ossified) than for a normal two-year-old animal. Both scapulae were bent giving the animal a sweenied appearance and one scapula was found to have a multiple fracture. The articular surface was eroded. The humerus when sectioned, showed a thin shaft wall, poor calcification at the epiphysis or growth line, and fewer trabeculae than normal. Gross examination showed the bone to be porous and weak. Autopsy of a 7-year-old cow showed that the head of one humerus bone had crushed in at one point making an opening into the marrow cavity.

Hevesy, Levi and Rebbe (1940) showed that bone salts are in a constant state of flux and in a process of continual rebuilding. They demonstrated by the use of labelled phosphorus that within four weeks 29 per cent of the mineral composition of the femur and tibia epiphyses were replaced.

The calcium and phosphorus of range cattle is provided principally by pasture forage. In many areas such forage may not at all times furnish adequate supplies of these elements. Savage and Heller (1947) reported that the leading perennial grasses of the

Southern Great Plains area contained 0.17 per cent phosphorus, 7.7 crude protein and 0.17 per cent calcium. Cattle grazing these forages were considered to be receiving an adequate calcium and phosphorus supply.

A study of the phosphorus content of forage in the Gulf Coast region of Texas by Fudge and Fraps (1944) showed that from areas where cattle were definitely deficient in phosphorus, grass samples averaged only .082 per cent phosphorus, while samples from normal areas contained an average of 0.170 per cent phosphorus. Samples of grass collected in the spring in Utah reported by Stoddard and Greaves (1942) averaged 0.283 per cent phosphorus and fall samples averaged 0.185 per cent. None of these samples were considered deficient in phosphorus. Becker, Neal and Shealy (1933) showed that analyses of 14 samples of forage from ranges producing healthy animals averaged 0.167 per cent phosphorus, while 67 samples from deficient areas averaged 0.103 per cent phosphorus. Of 51 samples of prairie hay from a deficient area in Minnesota reported by Eckles, Gullickson and Palmer (1932), 44 contained less than 0.33 per cent phosphoric acid. Of 54 samples from Montana reported by Scott (1929) samples from normal areas averaged more than 0.33 per cent phosphoric acid while those from deficient areas were considerably less than 0.33 per cent. Of 53 samples analyzed by Theiler (1927) from a South Africa area, 31 samples contained less than 0.19 per cent phosphoric acid and 48 samples contained less than 0.33 per cent.

Investigations regarding the nutritive value of forage has revealed some rather significant findings. Work by Tash and Jones

(1947) in Texas indicated that shorter range grasses were more heavily fortified with phosphorus than taller grass varieties during the same period and at approximately the same stage of maturity. Savage and Heller (1947) in their study of the nutritional qualities of range plants found that the quantity of phosphorus in the forage declined successively from early growth to maturity and dormancy. They further found that the calcium content of nearly all range forage species was more than double the phosphorus content. They noted that the monthly trend in average protein content of native grasses was directly related to the monthly changes in phosphorus, ash and moisture. The level of protein in the forages was observed to be directly related to successive changes in plant development, season of growth and quantity and distribution of precipitation. They stated that such palatable forbs as bush morning-glory, sand pea and horseweed that are eaten to some extent by cattle when the plants are young, usually contain more protein than the warm-weather grasses at that time. Watkins and Knox (1945) called attention to the fact that annual weeds often afforded considerable grazing in the early spring and frequently served as contributors of more phosphorus than that received by livestock grazing the native grasses. Their work was further substantiated by findings of Tash and Jones which indicated that at certain stages of growth, weeds are frequently more palatable and higher in phosphorus content than range grasses growing on the same soil. Black and co-workers (1943) found periods of heavy rainfall encouraged growth of new green forage, which when eaten by the cattle caused a marked increase in the blood plasma levels of phosphorus contrasted to lower plasma levels during extended periods of dry weather. Knox and Neale (1937), Stanley (1938) and Black and co-workers (1943) all pointed out that a low protein content is associated with a low content of phosphorus in the forage. Their work indicated that the lowest periods of protein and phosphorus in the forage occurred during the winter months and during periods of low rainfall. They noted that young succulent green forage was usually higher in phosphorus and protein than forage of more advanced maturity. Work by Guilbert (1930) in the Sacramento Valley of California showed that the phosphorus content of the native grasses roughly paralleled their protein content.

Research workers have proven that supplementing cattle with an adequate mineral supply is one way of overcoming the effects of low phosphorus as reflected in poor unthrifty cattle.

Early work by Theiler, Green and DuToit (1924) showed that aphosphorosis could be overcome by feeding precipitated calcium phosphate or bone meal. They stated that precipitated calcium phosphate was troublesome to feed and somewhat expensive. Their work also showed that 1 pound of wheat bran was as effective as 1 ounce of bone meal. They were among the first who tried the superphosphate manuring effect and found that it tripled the phosphorus content of the forage. They found that in regions of extremely low rainfall, and in areas having very shallow soil, phosphate manuring was not practical. Schmidt (1926) showed that mixtures of bonemeal and common salt fed to range cattle increased weight, prevented creeps and produced stronger calves. The feeding of 2 parts bone meal to 3 parts of salt increased the palatability of the bone meal. He found that finely ground rock phosphate when fed alone or mixed with salt and bone meal in equal parts did not give satisfactory results. He attributed the unsatisfactory results to the presence of flourine in the rock phosphate. Theiler (1928) after studying cows grazing phosphorus deficient veld for two years, observed that 80 per cent of the cows receiving bone meal supplement on pasture calved normally as against 51 per cent in the non-supplemental group. Bekker (1932) reported experiments which showed that the feeding of 2/3 of an ounce of dicalcium phosphate was as effective as 3 ounces of bone meal. He pointed out that since dicalcium phosphate was only slightly soluble in water, it should be hand dosed or mixed with common salt or some palatable feed. He also fed disodium phosphate by dissolving it in the drinking water. In this experiment he used 1 cc. of 90 per cent commercial sulfuric acid to each gallon of water to increase the solubility of the dicalcium phosphate. He showed that when disodium phosphate was dissolved in the water supply at the rate of approximately 45 grams per 6 gallons of water, the cattle drank 5.8 gallons each per day and thus obtained 1.56 ounces of disodium phosphate. Maynard, Greaves and Smith (1932-34) showed that steamed bone meal, mill run bran and cottonseed meal were good sources of phosphorus for fattening steers receiving a basal ration of beet by-products, barley and hay.

Work at the King Ranch in Texas (1944) compared several sources of phosphorus for breeding cows grazing native vegetation in an area decidedly deficient in phosphorus. Comparative results for two years showed:

Phosphorus Source	Av. Wt. of Calves At Weaning
1. No mineral.	417 pounds
2. Bone meal (free choice).	448 pounds
3. Disodium phosphate in the drinking water.	494 pounds
4. Pasture fertilized (200 lbs. superphosphate per acre).	514 pounds

The cows grazing the fertilized pasture produced the highest percentage of calves. They noted that some of the cows in the no mineral group developed a "creepy" condition.

Ross and associates (1949) showed the value of feeding a high phosphate mineral to growing heifer calves. One group of heifer calves fed 7.5 pounds of dicalcium phosphate per head over a 21 month period (an amount of phosphorus estimated to be slightly more than one half their needs) were 107 pounds heavier than heifers fed no phosphorus supplement. Another group of heifer calves fed 26 pounds of dicalcium phosphate per head during the same 21 month period were 166 pounds heavier than the no supplement group. They noted that the general thrift and vigor between the supplemented and unsupplemented heifers was even more noticeable than the difference in weight.

Livestock men and pasture experts are in general agreement that the first line of defense against phosphorus deficiency is, wherever practicable and economical, the systematic use of phosphatic fertilizers. According to Lush (1945) the first American effort to measure the effects of fertilizers and lime on pasture was started over fifty years ago in Rhode Island. Limed plots produced 2.5 times as much green material as unlimed plots. When lime was added to fertilized plots they produced 4 times as much green material as unfertilized plots. It was noticed that the best clover grew on the plots which received phosphoric acid. This observation together with many others has contributed to the evidence that no legume or grass can continue to be produced in large quantities unless the fertility of the soil is maintained at a high level.

Ten years of work by Crouch and Jones (1945) in East Texas has shown that highly productive pastures can be established on old worn out, previously cultivated land. Their methods in establishing pastures included clearing, drainage, the application of superphosphate, and the seeding of suitable legumes and grasses. Their first attempt at establishing pastures was by seeding several grasses, (bermuda and carpet) along with clovers and lespedezas. They found that the area furnished little feed during the first two years, but the application of 200 pounds of phosphoric acid per acre permitted the establishment of adapted clovers and grasses and increased both the yield and quality of pasture. Pastures at the station showed beneficial effects from phosphate fertilizations even after 9 years, but some decline in production was noted after 5 years. The pasturage was heavily used during the 10 years for the maintenance of a Hereford breeding herd. After phosphating the pastures, the cows maintained satisfactory condition, produced normal calf crops and developed good scale. They noted that cattle on native unfertilized pastures generally were small in scale and developed rather poorly. They cited the year, 1941, as an average picture of production. In that year the average stocking rate was 0.73 animal units per acre. In addition 3,500 pounds of hay was harvested per acre. Chemical analyses of forage from the fertilized pastures containing clovers, grasses and lespedeza were compared with those of forage samples from unfertilized pasturage. The samples from the fertilized pasture contained good to high amounts of protein, phosphorus and calcium. The unfertilized pasture forage showed good amounts of calcium, fair amounts of protein and were low to deficient in phosphorus. They concluded that phosphate was the first limiting element in their area for pastures and that phosphate was necessary for the establishment of white clover, hop clover and good grass pasturage.

Bartholomew and Gifford (1944) established highly productive pastures on upland soil which had been abandoned for crop production because of low productivity. Twenty acres of abandoned crop land was seeded to Bermuda grass, hop clover, Kobe and Korean lespedeza. Ten acres received 100 pounds of concentrated superphosphate per acre and the remaining ten acres received no treatment. The ten acre pasture not fertilized produced an average gain of 213 pounds of beef per acre and furnished grazing for 6 animals for 6 months. The phosphated tract produced an average gain of 312 pounds per acre over the same 6 month period. In addition it provided grazing for 14 animals during the first four months and grazing for 8 animals during the last two months.

Blaser and co-workers (1943) from Florida found that the nutrients calcium, phosphorus and potash are required in most cases for the satisfactory establishment of grasses and legumes on a sandy soil. They pointed out that the quality of pasture forage is frequently more important than yields. In their improved pasture program they found that unfertilized carpet grass averaged 83 pounds of beef per acre as compared with 140 pounds for limed and fertilized carpet grass. During the same two year period, carpet grass-lespedeza and carpet grass-clover pastures treated with lime, superphosphate and potash produced 168 and 582 pounds of beef per acre respectively. The increases in the phosphorus, potassium and calcium content of carpet grass resulting from fertilization were significant. The mean increase for calcium was 48 per cent, 78 per cent for phosphorus and 38 per cent for potassium as the result of fertilization.

Woodhouse and Lovvorn (1942) established productive pastures on North Carolina soils that had been severely depleted through cropping and erosion. They demonstrated that proper fertilization improved yields of vegetation, improved the kind and density of vegetation, insured earlier growth, insured more uniform distribution of grazing and yielded forage of higher feeding value. They found, initially, that the soils were so low in calcium and phosphorus that the addition of either one without the other produced little benefits. The addition of both materials more than doubled the yield the first season. They found, that when seeding grasses with lespedeza and white clover on untreated soil, over half of the vegetation was weeds with practically no grasses and clovers in the pastures. Under a treatment of mineral fertilizer and limestone, weeds were considerably reduced; lespedeza more than doubled and grasses and clovers increased. Their yield studies showed that fertilization increased total vegetation from

1,000 pounds to 1,500 pounds per acre per year. Population counts of vegetation showed that the desirable species, lespedeza and white clover, increased from 17 to 52 per cent in one case and from 36 to 66 per cent in another. These vegetative changes increased forage clover by at least one-third to one half.

Texas workers (1943) have shown that the application of phosphoric acid is necessary for the successful establishment of adapted pasture legumes in the Gulf Coast and prairie region of Texas. The seeding of pasture grasses and clovers on Lake Charles clay soils with an application of 80 pounds of P_2O_5 in the form of superphosphate produced an abundance of white clover. Where phosphate was not applied the clover failed to grow. Seven years' treatment of pastures with 80 pounds of P_2O_5 in the form of superphosphate per acre produced 54 per cent more forage than unfertilized pastures. The treatment nearly doubled the phosphoric acid content of the forage. Two years work at the King Ranch (1944) showed that the application of 150 pounds of superphosphate per acre to a 640 acre pasture increased the yield and feeding value of the pasture grasses so much that the rate of stocking was increased 50 per cent over the unfertilized pasture. The grasses on the fertilized plots contained 0.51 per cent phosphoric acid compared to 0.24 per cent for grasses from the unfertilized plots.

Brown and Munsell (1943) have reported a summary of their results obtained from an extensive grazing experiment covering a period of twenty years conducted in Connecticut. The initial studies were started on 36 acres of badly run-down permanent pasture with an upland glacial fine sandy loam, strongly acid and low in phosphorus. At the onset of their study the pasture was mostly covered with brush and trees and supported approximately one cow per ten acres. Their twenty year results showed that different fertilizer treatments had an effect upon botanical composition. Weeds were most prevalent on the unfertilized plots. Fertilizers had marked effects on the prevalence of important pasture species. Kentucky blue grass occupied only two per cent of the unfertilized plot but 70 per cent of some of the lime and phosphated pastures. White clover was more prevalent in the lime and phosphated areas as compared to the unfertilized areas. Analyses of forage showed that the non-fertilized areas contained about 75 per cent as much protein and 60 per cent as much phosphorus but a higher content of dry matter and fiber as compared with the phosphorus fertilized areas. The application of lime alone increased pasturage yields somewhat but lime plus superphosphate showed the greatest increases. The effects from the application of potash were shown to be negligible.

Carr and Rhoad (1943) studied the influence of lime and fertilizers on the Gulf Coast soils of Louisiana. They concluded that good pastures could be produced and maintained on the Gulf Coast soils through the use of (1) white clover, hop clover, Bermuda grass and Dallis grass as basic crops, (2) adequate fertilizers and (3) good management practices, including mowing and controlled grazing. Grazing studies showed that a pasture treated with lime and superphosphate produced more forage than pastures receiving only superphosphate and lime respectively.

Nelson (1941) developed quality forage on depleted waste land through the use of phosphates and lime. A three year study of pasture yields as measured by beef cattle showed that 186 pounds of gain per acre were realized on a pasture receiving no fertilization, while a comparable pasture receiving an application of limestone and superphosphate yielded 557 pounds of gain per acre and an additional advantage of 135 days more grazing time. The application of nitrogen in addition to lime and phosphate gave no significant forage increase over a lime and phosphate treatment. He found Bermuda grass to be the most dependable pasture base. His findings indicated that three winter legumes, hop clover, burr clover and white clover were the clovers which persisted from year to year and responded most favorably to the application of lime and phosphate. Lespedeza proved to be a desirable legume during the warm summer months. He noted that rainfall, because of its immediate effects, was the most important single factor in pasture production.

Pierre (1938) recognized that the availability of soil phosphorus to plants varied according to plant specie. He stated that plants with a large root system seemed to absorb concentrations of phosphorus more readily than plants with relatively poor root systems. He observed that the combination in which phosphorus is found in the soil has a decided effect upon its availability to plants.

Harper (1947) found soils that are very slightly acid to slightly alkaline rendered phosphorus more available to plants. In soils that were slightly acid to extremely acid, phosphorus became progressively less available to plants. Troug's (1947) study of soils bears out the general observations made by Harper.

Whitson and Stoddard (1927) studied the response of soils to phosphate fertilization and found that acid soils gave a greater response to phosphorus fertilization than non-acid soils. They found that the application of limestone for the purpose of reducing soil acidity enhanced the effects of phosphorus fertilization. They suggested that in acid soils the low availability of phosphorus was due largely to the existence of phosphorus in combination with iron and aluminum. Brown (1944) stated that the purpose of applying limestone to pastures was primarily to reduce soil acidity.

Research workers are in general agreement that the key to the improvement of pastures is the establishment of one or more legumes capable of growing in association with grass, partly because of the forage value of the legumes and partly because of their ability to fix nitrogen from the air and make it available to the grass.

It is generally accepted that phosphorus is most frequently the limiting factor for the growth of pasture plants. O'Brien and Obenshain (1942) showed that many forms of phosphates will produce marked increases in forage on phosphorus deficient soils. They found that the relative efficiency of the different carriers when compared on a phosphoric acid equivalent basis was in the following descending order: dicalcium phosphate, superphosphate, triple superphosphate, basic slag, tricalcium phosphate and raw rock phosphate. There is some disagreement among research workers as to the amount of phosphate fertilizer to apply.

Albrecht and Smith (1939) showed that lespedeza grown on a

Missouri soil receiving both lime and phosphate produced 20 to 26 per cent higher yields than when phosphate was applied alone. However, when the hays from the respective plots were fed to experimental animals, the difference in meat pounds became 60 to 80 per cent.

Work in Oklahoma (1945) showed, that in trials where dairy cows had free access to fertilized and unfertilized plots, the cows preferred those plots fertilized with 150 pounds of super-phosphate per acre. A total of 167 hours was spent on the fertilized and 110 hours on the unfertilized plots.

Harper and Daniels (1935) in a five year study of the analyses of blue stem and alfalfa taken from fertilized and non-fertilized plots found that the per cent of calcium and phosphorus in the forage was correlated with the effective seasonal rainfall. They found that during periods, when the rainfall was high, the calcium content of the plants decreased and the phosphorus content increased. Their findings further showed when the effective rainfall was low, the calcium content of the plants increased and the phosphorus content decreased.

DuToit and Malan (1932) stated, "That the general principle that the mineral content of the soil is reflected in the mineral content of the vegetation growing upon it is true, but this must not be taken to mean that the mineral content of a pasture can be increased by applying fertilizer to the soil. What probably does happen is that on a soil rich in minerals, grasses which naturally show a high percentage of minerals will flourish at the expense of those which are normally able to thrive on a poorer soil." On the other hand, work by Forbes, et al. (1910), by Brown (1933) and Venall and Wilkins (1936) showed definitely that both the phosphorus and calcium content of these species can be materially increased by field rates of applications of superphosphate and lime. Pierre and Robinson (1937) found that phosphate fertilization caused an increase in species of forage that were higher in phosphorus and reduced the presence of some of the lower phosphorus species.

With the phenomenal growth of pasture research in America in the past thirty years have come a variety of methods and ways in expressing pasture yields. In order to have a uniform method of interpreting pasture results the Society of Agronomy, the American Dairy Science Association and the American Society of Animal Production (1943) have cooperated and proposed tentative procedures and methods in management and for the expression of yields.

Procedure

This study was initiated in January, 1945. Two hundred and twenty acres of "worn out" land six miles northeast of Coalgate, Oklahoma were leased for this study. The objectives of this investigation were:

(1) To determine what measures would be necessary to improve the soils of this area so they would yield high quality pasture forage.

(2) To determine the relative value of improved pastures.

(3) To study the availability of calcium and phosphorus to steers grazing forage produced on soils fertilized in various ways.

The soils were mapped and chemical analyses were made to determine the plant nutrients lacking in the various soil types found within the area outlined above. In order that fair and accurate interpretations of results could be made, it was planned to compare pastures on the basis of soil classification.

Initially one hundred acres was divided into six pastures. Pastures A, B, and C consisted of 18.1 acres each and were located on a deep, medium textured, moderately to slowly permeable upland prairie soil. Pasture D, an 8 acre tract, was located on a medium textured, very slowly permeable (claypan) prairie soil. Pastures E and F, 10 acres each, were located on medium textured moderately to slowly permeable creek bottom soil.

All pastures in this group, except A, received an application of 2 ton of limestone per acre in the spring of 1945, after the land had been plowed. Bermuda grass roots were planted on the six pastures with a 3 row planter in May and June of 1945. Ten pounds per acre of ryegrass and two pounds per acre of legume seed were planted on all pastures and superphosphate (20% P_2O_5) was drilled at the rate of 150 pounds per acre in pastures C, D, and F about October 20, 1945. The ryegrass was drilled in 14 inch rows and the legume mixture was dropped (by drill) on the soil between the rows of ryegrass and above the superphosphate in those pastures where this fertilizer was applied. The legume mixture contained Big Hop clover, 12%; Little Hop, 12%; White Dutch, 19%; Ladino, 19%; Persian, 12%; Alsike, 6%; Black Medic, 12%; Subterranean, 2% and a miscellaneous group composed of Birdsfoot Trefoil, Button, Little Bur, Tift Bur and California Bur clovers, 6%. Ten pounds per acre of Korean lespedeza was broadcast on all pastures in March, 1946.

In the spring of 1946, three additional pastures, G, H, and I were located on formerly cultivated, shallow, medium textured, moderately permeable forest soils. Bermuda grass was planted in May and June, 1946, by dropping the roots from a platform constructed on the frame of a three disc plow, through a pipe which placed the roots in the furrow behind the first disc. Limestone was applied at the rate of 1½ tons per acre on pastures G and I and disked into the soil after the Bermuda grass was planted. Lovegrass was drilled in 14 inch rows at the rate of 1 pound per acre on H and I pastures in April, 1946, and at the same time pasture I received a 200 pound per acre application of 0-14-7 fertilizer. Ryegrass was drilled at the rate of 10 pounds per acre on G pasture and 0-14-7 fertilizer was drilled in 14 inch rows, 200 pounds per acre. Two pounds of a similar legume mixture, used in establishing pastures the previous year, was dropped on the soil above the fertilized zone on G and I pastures September 20, 1946. Legumes were planted without fertilizer on pasture H.

Some additional cultural practices were followed during the course of the study. Fifteen pounds per acre of a Korean-Kobe lespedeza mixture was drilled in all pastures except G in March, 1948, after the soil had been disked lightly to reduce competition from the hop clover. It was planned at the onset of the study that fertilizer would be applied in the fall every third year. Pastures C, F, and D received an application of 150 pounds per acre of superphosphate (20% P_2O_5) in the fall of 1948.

Fertilizer Treatment of Pastures and Description of Soil

Pasture	Soil Condition	Fertilizer Treatment	Area in Acres
A	Permeable Upland	None	18.1
B	Permeable Upland	Limestone	18.1
C	Permeable Upland	Limestone and Superphosphate	18.1
D	Dense Clay Subsoil	Limestone and Superphosphate	8.0
E	Bottomland	Limestone	10.0
F	Bottomland	Limestone and Superphosphate	10.0
G	Eroded Timber Soil	Limestone, Superphosphate and Potash	22.0
H	Eroded Timber Soil	None	11.3
I	Eroded Timber Soil	Limestone, Superphosphate and Potash	11.3

In addition to the above nine pastures, another area was prepared and seeded in the same manner as pasture C which was used as a reserve pasture for steers which were not grazing the experimental pastures during certain seasons of the year. Bermuda grass was planted in the reserve pasture in June, 1945, ryegrass and winter legumes in October, 1945, and lespedeza in March, 1946.

Twenty six head of 2-year-old steers purchased locally grazed pastures A, B, C, D, E and F during the first grazing season of 1946 and were sold off grass at the close of the grazing period. The rate of stocking for the various pastures for the grazing season of 1946 is shown in the following table.

Number of Animals Per Pasture 1946

Pasture	No. of Animals	Pasture	No. of Animals
A	4	D	3
B	5	E	4
C	6	F	4

In the fall of 1946, sixty choice weanling Hereford steer calves were purchased to be used in grazing the various pastures. They were rough wintered and in the spring of 1947, the steers were allotted to each of the various pastures. The number of steers allotted to each pasture was determined from data secured in 1946 and the anticipated carrying capacity of each pasture. Brand numbers were placed on the right hip and were used as identification for each steer. The plan of the experiment was to graze the steers for three successive grazing seasons and market them as grass fat three-year-old steers. At the beginning of the experiment, it was assumed that the pastures would carry fewer three-year-old steers than yearlings. With that in mind, representative steers were selected and allotted to the various pastures and were to be grazed each of the three grazing seasons in those pastures. They shall be designated "permanent" steers. The other steers were placed in the various pastures as the forage indicated that the pastures would carry additional steers or were grazed in the reserve pasture but were not grazed in a particular pasture for each of the three grazing seasons. These steers shall be designated as "reserve" steers.

The number of permanent steers assigned to each of the pastures is shown below:

Pasture	Steers per Pasture	Pasture	Steers per Pasture
A	4	E	4
B	4	F	4
C	4	H	2
D	3	I	2

The grazing seasons began in early April and ended approximately November 1 each year. A system of controlled grazing was used during the course of the study. During the grazing seasons, when there was an abundance of forage in any pasture, additional steers were added from the reserve pasture. However, as the amount of forage decreased in any one pasture during the grazing period, one or more of the reserve steers were removed from that pasture. This procedure was followed to secure maximum production from each pasture. The abundance of forage in 1947 necessitated securing twenty-two yearling heifers in addition to the sixty yearling steers to efficiently utilize the pastures. The steers and heifers were weighed at monthly intervals and an attempt was made to stock the pastures at a rate which would maintain as nearly as possible, similar average daily gains per beast per pasture.

This system of management was used to provide an index to the carrying capacity of the individual pastures. Three day weighings constituted the basis for determining the initial and final weights for each semi-annual grazing season.

Salt was provided free choice to the steers of all pastures. No other mineral was provided during either the summer or winter period. Water was provided from a well during both seasons. Each fall following the grazing season, the steers were placed in winter traps and fed prairie hay and a protein supplement. All of the steers assigned permanently to various pastures were designated as Lot I and received corn gluten meal as their protein feed.

One of the objectives of the experiment was to determine the availability of phosphorus to steers when the phosphorus was applied to the soil. To provide a more rigorous test of the ability of forage produced on phosphorus fertilized soils to support adequate phosphorus nutrition, corn gluten meal was selected as the protein supplement for the permanent steers because it contained approximately one-third less phosphorus than cottonseed cake. The reserve steers were designated as Lot II and were fed cottonseed cake as their protein supplement. Samples of winter protein feeds were analyzed by the Department of Agricultural Chemistry. The average daily winter ration per steer for the various years was as follows:

		1947-1948	1948-1949
Lot I	Corn Gluten Meal	1.2 lbs.	1.5 lbs.
	Prairie Hay	14.1 lbs.	17.2 lbs.
Lot II	Cottonseed Cake	1.2 lbs.	1.4 lbs.
	Prairie Hay	12.6 lbs.	13.4 lbs.

Blood samples were collected periodically from all the permanent steers. During the two wintering periods blood samples were taken from ten of the reserve steers. Blood was drawn by venous puncture and collected in lithium citrated tubes. The blood plasma was analyzed quantitatively for inorganic phosphorus (Fiske and Subbarow (1925)), and for calcium (Clark and Collip (1925)). Blood analyses were treated statistically (Senedecor (1946)).

Fenced exclosures were placed on representative areas within the individual pastures at the beginning of each grazing season and were moved to a new area each spring. Forage from these quadrant exclosures were clipped at various intervals during the grazing season. Calcium, phosphorus, potash and nitrogen determinations were made separately for legumes, grasses and weeds clipped from these exclosures.

Rainfall distribution was tabulated throughout the experiment.

Weight data were used in computing the following for each pasture:

Grazing Period	Winter Period
1. Gain in Period	1. Gain in Period
2. Average Daily Gains	2. Average Daily Gains
3. Total Gains	3. Total Gains
4. Gains per Acre	

The experiment involving the sixty steers was terminated July 1, 1949. At the conclusion of the experiment the steers were graded and appraised by a committee composed of Jack Jessup, National Livestock Commission Company, Oklahoma City; Jake Sims, Sims Commission Company, Oklahoma City; and Clyde Manning, head cattle buyer of Wilson and Company, Oklahoma City. The steers were sold on the Oklahoma City market July 11, 1949. At the time of slaughter the tarsal bones from the left fore-leg of each permanent steer was saved for chemical analyses.

Results and Discussion

SOIL ANALYSES

Soil analyses showed that the soil of all pastures was highly acid and very low in available phosphorus.

The soil was classified and found to be one of the following general classes:

(1) Deep, medium textured, moderately to slowly permeable upland prairie soil.

(2) Medium textured, very slowly permeable (claypan) prairie soil.

(3) Deep, medium textured, moderately to slowly permeable creek bottom soil.

(4) Shallow, medium textured, moderately permeable forest soil.

RAINFALL

The average monthly distribution of rainfall at the Coalgate station is given in table I. It will be noted that the heaviest precipitation occurred during the months of April, May and June and it was during these months that the clovers were most prevalent on the pastures.

The extremely dry spring of 1948 partially explains the low gains per acre for most pastures, especially for pasture C during the summer period of 1948. The presence of limestone and phosphate on C pasture stimulated a very dense growth of hop clovers during the winter of 1947, but lack of rainfall in the spring caused much of the clover to die when but 2 or 3 inches high. Crouch and Jones (1945) and Nelson (1941) remarked that the immediate effect of rainfall was the most important single factor in pasture production.

TABLE I

Coalgate Rainfall Distribution

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1945	1.30	9.00	10.73	5.13	4.00	12.48	5.64	4.14	6.20	2.10	1.60	.80	63.13
1946	2.82	5.39	2.92	3.43	6.38	3.73	.22	2.31	3.03	.48	10.33	6.79	47.83
1947	.33	.33	1.81	7.26	8.67	3.97	3.22	1.57	2.12	1.16	2.96	5.44	38.84
1948	.65	4.28	2.13	.78	7.01	5.36	4.42	1.88	1.46	2.48	.24	1.62	32.25
1949	5.19	3.07	3.75	6.39	5.84	5.39							

Twelve Year Average Rainfall Distribution (1937-1948)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total Average
1.73	4.00	3.26	5.24	5.40	5.97	3.22	3.15	2.28	2.92	3.12	2.96	43.25

VEGETATION DIFFERENCES

Fertilizers had marked effects on the prevalence of important pasture species. It has been quite obvious that fertilization has stimulated desirable clovers and grass species and has decreased the weed population. After four years, weeds occupied about one-third of the area in the non-phosphated pastures, about one-twelfth the area of limed pastures and were practically gone from the phosphated pastures. These observations are in agreement with Brown and Munsell (1943) who reported that weeds were most prevalent in unfertilized pastures. An application of limestone alone has stimulated the growth of clover and the further addition of phosphate has resulted in denser growths of clover. Initial seeding caused some clover to appear in an untreated prairie upland pasture (A) but their spread has been markedly slower than in pastures receiving lime or lime and phosphate. After three years clovers were almost non-existant in an untreated eroded timber land pasture (H) and some areas of bare ground were in evidence contrasted to dense growths of clovers in a comparable fertilized pasture (I). Results reported by Crouch and Jones (1945) showed that limestone and phosphorus were necessary to establish clovers. Brown (1944) stated that the purpose of applying limestone was to reduce soil acidity so that desirable clovers could become established.

After four years the predominate legumes on the prairie upland pastures (A, B and C) were Big and Little Hop with evidence of some lespedeza. On prairie bottom land pastures (E and F), White Dutch, Alsike and hop clovers remained as the major clover species. After three years on one fertilized timber land pasture

(G) lespedeza appeared as the predominant legume. Weeping lovegrass continued to diminish each successive year in the untreated eroded timber land pasture (H) while a comparable fertilized pasture (I) exhibited a dense cover of hop clovers and considerable lovegrass.

Fertilized pastures produced greater pounds of air dry forage per acre with a higher protein content than comparable unfertilized pastures. Table II shows the protein content of forage harvested from pasture exclosures. These results are in accord with the findings of most pasture workers. Blaser and co-workers (1943) pointed out that the quality of pasture forage is frequently more important than yields. Crouch and Jones (1945) attributed the high protein levels of forage from fertilized pastures to the presence of legumes. Table II shows that during the months of April and May the pasture forage had a relatively high protein content and that as the grazing season progressed the protein content decreased. The presence of abundant clovers during April and May accounts for these high protein levels. Later in the summer, when the clovers were not so abundant the forage consisted primarily of grasses which have been shown by Fudge and Fraps (1944) to be lower in protein content than legume plants.

BEEF GAINS OF PASTURES

All pasture workers are in agreement that fertilization tends to provide higher quality and more abundant forage per acre which indirectly results in greater gains of beef per acre. The pounds of gain produced per acre for the various pastures is given in table III.

TABLE II

Average Protein Content of Forage Harvested from Pasture Exclosures
Southeast Pasture-Fertility Station, near Coalgate, Oklahoma.

Pasture No.	Percent Protein - 1947					Percent Protein - 1948			
	May 30			July 24	October 21	June 6		July 16	September 15
	Grass	Legumes	Weeds	Grass	Grass	Grass	Legumes	Grass	Grass
A	7.2	13.2	6.7	6.7	6.1	6.9	12.5	7.2	5.8
B	8.3	10.3	8.3	7.0	5.9	7.7	15.5	7.7	6.0
C	10.3	13.3	—	8.3	8.1	8.1	16.9	8.8	6.3
D	9.4	12.1	8.4	8.4	7.2	8.1	14.6	8.5	6.6
E	8.2	12.5	7.1	11.1	7.0	8.3	13.6	10.0	6.8
F	7.5	12.5	—	11.2	7.9	9.5	14.9	11.6	6.9
G	4.8	13.6	9.1	9.9	7.1	7.0	14.7	10.3	8.5
H	6.1	12.2	8.6	5.1	7.1	5.3	10.2	6.8	6.3
I	5.2	13.2	7.3	5.3	7.2	6.1	10.6	7.8	7.5

The grass in pastures A to G inclusive was principally Bermuda and in pastures H and I it was lovegrass.
The legumes were principally Big Hop Clover and lespedeza.

TABLE III

Pounds of Gain Produced per Acre

Pasture No.	1946	1947	1948	3 Yr. Ave.	1949 (81 Days)
A	65.0	67.6	67.0	66.5	40.4
B	81.7	95.5	98.6	91.9	51.7
C	107.9	130.1	88.4*	108.8	112.8
D	102.9	122.1	94.6	106.5	106.6
E	139.9	184.6	182.8	169.1	103.8
F	140.4	217.8	197.2	185.1	150.3
G	——	100.7	95.7	98.2	61.0
H	——	58.1	61.8	60.0	23.9
I	——	91.9	106.8	99.4	67.3

* Severely overgrazed in fall of 1947 and dry weather prevented Hop Clover development in 1948.

In comparing the pastures located on a prairie upland soil, it will be noted that pasture B which was treated with limestone produced 25.4 pounds more beef gain per acre per year over a three year period than did pasture A which received no treatment. Results for 1949 (April 11 to July 1) showed that the limestone pasture B produced 11.3 pounds greater gain than did the untreated pasture A for the 81 day grazing period. Even greater gains were shown for pasture C which received a lime and phosphate application. A three year average showed that it produced 42.3 pounds more yearly gain than did the comparable but unfertilized A pasture. The application of superphosphate and limestone to pasture C resulted in 16.9 pounds more yearly gain over a three year period than did a similar pasture receiving only the limestone application (pasture B). During the 81 day grazing period of 1949, pasture C which was treated with limestone and phosphate produced 61.1 pounds more gain than pasture B which was treated only with limestone and 72.4 pounds more gain than the unfertilized pasture A.

Some very interesting data are shown in table III when pastures established on eroded timber land are compared. Pasture I which was located on eroded timber land and received applications of limestone, superphosphate and potash showed 39.4 pounds more yearly gain per acre over a two year period than did a similar pasture which received no fertilizer (pasture H). During the 81 day grazing period for 1949, pasture I produced 43.4 pounds more gain than did pasture H. Pasture G located on eroded timber land and fertilized with limestone, superphosphate and potash but seeded differently than pasture I produced an average yearly gain of 98.2 pounds for the years 1947 and 1948 which was practically the same as the gain produced on pasture I. The gain per acre in 1949 for 81 days was 61.0 pounds and was 6.3 pounds less than the gain produced on pasture I.

The clay pan prairie upland pasture (D) which received applications of lime and phosphate produced an average yearly gain of 106.5 pounds per acre over a three year period and 106.6 pounds of gain per acre for 1949.

Bottomland pasture F fertilized with limestone and superphosphate produced 16 pounds greater beef gains per acre per year for a three year grazing period and in the 81 day grazing period of 1949 produced 46.5 more pounds of beef gain per acre than did a comparable pasture (E) which was treated with limestone. It will be noted that these bottomland pastures produced approximately 77 pounds more yearly gain than did similarly treated prairie upland pastures during a three year period.

Table IV gives the grazing results for each of the years of this study. It will be noted that fewer acres were required per beef unit for the phosphate treated pastures than for those pastures treated with limestone or those receiving no fertilizer treatment. During each year of the experiment, one beef unit for each pasture consisted of one beef animal. The age, however, was not the same for each of the years. For the years 1946, 1947, 1948 and 1949 the age of the cattle was 2 years, 1 year, 2 years and 3 years respectively. Comparison of prairie upland pastures showed that pasture C fertilized with limestone and phosphorus required

3.0 acres per 2-year-old steer in 1946, 1.4 acres per yearling steer in 1947, 2.8 acres per 2-year-old steer in 1948, and 2.3 acres per 3-year-old steer in 1949. A comparable pasture (B) treated with limestone was grazed with the same class of stock as pasture C but required 3.6 acres in 1946, 2.1 acres in 1947, 2.8 acres in 1948 and 3.3 acres in 1949. In contrast a similar untreated pasture (A) for the same grazing periods required 4.5 acres, 3.1 acres, 3.7 acres and 4.0 acres per beef unit for the respective years.

Prairie bottomland pastures were located on more fertile soil and consequently required fewer acres per steer than prairie upland pastures. Pasture F fertilized with limestone and phosphate required 2.5 acres in 1946, 0.7 acres in 1947, 1.3 acres in 1948 and 1.3 acres in 1949 per beef unit. Pasture E treated only with limestone required 2.5 acres, 1.0 acre, 1.4 acres and 1.8 acres per beef unit during corresponding grazing seasons. Pasture I located on eroded timberland, received applications of limestone, phosphate and potash and required 1.9, 1.5 and 2.3 acres per beef unit during the grazing seasons of 1947, 1948 and 1949 respectively. A comparable untreated pasture (H) required 2.2, 3.0 and 5.0 acres per beef unit during the same grazing seasons.

Table IV further shows that in some instances fewer than 2 acres for 2 and 3-year-old steers were required, which is considerably less than the 8 to 10 acres per yearling steer as reported by Savage and Heller (1947) in the Southern Great Plains Region.

The greater carrying capacity of the fertilized pastures agrees with work reported by Barthalomew and Gifford (1944) in which they

TABLE IV

Grazing Results

Results of Grazing on Pastures in 1946
(April 26 to October 26 - 183 days)

Pasture	Acres	Av. No. Cattle Per Pasture	Acres Required Per Steer	Av. Daily Gain	Total Gain Per Acre	Gain Per Acre By Periods		
						4/26 to 5/25	5/25 to 7/27	7/27 to 10/27
A	18.1	4	4.5	1.62	65.0	20.3	19.6	25.1
B	18.1	5	3.6	1.62	81.7	31.4	24.3	26.0
C	18.1	6	3.0	1.79	108.0	34.8	35.4	37.8
D	8.0	3	2.7	1.51	102.9	38.4	43.1	21.4
E	10.0	4	2.5	1.92	139.9	43.3	51.5	45.1
F	10.0	4	2.5	1.93	140.4	41.9	61.0	37.5

Results of Grazing on Pastures in 1947
(April 14 to November 2 - 202 days)

Pasture	Acres	Av. No. Cattle Per Pasture	Acres Required Per Steer	Av. Daily Gain	Total Gain Per Acre	Gain Per Acre By Periods		
						4/14 to 6/13	6/13 to 8/2	8/2 to 11/2
A	18.1	5.8	3.1	1.04	67.6	36.2	23.2	8.2
B	18.1	8.7	2.1	.98	95.5	49.4	32.9	13.2
C	18.1	13.4	1.4	.86	130.1	83.8	35.6	10.8
D	8.0	5.8	1.4	.84	122.1	85.0	44.4	- 7.2
E	10.0	9.7	1.0	.94	184.6	108.5	73.5	2.6
F	10.0	13.7	0.7	.79	217.8	135.6	92.5	-10.3
G	22.0	8.7	2.5	1.26	100.7	43.2	33.2	24.3
H	11.3	5.1	2.2	.63	58.1	35.3	21.2	1.5
I	11.3	6.1	1.9	.84	91.9	53.6	33.2	5.3

TABLE IV (Continued)

Grazing Results

Results of Grazing on Pastures in 1948
(April 15 to November 2 - 200 days)

Pasture	Acres	Av. No. Cattle Per Pasture	Acres Required Per Steer	Av. Daily Gain	Total Gain Per Acre	Gain Per Acre By Periods		
						4/16 to 6/1	6/2 to 8/2	8/2 to 11/2
A	18.1	4.9	3.7	1.16	67.0	29.0	25.1	12.9
B	18.1	6.6	2.8	1.32	98.6	38.0	42.5	18.0
C	18.1	6.6	2.8	1.18	88.4	39.3	39.0	10.1
D	8.0	3.0	2.7	1.18	94.6	37.1	34.4	23.1
E	10.0	7.3	1.4	1.24	182.8	76.8	87.5	18.5
F	10.0	7.9	1.3	1.26	197.2	84.4	71.9	40.8
G	22.0	7.3	3.0	1.40	95.7	30.0	42.5	23.2
H	11.3	3.8	3.0	0.92	61.8	32.3	28.8	0.7
I	11.3	7.4	1.5	1.36	106.8	39.7	56.2	10.9

Results of Grazing on Pastures in 1949
(April 11 to July 1 - 81 days)

Pasture	Acres	Av. No. Cattle Per Pasture	Acres Required Per Steer	Av. Daily Gain	Total Gain Per Acre
A	18.1	4.0	4.5	2.26	40.4
B	18.1	5.5	3.3	2.10	51.7
C	18.1	8.0	2.3	3.15	112.8
D	8.0	3.8	2.1	2.81	106.6
E	10.0	5.4	1.8	2.38	103.8
F	10.0	7.7	1.3	2.42	150.3
G	22.0	7.2	3.1	2.29	60.99
H	11.3	2.0	5.7	1.17	23.89
I	11.3	3.8	2.3	2.50	67.26

found pastures treated with limestone required less acres per beef steer than untreated pastures. When limestone and superphosphate were applied the carrying capacity of the pastures was even greater.

Pastures C and F were stocked very heavily in 1947 and inadvertently were overgrazed. Below average rainfall in the winter of 1947 and spring of 1948 coupled with overgrazing in 1947 reduced beef gains and carrying capacity of these pastures materially during the 1948 grazing season.

BLOOD ANALYSES

Blood analyses are shown in tables V and VI. The tables show that there was little difference between blood calcium levels for the permanent steers of the various pastures. This agrees with the findings of numerous other research workers who have found that the calcium level of the plasma of steers does not fluctuate much when grazing various kinds of herbage. The average blood calcium levels ranged from 8.9 to 14.0 mgs. per cent which is comparable to levels found for yearling range steers by Savage and Heller (1947) in their study at the Southern Plains Experimental Range.

Table V shows that during the grazing season of 1947 average plasma phosphorus levels for all permanent steers ranged from 4.3 mg. to 8.9 mg. per cent which is above the 4.0 mg. per cent level which Black (1943) considered the minimum level for normal growth. The average plasma phosphorus levels of steers in pastures A and H, which received no treatment, did not fall below 4.5 mg. per cent during the grazing season of 1947 and were similar to plasma levels reported by Knox and associates (1941) and by Becker and co-workers (1933) for yearling steers grazing phosphorus deficient forage.

In the winter period of 1947-1948 the plasma phosphorus levels of the permanent steers were quite low in most cases. The lowest average value for a particular period was 2.5 mg. per 100 ml. of plasma which was found in the steers of pasture A in February. The low phosphorus levels were undoubtedly a direct result of feeding a winter ration low in phosphorus and agrees with the work reported by Beeson (1941) in which he caused blood levels of steer calves to drop from 6 mg. to a low of 3.59 mg. per cent in 60 days by feeding a phosphorus low ration. Henderson and Weakley (1930) reported a similar drop in the phosphorus plasma level of growing dairy heifers when fed a ration low in phosphorus. Many of the permanent steers chewed wood, sticks and tin, indicating they had a craving for something deficient in their diet. These symptoms are identical with those reported by Maynard, Greaves and Smith (1932) and Beeson (1941) for steers fed a low phosphorus diet.

Table VII shows the chemical analyses for protein supplements fed during the winter. The corn gluten meal fed the permanent steers contained considerably less phosphorus than the cottonseed meal which was fed to the reserve steers. The hay fed was from soils known to be low in available phosphorus. Table VI shows that the average inorganic plasma phosphorus values for 10 of the reserve steers fed the same hay but fed cottonseed cake as the protein feed did not fall below 4.62 mg. per cent at anytime during the winter. These results paralleled findings by Beeson and co-workers (1941) who found that steer calves maintained phosphorus levels above 4 mg. per cent when they were fed a phosphorus deficient ration supplemented with cottonseed cake. Maynard, Greaves and Smith (1932) also showed that the inorganic phosphorus levels of yearling steers, showing characteristic pica and other phosphorus deficiency symptoms, rose from 2.41 to 5.41 mg. per cent after receiving cottonseed meal in addition to their low phosphorus diet.

Table V further shows that after the steers were on pasture for 18 days in 1948 the average plasma phosphorus for all permanent steers was higher than the plasma levels during late winter, which is in agreement with findings by Watkins and Knox (1945), Black (1943) and Stanley (1938) where they noted that young succulent forage was usually high in phosphorus and when eaten by cattle caused a parallel rise in inorganic phosphorus levels.

Considerable fluctuation in the plasma inorganic phosphorus values of all steers during 1947 and 1948 was observed and in some instances may have been due to some indiscernable factor as reported by Palmer, Cunningham and Eckles (1930) for dairy cows and by Robinson and Huffman (1926) for beef cattle. The number of steers in each pasture which were bled for the chemical determinations was small and definite trends were not readily recognized. This was particularly true during the early part of the experiment, (1947 and 1948). During 1947 very little difference in the plasma phosphorus level was observed. This may have been partly due to the fact that the steer calves came from an area known to have soils adequately supplied with phosphorus and considerable phosphorus may have been stored. In addition, the steer calves were fed cottonseed cake in the winter of 1946-47 and may have stored considerable quantities of phosphorus. During 1948, the rainfall was considerably below the 12 year average as shown in Table I. As has been pointed out by many research workers, the phosphorus content of herbage is directly correlated with rainfall. This may have been responsible for the failure of steers grazing phosphate fertilized pastures to show higher plasma phosphorus values than those grazing untreated pastures during these periods.

Average inorganic phosphorus values for the winter period of 1948-1949 for the permanent steers that had grazed pastures C, D, F and I which were fertilized with limestone and phosphate remained above 4 mg. per cent and did not fall as they had the previous winter. This suggests that the forage eaten in the summer may have enabled these steers to maintain adequate phosphorus nutrition throughout the winter. This condition is in agreement with statements by Eckles and workers (1932) in which they suggested that when cattle ingest surplus phosphorus some of the phosphates are absorbed by bone tissue and by other body tissue and that in times of low phosphorus ingestion the cattle call upon these reserves to maintain a normal plasma phosphorus level. It was noted that the average inorganic phosphorus values of the other permanent steers did not go below 4 mg. per cent as early as they had the previous winter. This belated drop in plasma phosphorus values coincides with a statement by Beeson (1941) in which he stated that younger animals have a greater demand for phosphorus than older animals

TABLE V

Blood Analyses

Average Inorganic Phosphorus in Blood Plasma (mg/100 ml.) for Permanent Steers

1947 - 1948

Pasture	Grazing Period (April 14 to November 2)				Winter Period (November 2 to April 1)			
	4/14/47	6/3/47	8/2/47	10/2/47	11/24/47	1/14/48	2/10/48	4/5/48
A	6.4	6.6	6.7	5.6	4.9	4.3	2.5	3.4
B	6.5	6.6	7.4	5.1	4.4	4.0	3.0	3.9*
C	6.1	4.9*	6.1	4.3	4.1	3.8	3.1	3.2
D	6.4	6.9	8.9	5.5	5.2	4.2	2.7	3.1
E	6.6	7.1	7.5	5.0	4.4	4.4	3.0	3.6
F	6.4	6.6	9.3	5.5	5.9	5.0	3.6	4.2
H	8.2	6.1	7.1	6.2*	6.2	4.4	3.4	2.5
I	5.6	5.7	6.8	5.4	4.0	3.4	2.8	2.5

Average Calcium Levels in Blood Plasma (mg/100 ml.) for Permanent Steers

Pasture	4/14/47	6/3/47	8/2/47	10/2/47	11/24/47	1/14/48	2/10/48	4/5/48
A	11.0	10.2	10.2	11.2	9.8	10.4	10.5	8.2
B	10.7	10.4	11.0	11.0	10.1	9.8	10.1	9.5
C	10.9	9.9	10.6	11.1	10.6	10.3	11.2	10.0
D	10.6	10.4	10.4	10.6	9.7	9.5	10.3	8.7
E	11.1	11.1	10.6	11.2	9.9	10.0	10.4	9.9
F	10.1	10.3	9.9	10.6	10.0	9.3	10.9	9.0
H	10.4	9.8	11.2	11.5	9.8	10.4	11.7	9.5
I	10.3	9.6	11.4	10.9	9.6	10.5	9.6	8.6

TABLE V (Continued)

Blood Analyses

Average Inorganic Phosphorus in Blood Plasma (mg/100 ml.) for Permanent Steers

1948-1949

Pasture	Grazing Period (April 1 to November 1)					Winter Period (November 1 to April 11)			
	4/19/48	5/22/48	7/2/48	8/2/48	11/1/48	12/8/48	1/6/49	2/7/49	4/4/49
A	4.0	4.1	3.6	5.0	4.2	4.0	3.7	3.9	2.9
B	4.5	4.3	4.8	5.8	4.5	4.0	3.8	4.2	3.5
C	3.9	4.1	3.2	4.7	5.0	4.5	4.3	4.6	4.6
D	4.9	5.1	5.9	7.1	4.0	4.1	4.0	3.4	4.6
E	5.3	5.4	4.9	7.1	4.4	4.2	4.2	4.8	3.7
F	5.6	6.3	7.7	7.2	5.0	4.4	4.5	5.1	4.4
H	4.3	3.7	4.2	6.1	3.8*	3.9	4.0	4.1	3.1
I	2.6	3.5	4.6	6.2	5.1	4.7	4.5	4.2	4.3
Average Calcium Levels in Blood Plasma (mg/100 ml.) for Permanent Steers									
A	10.7	11.3	10.6	11.1	11.4	11.2	10.1	11.1	10.4
B	10.8	11.6	10.9	10.1	11.5	10.7	9.2	9.5	11.0
C	11.6	12.5	11.2	11.0	11.5	11.2	9.7	11.5	10.3
D	10.6	11.8	9.3	9.6	10.7	10.8	10.1	10.2	11.3
E	11.3	10.6	10.2	9.8	10.6	10.8	10.5	11.1	10.5
F	11.3	11.1	10.0	10.0	11.4	10.6	10.4	9.6	10.4
H	11.1	13.7	11.7	10.5	11.3	11.0	9.8	9.4	11.6
I	11.2	11.2	11.6	10.8	11.1	9.9	9.1	8.0	11.3

TABLE V (Continued)

Blood Analyses

Average Inorganic Phosphorus in Blood Plasma (mg/100 ml.) for Permanent Steers

1949

Pasture	Grazing Period (April 11 to July 1)		
	5/9/49	6/1/49	7/1/49
A	5.1	3.4**	4.6*
B	6.7	4.4	6.2
C	7.9	7.0	7.1
D	6.7	5.6	6.5
E	5.9	4.5	6.6
F	7.5	4.9	5.9
H	4.2	2.5*	3.8**
I	7.0	7.5	6.8
Average Calcium Levels in Blood Plasma (mg/100 ml.) for Permanent Steers			
A	10.7	10.8	9.9
B	13.0	10.8	9.9
C	13.2	11.6	11.4
D	13.0	11.1	10.1
E	13.4	11.4	11.7
F	12.7	11.0	10.1
H	11.1	11.2	11.9
I	13.3	13.1	10.5

Snedecor's Analysis of Variance was used to test the statistical significance of phosphorus plasma levels. Pastures A, B and C were one comparative group, E and F another group and H and I another group. D pasture was not comparable to any other pasture and no test was made on it.

* Significant at the 5 per cent level of probability.

** Significant at the 1 per cent level of probability.

TABLE VI

Blood Analyses for Reserve Steers Fed Cottonseed Cake

Date	Phosphorus	Calcium
	1947-1948 Average for 19 Steers	
3/8/48	4.62	9.13
	1948-1949 Average for 10 Steers	
12/8/48	5.46	10.90
1/6/49	5.59	9.93
2/7/49	6.19	10.24
3/12/49	6.01	11.73
4/4/49	6.15	10.36

TABLE VII

Composition of Protein Supplements Fed During Winter
Coalgate, Oklahoma

Feed	Protein %	Phosphorus %	Calcium %
	1947-1948		
Corn Gluten Meal	49.00	0.418	0.19
*Cottonseed Cake	44.00	1.32	0.25
	1948-1949		
Corn Gluten Meal	40.57	0.511	0.37
*Cottonseed Cake	44.15	0.83	0.22

* Cottonseed cake composition is not the actual analyses for that fed. Composition figures shown are from analyses of other cottonseed cake samples comparable to that which was fed.

and therefore phosphorus deficiencies would occur sooner in younger animals. Average inorganic phosphorus levels as low as 2.9 mg. and 3.1 mg. per cent were recorded for pasture A and H steers which had grazed pastures with no fertilizer treatment. Even though the blood levels of steers that grazed pastures receiving only limestone dropped below 4 mg. per cent their plasma phosphorus levels were 0.4 to 0.6 mg. higher than for steers which had grazed the untreated pastures. In late winter some of the permanent steers again manifested aphosphorosis in that they chewed the wood on their feed bunks, sticks and tin. The picture below shows one steer from pasture A chewing a piece of tin, April 4, 1949.

One month after the permanent steers had been turned to pasture in 1949, inorganic phosphorus values for steers of all pastures were well above the late winter level just prior to being placed on pasture. This immediate rise indicated that the young succulent forage furnished high amounts of phosphorus. Eckles, Gullickson and Palmer (1927) found that abnormally low plasma levels (below 3 mg.) of phosphorus deficient cows were restored to normal values of 5 mg. per cent and above in a short period of 5 to 17 days. The steers of H and A pastures showed levels below 4 mg. in June. Since there were only two permanent steers in pasture H and only one permanent steer in pasture I it is difficult to draw definite conclusions from such small numbers.

It is interesting to compare the plasma phosphorus picture of steers from pastures A, B and C for the period of December 8, 1948 to July 1, 1949. This is graphically presented in Figure 1. It will be noted that the inorganic phosphorus values for the steers of the untreated pasture A were below 4 mg. per cent in January, February and late March and rose to 5.1 mg. per cent when turned to pasture, but dropped to 3.4 mg. (shown to be statistically significant) in June but rose to 4.6 mg. per cent just prior to terminating the experiment. Average inorganic phosphorus levels of steers grazing B pasture (treated with limestone) followed the same general trend as steers of A pasture but their levels were consistently higher throughout the period. In contrast the phosphorus values for steers of the lime and phosphate pasture (C) were higher than the levels of B pasture steers and did not at any time fall below 4.3 mg. per cent.

DISTRIBUTION OF GAINS OF THE STEERS

The distribution of gains for the permanent steers is given in Table VIII. It will be noted that the cattle made the greatest rate of gain in April and May when the grasses were young, lush and tender. It was during this period that Crouch and Jones (1945) found that the forage of improved pastures contained the greatest quantities of protein and phosphorus. The rates of gain declined in July and August which is similar to work reported by Savage and Heller (1947) wherein they stated that declines in gains during July and August were in direct proportion to successive decreases in the nutritional qualities of the forage. There was a slight increase in gains for a short time in September followed by a gradual decline in fall gains.

Table IV shows that the average daily gains for steers of the various pastures were quite similar for the grazing seasons of 1947 and 1948, which was accomplished through a management of controlled grazing.

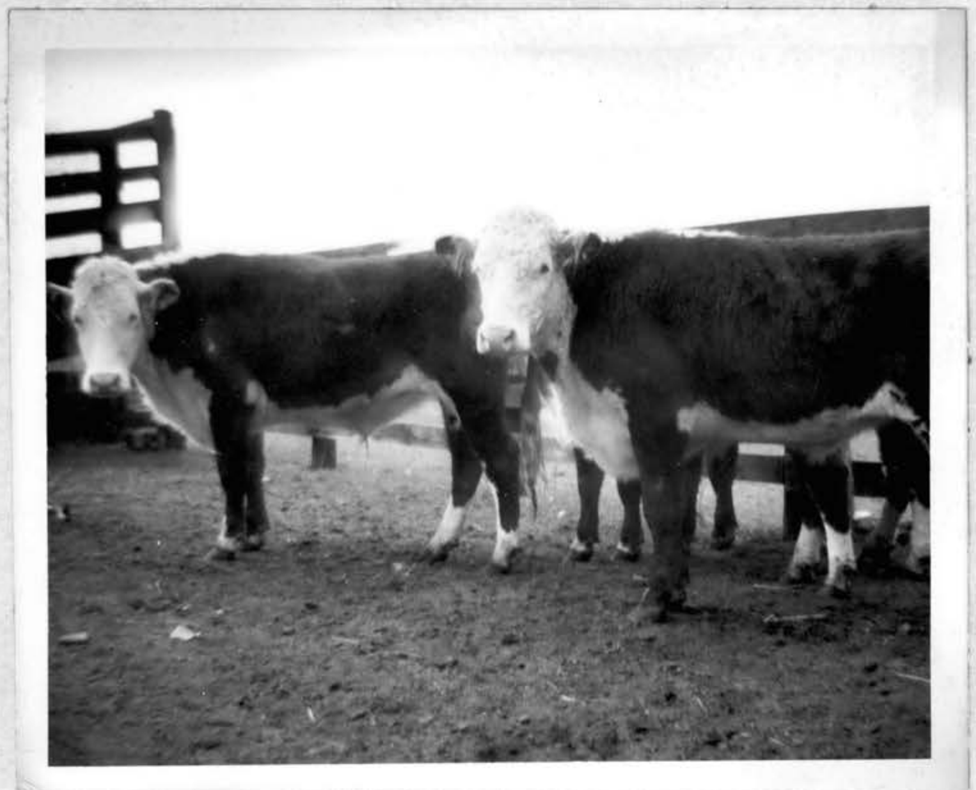
Table IX shows that the gains during the winter period of 1947-1948 for permanent steers of all phosphated pastures were greater than gains for steers from comparable untreated pastures. While the beef gains during the same period for permanent steers grazed in limestone treated pastures were greater than the gains of steers grazed in comparable untreated pastures their gains were not as great as those of steers grazing phosphated pastures. This advantage in winter gains has suggested that steers that had grazed fertilized pastures during the previous summer went into the winter fortified with a larger storage of phosphorus. Beeson (1941) called attention to the fact that steer calves on a low phosphorus diet required 30% more feed and gained 37% slower than calves receiving adequate phosphorus.

All permanent steers, except those from pastures F and I, lost weight during the 1948-1949 winter period. The severe weather during this period was probably responsible in a large part for this weight loss.

In late winter it was noted that the steers that had grazed fertilized pastures the previous summer appeared a little fleshier and thriftier than steers from comparable unfertilized pastures. Pictures on page 66 show the comparative differences in winter condition between steers from a fertilized pasture (C) in contrast to steers from a comparable unfertilized pasture (A).

FINAL WEIGHTS AND APPRAISAL DATA

Table X shows that after three grazing seasons the permanent steers which had grazed fertilized pastures were considerably heavier than steers grazing untreated pastures. These weight differences did not become so noticeably evident until after May of the 1949 grazing season and seemed to parallel the plasma phosphorus levels of the steers. Results showed that steers from a prairie upland pasture fertilized with limestone and superphosphate (C) in comparison to steers grazing a comparable untreated pasture (A) had 39.4 per cent higher plasma phosphorus values for the grazing season of 1949 and were forty pounds heavier at the conclusion of the experiment. Steers on a prairie upland pasture treated with limestone (B) had 22.5 per cent higher phosphorus levels for the grazing season of 1949 and were ten pounds heavier



Steers of A Pasture in March 1949.

Steers of C Pasture in March 1949.

TABLE VIII

Distribution of Average Monthly Gains of Permanent Steers During Grazing Periods

Pasture	April	May	June	July	Aug.	Sept.	Oct.*
			1947				
A	28.8	33.8	52.5	20.0	21.3	3.8	- .25
B	33.0	85.0	37.5	25.0	21.3	2.5	10.3
C	33.5	83.8	41.3	3.4	21.3	1.3	21.8
D	33.3	80.0	36.7	16.7	21.7	-23.3	- 8.0
E	39.0	90.0	37.5	35.0	20.0	6.3	-25.0
F	32.5	68.8	58.8	1.3	11.3	- 7.5	24.5
H	29.5	47.5	20.0	27.5	10.0	5.0	-28.0
I	18.5	85.0	42.5	22.5	22.5	22.5	-36.0
			1948				
A	71.3	43.8	46.3	46.3	40.0	26.3	20.3
B	62.0	56.3	55.0	56.3	27.5	26.3	-17.5
C	45.5	75.0	38.8	65.0	47.5	3.8	-16.8
D	34.0	65.0	61.7	30.0	33.3	23.3	5.0
E	97.0	67.5	53.8	65.0	55.0	16.7	-55.5
F	87.3	67.5	46.3	33.8	42.5	12.0	
H	60.0	42.5	42.5	52.5	12.5	12.5	-24.5
I	74.5	35.0	55.0	62.5	15.0	10.0	- 5.0
			1949				
A	63.0	92.5	27.5*				
B	71.5	103.8	-11.3				
C	106.3	132.5	23.8				
D	92.7	98.3	31.7				
E	62.5	133.8	16.3				
F	72.8	95.0	00.0				
H	70.0	30.0	30.0				
I	10.0	90.0	50.0				

* Weights for October, 1947, 1948 and June, 1949 are shrunk weights accounting for some discrepancy in total gain for that particular period. Some discrepancy is evident for the April gains due to the fact that the steers were placed on pasture after an overnight shrink and the May 1 weight was a "full" weight.

TABLE IX

Winter Gains for Permanent Steers

Pasture	1947 - 1948 November 20 to April 1	1948 - 1949 November 1 to April 10
A	1.3	-25.0
B	11.8	- 9.0
C	27.0	-35.0
D	26.0	-18.0
E	23.0	- 3.0
F	50.3	+ 7.0
H	35.0	-23.0
I	63.0	+17.0

than steers from a similar untreated pasture. It will be noted that the one permanent steer in the fertilized eroded timberland pasture (I) compared to the two steers in a similar untreated pasture was a little heavier in weight prior to the 1949 grazing season but averaged 218 pounds heavier at the end of the grazing period. The plasma phosphorus level of this steer was 46.6 per cent higher than the average plasma level of the two steers which grazed the untreated pasture.

Table IV shows that the permanent steers grazing fertilized pastures made larger daily gains during the 1949 grazing period than the steers grazing the untreated pasture and accounts for their heavier weight on July 1. The fact that big weight differences between steers grazing pastures treated in different ways did not become apparent until after two years suggests that a shortage of phosphorus in a growing steer's diet is slow to manifest itself. Such factors as rainfall as it affected the phosphorus content of forage and previous phosphorus storage may also have been factors responsible for failure of weight differences to show up prior to the 1949 grazing season. These results are in accord with those of Henderson and Weakley (1930) in which they found that young dairy heifers fed a low calcium and phosphorus diet grew nearly as well as normal fed heifers, but over a period of two years did not make as good gains. The higher plasma phosphorus levels and faster gains in 1949 of the steers grazing fertilized pastures suggests that these steers were getting a higher phosphorus and higher protein forage than steers grazing unfertilized pastures. Crouch and Jones (1945) found that forage from fertilized pastures was higher in protein and phosphorus content. They found that beef cattle grazing fertilized pastures, contrasted to cattle grazing unfertilized pastures over a period of years were larger in mature size.

In comparing the appraised value and grade classification of the permanent steers of the different pastures, Table X, it will be noted that the steers from the fertilized pastures were appraised at a higher value and graded higher than steers from unfertilized pastures. Steers graded as slaughter steers were considered to have graded higher than one which failed to get fat enough to grade higher than a feeder steer.

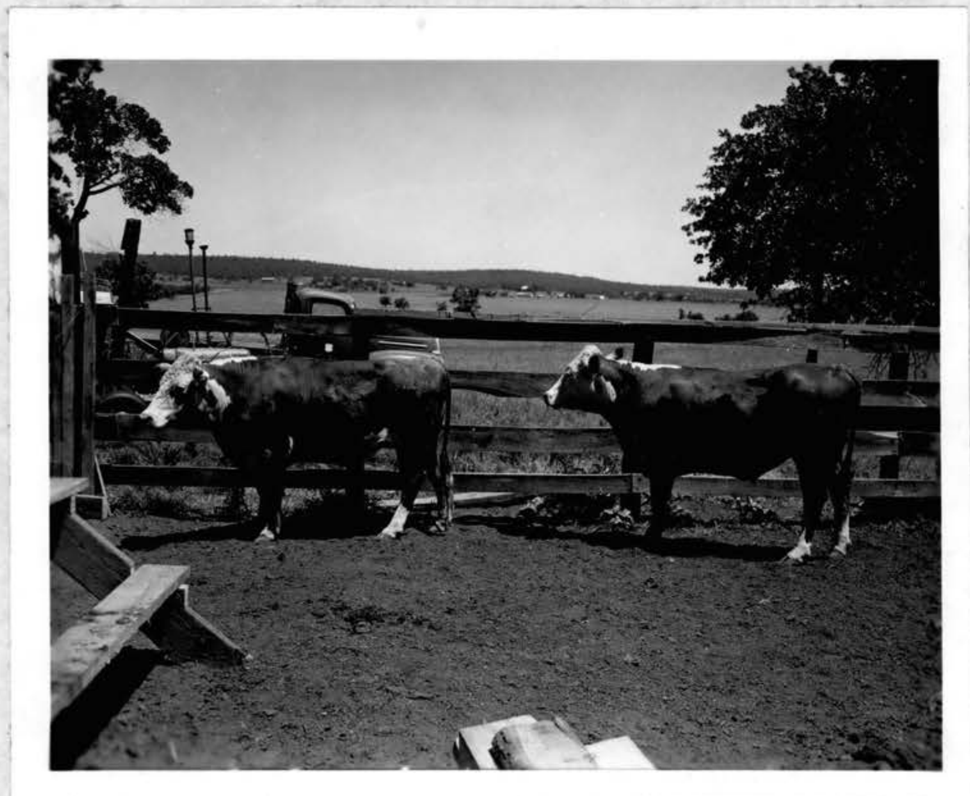
All four permanent steers from the untreated prairie upland pasture (A) were classified as feeder steers and were appraised at an average value of $19.75 per cwt. The four permanent steers from a similar pasture treated with limestone (B) were likewise classified as feeder steers but were appraised at $21.50 per cwt. It was evident that the B steers were fleshier steers than the A pasture steers which accounts for the $1.75 higher appraisal value. Two of the four permanent steers from a comparable prairie upland pasture fertilized with limestone and superphosphate (C) were classified as slaughter steers while two were classified as feeders. The steers of pasture C were fatter than either those of pasture B or A and were appraised at an average of $22.00 per cwt. or $2.25 higher than steers from the limestone pasture (B) and $0.50 per cwt. higher than steers from the untreated pasture (A).

Comparative results from bottomland pastures show that one of the four permanent steers from the limestone treated pasture (E) was classified as a slaughter steer while two of the four permanent steers from a similar pasture fertilized with limestone and phosphate (F) were classified as slaughter steers. Steers from pasture E were appraised at an average of $21.38 per cwt. which is slightly lower than the $21.75 per cwt. appraisal of the steers from F pasture.

The two permanent steers from the untreated timberland pasture classified as high as did the one steer from the fertilized timberland pasture, but were appraised at $.50 per cwt. less. Here again it was evident that the steer from the fertilized pasture was fleshier than the two steers from the untreated pasture, which accounts for the higher appraisal value.

It is interesting to note that all three permanent steers from fertilized pasture D were classified as slaughter steers.

The following pictures show the differences that existed at the conclusion of the study between steers that had grazed fertilized pastures in comparison with steers that had grazed untreated pastures.



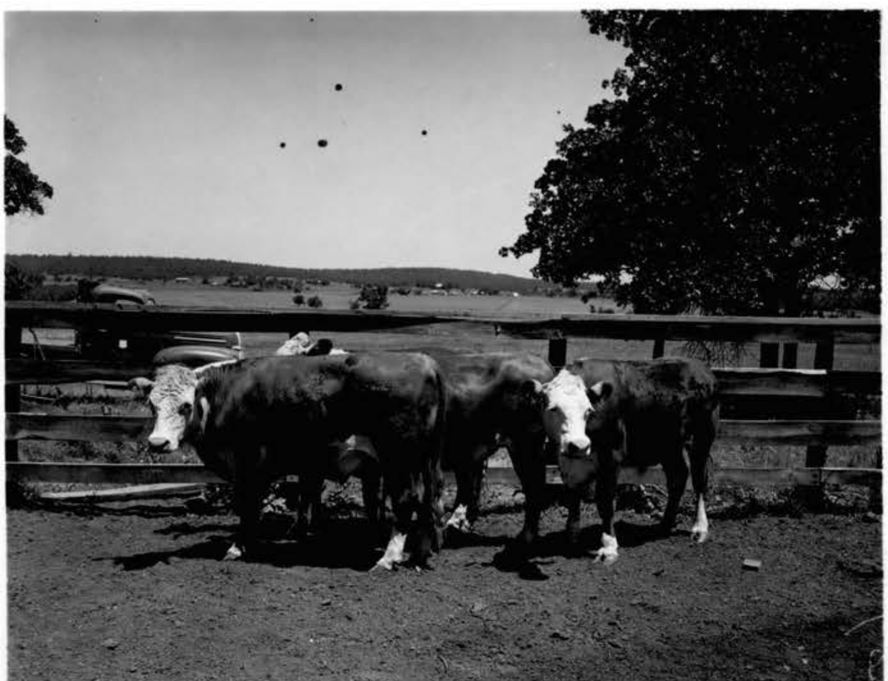
The steer on the left grazed pasture C, a prairie upland pasture which received limestone and superphosphate. The steer on the right grazed pasture A which received no treatment. It is apparent that the steer from pasture C was sleeker and fleshier.

Pictured below are representative steers that grazed eroded timberland pastures.

The steer on the left grazed pasture H which was an untreated pasture. This steer weighed 433 pounds at the beginning of this study and 835 pounds at the close of this study.

The steer on the right grazed pasture I which received limestone, superphosphate and potash. His initial weight was 398 pounds and his final weight was 1070 pounds.

Steers from Pasture A (no treatment) at the close of the study.



Steers from Pasture C (limestone and phosphate) at the close of the study.

TABLE X

Total Gains, Appraisal Price and Grade

Pasture	Steer No.	4/14/47 Initial Wt.	11/2/47	4/1/48	11/1/48	4/11/49	7/1/49 Final Wt.	Gain	Appraised Price Per Cwt.	Slaughter or Feeder Grade
A	22	433	632	635	877	865	1070	637	$20.00	Feeder
	37	425	648	607	847	825	980	555	18.50	Feeder
	55	342	513	512	752	725	885	543	19.00	Feeder
	56	440	696	665	958	918	1130	690	20.00	Feeder
							Av.	606	$19.75	
B	4	377	545	576	793	843	995	618	$21.50	Feeder
	26	425	616	566	867	788	995	570	21.50	Feeder
	42	393	593	610	907	920	1070	677	21.50	Feeder
	57	458	673	640	918	898	1055	597	21.50	Feeder
							Av.	616	$21.50	
C	7	440	582	582	802	733	1045	605	$21.50	Feeder
	13	367	553	575	825	898	1050	683	23.00	Slaughter
	51	457	612	575	848	732	1070	613	21.50	Feeder
	59	397	576	563	858	832	1080	683	22.00	Slaughter
							Av.	646	$22.00	
D	19	360	503	486	810	748	995	635	$21.50	Slaughter
	49	418	582	651	837	912	1085	667	23.50	Slaughter
	52	472	636	616	863	797	1045	573	23.00	Slaughter
							Av.	625	$22.67	
E	1	408	625	606	928	932	1110	702	$20.50	Feeder
	21	468	666	720	970	993	1260	792	20.50	Feeder
	23	393	576	598	900	933	1070	677	23.50	Slaughter
	82	385	598	503	850	777	1045	660	21.00	Feeder
							Av.	708	$21.38	

TABLE X (Continued)

Total Gains, Appraisal Price and Grade

Pasture	Steer No.	4/14/47 Initial Wt.	11/2/47	4/1/48	11/1/48	4/11/49	7/1/49 Final Wt.	Gain	Appraised Price Per Cwt.	Slaughter or Feeder Grade
F	3	470	572	605	903	912	1090	620	$22.00	Slaughter
	15	388	533	538	817	757	935	547	21.50	Feeder
	32	425	576	593	912	942	1150	725	21.50	Feeder
	44	473	636	705	966	1013	1120	647	22.00	Slaughter
							Av.	635	$21.75	
H	14	393	503	522	753	713	870	477	$19.50	Feeder
	17	433	546	563	728	722	835	402	21.00	Feeder
							Av.	439	$20.50	
I	12*	395	——	——	——	——	——	——	——	——
	54	398	595	593	903	920	1070	672	$21.00	Feeder
							Av.	672	$21.00	

* Steer broke his leg in October, 1948 and was then slaughtered.

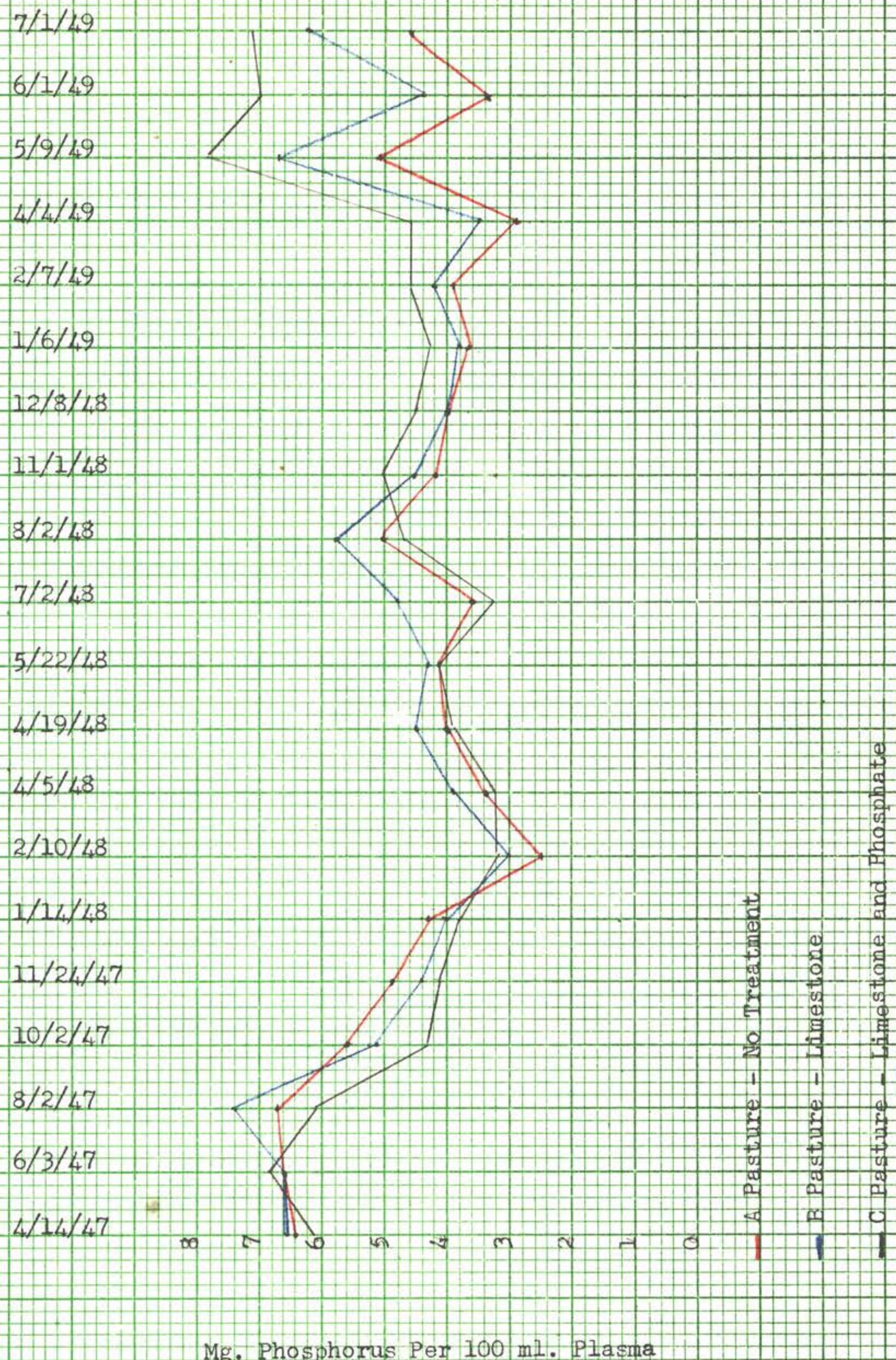


Figure 1

Plasma Phosphorus Levels of Steers - Pastures A, B and C

Summary and Conclusions

1. Highly productive pastures were established on old "worn out" land in Southeast Oklahoma by the use of fertilizers, judicious selection of plants to be established and employment of proper managerial practices of seeding and grazing.

2. An application of two tons of limestone per acre increased forage yields as measured by beef gains and encouraged the growth of legumes. Soils treated with two tons of limestone and 150 pounds of superphosphate produced even larger forage yields than did soils treated with limestone or those receiving no treatment.

3. Prairie upland pastures treated with limestone and limestone plus superphosphate produced 25.4 and 42.3 pounds more yearly gain per acre over a three year period than did a comparable unfertilized pasture. During the 81-day grazing season of 1949 these fertilized pastures produced 11.3 and 72.4 respectively more beef gain per acre than the unfertilized pasture.

4. The addition of lime, superphosphate and potash to an eroded timber upland soil seeded to Weeping lovegrass and winter legumes produced 39.4 pounds more yearly gain per acre over a three year period and 43.4 pounds more beef gain per acre during the 81-day grazing period of 1949 than did a comparable unfertilized pasture.

5. Differences in daily gains of steers did not become evident until the second month of the third grazing season. The daily gains of the steers grazing the prairie upland pastures during the 1949 grazing season were: 2.26 pounds (Pasture A, untreated), 2.10 pounds (Pasture B, limestone) and 3.15 pounds

(Pasture C, limestone and phosphate). The addition of superphosphate and limestone to creek bottom soils increased the daily gain of steers grazing such a pasture .04 pounds as compared to steers grazing a comparable soil treated with only limestone. Steers grazing an eroded timberland pasture treated with limestone, phosphate and potash made .83 pound more daily gain than did steers grazing a comparable untreated pasture.

6. Steers grazed on fertilized pastures were heavier, fatter and were appraised at a higher value than steers from comparable unfertilized pastures.

7. Consistent significant differences in the plasma calcium levels of steers were not observed in this study.

8. During the first two years of this study a consistent significant difference in plasma phosphorus levels of steers grazing the various pastures was not observed. During late winter of the second wintering period, pronounced plasma phosphorus differences were found among the steers which had grazed the various pastures the preceding summer. The steers that had grazed in pastures which had been treated with superphosphate had higher plasma phosphorus levels than those grazing pastures treated only with limestone or those receiving no treatment. The plasma phosphorus levels of the steers grazing in phosphate treated pastures during the 1949 grazing season were significantly higher than those grazing in pastures treated with limestone or those receiving no treatment.

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