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Influence of phosphorus supplementation on growth and reproductive characteristics of beef cows in the semi-arid bushveld of South Africa

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DECLARATION

I declare that this thesis for the MSc (Animal Science) degree at the University of Pretoria has not been submitted by me for a degree at any other university.

Signed…………………………………

Michelle Orsmond

SUMMARY

Influence of phosphorus supplementation on growth and reproductive characteristics of beef cows in the semi-arid bushveld of South Africa

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In this study the effect of phosphorus supplementation on growth and reproductive characteristics of grazing beef cows in the sweet bushveld of the Limpopo Province was studied. The parameters studied were weight of the cows and heifers, birth weight, weaning weight and weight gain in calves, and conception rates and intercalving periods of cows.

The experiment was subdivided into three separate trials. In the first two trials, Bonsmara cows were block selected according to age and mass and randomly allocated in either a control group or one of three treatment groups in Trial 1, or a control group and a treatment group in Trial 2. The treatment groups received phosphorus supplementation all year round (T1), phosphorus supplementation in the summer months only (T2), and phosphorus supplementation in the summer months with a winter lick (T3). Trial 1 was conducted during the years 1995 to 1997 and Trial 2 from 1998 to 2002. All the experimental animals grazed on veld that was predominantly *Combretum*

appiculatum with a small portion of a transitional veld consisting of a mixture of *Terminalia sp.* and *A. tortilis* trees.

In the third trial, the experimental animals were from four different breed types, namely Afrikaner type, Simmentaler type (Simmentaler x Afrikaner x Simmentaler), Nguni type as well as a Bonsmara type (Afrikaner x Simmentaler x Bonsmara). These animals were block selected according to age and mass and randomly allocated to two treatment groups, with one being a control group (C) and the other received Kimtrafos 12 P P supplementation all year round (T4). This trial took place from 1998 to 2002 and the cows grazed on predominantly *Acacia tortilis* veld.

In all of the trials cows were weighed every four weeks throughout the years. Records were also kept of the cows calving interval and birth weights of calves were recorded. Calves were also weighed every four weeks until weaning, and after weaning all calves were reintroduced into the trial.

In the first trial, phosphorus supplementation did not have a significant effect on cow weight (significance level varied between P= 0.1308 and P= 0.6098). There was however a tendency towards significance in the month of October (P= 0.0927). The effect of phosphorus supplementation was however significant in Trial 2 with a significance level of $P < 0.01$. This difference between Trial 1 and 2 could be attributed to a larger sample, with more experimental animals over a longer time period in Trial 2. Animals in Trial 2 were also more homogenous and better randomly allocated into groups than the animals in Trial 1. In Trial 3, it was found that treatment had a varied effect on cow weights. Treatment was significant for the months of June through to November (significance levels varied between P= 0.0010 and P= 0.0576), tended towards significance in May and December (P= 0.0611 and P= 0.0738 respectively) and was not significant in the months of January through to April (significance varied between P= 0.1151 and P= 0.2721). The months where treatment had a significant effect were the months that coincided with the last trimester of pregnancy, as well as the months when the cows would have calved down.

In Trial 1, phosphorus supplementation had no statistically significant effect on birth weight, weaning weight or weight gain of calves (with significance levels of P= 0.5349, P= 0.7893 and P= 0.8065 respectively). In Trial 2 however, treatment had no effect on birth weight (P= 0.7003), but was significant for weaning weight (P= 0.0272) and weight gain (P= 0.0524). Here the phosphorus-supplemented group was heavier than the control group. In Trial 3, treatment once again had no significant effect on birth weight (P= 0.1904), but did show a tendency towards significance for weaning weight (P= 0.0587) and was significant for weight gain in calves (P= 0.0464). Again the calves from the phosphorus-supplemented cows were heavier than those from the control group cows.

There was no improvement in the reproductive status of phosphorus-supplemented cows. Phosphorus supplemented cows did not return to oestrus sooner nor did they calve earlier.

ABSTRACT

In this experiment, the influence of phosphorus supplementation on growth and reproductive characteristics of beef cows in the semi-arid bushveld of South Africa was studied. The parameters in this study included weight, intercalving period and conception rates of cows, as well as birth weight, weaning weight and weight gain of calves. The experiment consisted of three trials. Trial 1 involved Bonsmara cows with four dietary supplementation groups. These were control, phosphorus supplementation all year round, phosphorus supplementation in the summer months and summer phosphorus supplementation with a winter lick. Trial 2 dealt with Bonsmara cows and included two dietary supplementation groups, namely control and phosphorus supplementation all year round. Trial 3 compared four different breeds (Afrikaner, Simmentaler, Nguni and Bonsmara) and included two dietary supplementation groups, notably a control group and a Kimtrafos 12 P supplementation all year round. Phosphorus supplementation had no significant effect on cow weight in Trial 1 ($p > 0.1$), but was significant in Trial 2 ($p < 0.001$) with the supplemented group performing better than the control group. In Trial 3, phosphorus supplementation had a varied effect on cow weight, because it only had an effect for the months of June to November ($p < 0.05$). Phosphorus supplementation had no significant effect on birth weight in any of the trials. Treatment did however either show a tendency towards significance or was significant for weaning weight and weight gain in Trial 2 ($p = 0.0272$ and $p = 0.0524$ respectively) and Trial 3 ($p = 0.0587$ and $p = 0.0464$ respectivey), with the treated groups performing better than the control groups. There was no improvement in calving interval or conception rate for phosphorus supplemented cows in any of the trials.

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LIST OF ABBREVIATIONS

B1: Bonsmara cows

B2: Afrikaner type cows

B3: Simmentaler type cows

B4: Nguni type cows

B5: Bonsmara type cow

C : Control for veld type 1 (Combretum veld type)

C2: Control for veld type 2 (*Acacia Karoo* veld type)

d : days

kg: kilograms

P : Phosphorus

T1: Phosphorus-salt supplementation (P-NaCl) all year round

T2: Phosphorus supplementation during the summer months only

T3: Phosphorus supplementation during the summer months only with a Winter lick during the winter months

T4: Kimtrafos 12 P supplementation

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CHAPTER 1: INTRODUCTION

1.1 PROJECT THEME

Production physiology focusing on growth and reproduction.

1.2 PROJECT TITLE

Influence of phosphorus supplementation on growth and reproductive characteristics of beef cows in the semi-arid bushveld of South Africa.

1.3 AIMS

The aims of this project were to:

1) Study the effect of phosphorus supplementation on the live weight of grazing beef cows.
2) Study the effect of phosphorus supplementation on the reproduction of grazing beef cows.
3) Study the effect of phosphorus supplementation on the growth of calves of supplemented vs. unsupplemented grazing beef cows.
4) Study the above effects in different breed types of grazing beef cows.

1.4 MOTIVATION

The aim of the South African livestock industry is to improve efficiency and economic return. In the business of grazing beef cattle, profit relies on factors such as growth and reproduction. It is therefore beneficial to implement methods to increase and improve growth rate as well as influence reproduction by improving calving percentages and calving interval. Birth weights and weaning weights of calves are also good indicators of the reproductive status of cattle herds. All the above-mentioned factors are affected by the mineral status of the pastures on which the cattle herd grazes. Extensive areas of phosphorus-deficient soils occur throughout the world, and a deficiency of this element can be regarded as the most widespread and economically important of all the mineral disabilities affecting grazing livestock (McDonald *et al*., 1995). In South Africa, natural pastures and especially the grassland areas, are considered low in phosphorus for at least part of the year (Du Toit *et al*., 1940).

There is an ongoing debate as to whether phosphorus supplementation is a viable method of improving growth and reproduction in grazing cattle (Karn, 2000). The confusion surrounding this topic is mainly due to the fact that the exact phosphorus requirement of grazing cattle is not known. This is due to the many factors affecting phosphorus requirements, such as the breed of cattle (McDowell, 1996) and the nutrient interactions (Bortolussi *et al*., 1999). These factors, coupled with varied results concerning the best way to measure the animal's phosphorus status, make it difficult to determine exact requirements for the mineral (Karn, 2000). Another factor fuelling the debate is what the level of phosphorus deficiency in soil, and therefore plants, has to be in order to have an effect on the phosphorus status of the animal, with some trials showing that regions with minimal phosphorus deficiencies having little or no effect on the animal's phosphorus status (Read *et al*., 1986c).

1.5 HYPOTHESIS

Ho: Phosphorus supplementation does not significantly influence the growth and reproductive characteristics of extensive beef cows in the semi-arid bushveld of South Africa.

Ha: Phosphorus supplementation influences the growth and reproductive characteristics of extensive beef cows in the semi-arid bushveld of South Africa.

<u>Growth focus/characteristics:</u>

- Growth rate of cow/heifer

<u>Reproductive focus/characteristics:</u>

- Calving percentage
- Calving interval

- Maintenance of weight and body condition score after parturition
- Weaning weight of calf
- Growth rate of calf during lactation (indication of milk yield)

Variables in phosphorus supplementation:

- Treatment groups (all year vs. summer vs. summer with winter lick)
- Different breeds and therefore breed size

Other variables:

- Age of cow/ heifer when she entered the trial
- Season (including rainfall)
- Sex of calves (male vs. female regarding weight)

CHAPTER 2: LITERATURE REVIEW

2.1 NUTRITIONAL IMPORTANCE OF PHOSPHORUS

Phosphorus has the most known functions of all known minerals in the animal body. The majority of phosphorus in the body is found in bone. Bone is highly complex in structure and its mineral matter makes up approximately 460g per kilogram dry matter of bone, with the two most abundant mineral elements being calcium and phosphorus (McDonald *et al*., 1995). About 80-85% of the phosphorus found in the body is located in bone in a 1:1.7 ratio with calcium (Ternouth, 1990). The calcium and phosphorus in bone are combined in a form similar to that of the mineral hydroxyapatite (McDonald *et al*., 1995). Calcium and phosphorus provide bone with the strength needed for the animal to perform daily activities (Karn, 2000). Other than phosphorus being a structural component of bone it also serves as a phosphorus reserve for the animal as phosphorus can be reabsorbed in times of depletion (Minson, 1990). This reserve is only useful in times of temporary depletion and various studies have shown different levels of reabsorption. It has been shown that 30% of bone phosphorus can be reabsorbed (Ternouth, 1990), but that the level of reabsorption of bone phosphorus depends on the animal's history of phosphorus nutrition (Minson, 1990; Karn, 2000).

The remaining 15-20% of phosphorus found in the body occurs in various forms. It occurs as phospholipids, which are needed for the maintenance of cell wall structure as well as being components of myelin sheaths of nerves. As phosphoproteins, these contain phosphoric acid as their prosthetic group and include the caseins of milk, as well as nucleic acids, which are needed for the transfer of genetic information.

Phosphorus also plays a vital role in energy metabolism, notably the formation of sugar phosphates as well as AMP, ADP, ATP and creatine phosphate. Phosphorus also forms part of the animal's fluid buffering system (NRC, 1984; McDonald *et al*., 1995; Karn, 2000). Then there is the role of phosphoric acid esters, which play an important part in a wide variety of metabolic reactions in living organisms.

Phosphorus also plays a vital role in digestion, as it is required by rumen microbes for optimum rumen microbial activity to occur. Komisarczuk *et al*. (1987) showed that rumen microbial activities can be maintained if ruminal inorganic phosphorus levels are at least 75-100mg/l. Ternouth (1990) found that even when animals are on a phosphorus deficient diet, rumino-reticulum phosphorus levels are normally above levels necessary for optimal microbial activity. However, it does not seem likely that when blood inorganic phosphorus falls below 20mg/l (and animals are exhibiting clinical signs of deficiency) that ruminal phosphorus levels would be maintained (Karn, 2000).

Phosphorus, like calcium, is required for bone formation, and a deficiency in phosphorus can cause rickets or osteomalacia. When animals have a dietary phosphorus deficiency they may show signs of ‘pica’ or depressed appetite, also known as aphosphorosis, where animals have an abnormally poor appetite and chew bones, wood, rocks and other foreign materials (McDonald *et al*., 1995). It has been reported that in severe cases of pica, animals have contracted botulism from eating bones from old carcasses and have died as a result (Theiler *et al*., 1927; McDowell *et al*., 1983). A deficiency in phosphorus was also shown to cause stiff joints, muscular weakness, poor fertility and a reduction in milk yield. Phosphorus deficiency also seems to have an effect on the ovaries resulting in depression, inhibition or irregularity of oestrus. Low live weight gains in adult animals and reduced growth in young animals are symptoms of deficiency in all species, with a deficiency in cattle being more common than in sheep, as sheep are more selective grazers (McDonald *et al*., 1995).

2.2 OTHER MINERALS IMPORTANT FOR GROWTH AND REPRODUCTION

2.2.1 Calcium

Calcium is the most abundant mineral in the animal body, with 99% of calcium found in the skeleton and teeth (McDonald *et al*., 1995). The rest is an essential constitute of living cells and tissue fluids. Calcium is needed for a number of enzyme systems; for example those involved in the transmission of nerve impulses and contractile properties of muscle. Calcium is found in blood plasma and is concerned in the coagulation of blood (McDonald *et al*., 1995). Calcium is also needed in the correct ratio to phosphorus, although some research shows that an exact ratio is not required. Phosphorus just has to meet requirements, and it is recommended not to allow total daily phosphorus intake to exceed daily calcium intake for young beef cattle, as this may cause urinary calculi (Rasby *et al*., 1998). However, a deficiency of calcium in young growing animals, as well as an incorrect Ca: P ratio can lead to rickets and osteomalacia (McDonald *et al*., 1995). The symptoms of rickets are misshapen bones, enlargement of joints, stiffness and lameness (McDonald *et al*., 1995).

Calcium levels also affect the phosphorus status of an animal. The reabsorption of calcium and phosphorus from bone is controlled by parathyroid hormone, which in turn is controlled by calcium levels in the blood (McDonald *et al*., 1995). The release of parathyroid hormone also results in an increase in the absorption of phosphorus from the intestine. Calcium deficiency in pastures has also been shown to be a limiting factor where phosphorus supplementation is concerned (Cohen, 1973 as cited in Read *et al*., 1986b).

2.2.2 Magnesium

Magnesium is closely associated with phosphorus and calcium. It is estimated that about 70% of magnesium is found in the skeleton of the animal (McDonald *et al*., 1995). The rest occurs in the soft tissues and fluids, and is of crucial importance to the well being of the animal. Magnesium is the most common enzyme activator and is therefore essential for the efficient metabolism of carbohydrates and lipids. It is involved in many cellular reactions including cellular respiration as well as the formation of AMP, ADP and ATP (McDonald *et al*., 1995). Deficiency can lead to magnesium tetany, which is characterised by low magnesium in plasma and cerebrospinal fluid (Rasby *et al*., 1998).

2.3 PHOSPHORUS HOMEOSTASIS AND REQUIREMENTS

In order to determine phosphorus requirements, one has to understand how the animal body controls phosphorus levels, for example by secretion. Understanding the significance of phosphorus levels in various organs and body fluids and how these levels are controlled can help develop an understanding of how these levels can be used as possible phosphorus status indicators (Karn, 2000).

Calcium and phosphorus can be reabsorbed from the bone (McDonald *et al*., 1995). The amount of reabsorption that occurs is controlled by parathyroid hormone. When blood calcium levels are low, the parathyroid gland is stimulated to secrete more parathyroid hormone. This induces the kidney to increase production of 1,25-dihydroxycholecalciferol, a metabolite of vitamin D3, which in turn enhances the intestinal absorption of calcium. 1,25-dihydroxycholecalciferol also increases the absorption of phosphorus from the intestine and enhances phosphorus and calcium reabsorption from the bone (McDonald *et al*., 1995). Challa *et al*. (1989), Coates & Ternouth (1992), Hendricksen *et al*. (1994) and McLean & Ternouth (1994) all showed that phosphorus absorption from the intestine is related to phosphorus intake but Coates & Ternouth (1992) found that phosphorus intakes had no effect on phosphorus absorption coefficients. For animals on a balanced diet, accretion and reabsorption of bone is in dynamic equilibrium (Cohen, 1980). Braithwaite (1975) found that young animals could adjust their rate of bone deposition in response to nutritional changes. Mature animals seem to lose this ability, and this means that when on a low phosphorus diet, they have a higher rate of phosphorus turnover.

Another aspect affecting phosphorus homeostasis is salivary phosphorus. The phosphorus concentration of saliva generally exceeds that of serum levels by a factor of at least five for cattle and is mostly inorganic phosphate (Cohen, 1980). Most endogenous faecal phosphorus loss is due to unabsorbed salivary phosphorus, which is a product of salivary phosphorus volume and concentration (Ternouth, 1989). Salivary phosphorus volume/output is affected by dry matter intake (Karn, 2000) and is also dependent on phosphorus intake with the turnover of phosphorus in ruminant saliva on a daily basis being greater than or similar to daily phosphorus intake (Cohen, 1980). Salivary phosphorus concentration is directly related to plasma phosphorus concentration (Karn, 2000) and varies inversely with the flow rate of saliva, which keeps the daily output of salivary phosphorus constant (Cohen, 1980). Coates & Ternouth (1992) believe that ruminants on low phosphorus levels probably control loss of endogenous faecal phosphorus by increasing phosphorus absorption and by reducing salivary phosphorus flow. In general, diet and saliva are the only sources of phosphorus in the rumen, with salivary phosphorus being the most important (Cohen, 1980).

The main site for phosphorus absorption is the small intestine with very small amounts being absorbed from the rumen, omasum, abomasum and large intestine. Phosphorus absorption is either passive, when there is a high luminal concentration of phosphorus, or active. This means that phosphorus absorption will have higher energy costs under phosphorus deficient conditions. Active diffusion of phosphate in the small intestine is by a different pathway to the transport of calcium and is independent of calcium (Cohen, 1980).

In cattle, phosphorus is lost mainly in the faeces (Karn, 2000). Barrow & Lambourne (1962) found that faecal inorganic phosphorus is dependent on phosphorus intake, but organic phosphorus excretion is independent of ingested phosphorus and remains more or less constant. The amount of phosphorus in the faeces depends largely on the amount of phosphorus in the animal's diet, as well as the quality of the diet and the animal's physiological state (Karn, 2000). Bortolussi *et al*. (1996) showed that on phosphorus depletion diets, growing cattle had faecal phosphorus levels of 200% more than their phosphorus intake, and cattle on repletion diets showed faecal phosphorus levels ranging from 58-73% of phosphorus intake. Other studies have shown faecal phosphorus excretion levels of 44-74% of ingested phosphorus (Betteridge and Andrewes, 1986) as well as 88-103% of ingested phosphorus (Hendricksen *et al*., 1994). According to Challa *et al*. (1988) ruminants control phosphorus levels in the body through control of the amount of phosphorus excreted in the faeces. In turn endogenous faecal phosphorus loss is almost entirely the result of unabsorbed salivary phosphorus, which is a product of salivary phosphorus concentration (related to plasma phosphorus concentration) and phosphorus volume (related to dry matter intake) (Ternouth, 1989; Karn, 2000).

Phosphorus is also excreted in urine (Challa *et al*., 1989), although this is minimal when compared to faecal phosphorus excretions, with urinary phosphorus excretions only being 4-9% of total phosphorus excretion (Betteridge *et al*., 1986). This is due to the fact that the ruminant kidney has a great ability to reabsorb phosphate (Mayer *et al*., 1966).

Phosphorus requirements are calculated as the sum of phosphorus retained by the animal, less the phosphorus lost in animal products, like milk and conceptus, and less endogenous phosphorus losses, like faeces and urine (Cohen, 1980). Factors affecting phosphorus requirements of cattle are the availability of phosphorus in feed (Ternouth, 1990), nutrient interactions (Bortolussi *et al*., 1999), differences between breeds (McDowell, 1996) as well as the effect of parasitism and disease (Ternouth, 1990). Another factor affecting phosphorus requirements is the animals production status i.e. whether the animal is pregnant, lactating, growing or on maintenance (Karn, 2000), with phosphorus requirements increasing with an increase in the animals production status (De Brouwer *et al*., 2000).

The NRC (1984) recommends that a dry, pregnant cow requires 19.5g phosphorus a day while De Brouwer *et al* (2000) recommends that a lactating cow weighing 550kg requires 30g of phosphorus a day. The NRC (1984) recommended requirements by calculating a maintenance requirement, 2.8g phosphorus per 100kg live weight, and then added additional phosphorus depending on the animal's production status. The NRC (1984) recommendation for weight gain is 3.9g phosphorus per 100g of protein gained, for lactation it is 0.95g phosphorus per litre milk produced, and for foetal growth, 7.6g phosphorus per 1kg foetal weight over the last 3 months of gestation. However in the NRC (1996) the maintenance requirement for phosphorus was reduced to 1.6g phosphorus per 100kg of live weight.

Phosphorus requirements are usually based on endogenous faecal phosphorus loss as well as phosphorus absorption values (Karn, 2000). The ARC (1980) based maintenance phosphorus requirement for cattle 12 months of age and over 300kg, on a fixed endogenous faecal loss of 10mg phosphorus per kg live weight and an absorption coefficient of 0.58. However, phosphorus absorption coefficients of 0.64-0.92 have been reported with no indication of the age of the cattle having an effect on the values (Coates & Ternouth, 1992). It seems low absorption coefficients are more likely to occur when diets contain phosphorus concentrations well above requirements (Karn, 2000). It has also been reported that low nitrogen intake can depress phosphorus absorption (Bortolussi *et al*., 1996). Endogenous faecal phosphorus losses are related to phosphorus intakes as well as dry matter intake (Ternouth, 1990; Coates & Ternouth, 1992) but endogenous faecal phosphorus cannot be considered a constant value (Karn, 2000). Values for endogenous faecal phosphorus vary from 7.0 to 27.5mg phosphorus per kg live weight for grazing heifers, breeding cattle and steers (Coates & Ternouth, 1992; McLean & Ternouth, 1994; Bortolussi *et al*., 1996; Ternouth, 1990).

As phosphorus absorption is affected by dietary nitrogen levels as well as phosphorus intakes (Bortolussi *et al*., 1996), and because endogenous faecal phosphorus values are affected by phosphorus and dry matter intake (Coates & Ternouth, 1992), it has been suggested that phosphorus requirements should therefore not be based on a constant endogenous faecal phosphorus value or on a single phosphorus absorption value (Karn, 2000). It would therefore be beneficial for more research to be done in order to achieve a more definite value for phosphorus requirements.

2.4 INTERACTIONS BETWEEN PHOSPHORUS AND OTHER NUTRIENTS

2.4.1 Calcium

It was previously mentioned that, it is difficult to separate the physiological functions of calcium and phosphorus. The interactions between these two minerals are important and require further discussion. Calcium and phosphorus are reabsorbed from bone, but the level at which this occurs is under direct endocrine control via parathyroid hormone, which in turn responds to the level of calcium in the blood (McDonald *et al*., 1995). Parathyroid hormone is unaffected by the phosphorus levels in the blood (Sherwood et al., 1968), it has however been demonstrated that parathyroid hormone increases the phosphorus concentration of saliva (Tomas, 1974). Therefore, a major regulatory mechanism of phosphorus turnover is largely dependent on the animal's calcium status (Cohen, 1980). Parathyroid hormone also stimulates the kidney to increase production of 1,25-dihyroxycholecalciferol, which increases calcium absorption from the intestine. In addition, 1,25-dihydroxycholecalciferol increases the absorption of phosphorus from the intestine. A high calcium intake thus associated with a reduction in the production of 1,25-dihydroxycholecalciferol leads to a decrease in phosphorus absorption from the intestine as well as a decrease in the secretion of parathyroid hormone (Cohen, 1980). This results in a lowering of the phosphorus concentration of saliva and a decrease in reabsorption of phosphorus from bone (Cohen, 1980). This coupled with a low phosphorus intake can lead to a deficiency of phosphorus, and supplementation will therefore give results in terms of decreasing the effect of the phosphorus deficiency. On the other hand when calcium intake is low, all these mechanisms are mobilised resulting in an increase in the availability of phosphorus for tissue growth (Cohen, 1980) and then it is quite common to observe no response to phosphorus supplementation.

An experiment was done (Theiler *et al*., 1937) where heifers were fed a low phosphorus diet with adequate levels of calcium. The heifers showed a decrease in feed intake, low weight gain and signs of aphosphorosis. Heifers given a diet low in both phosphorus and calcium, but adequate in other nutrients, had normal feed intake and growth rate and showed no signs of deficiency. When an autopsy was done 18 months later however, the heifers showed severe demineralisation of bone and rickets as well as low plasma phosphorus levels. It is therefore beneficial in certain circumstances, such as in areas with known calcium deficiencies, to give a supplementation of both calcium and phosphorus (Cohen, 1980). Cohen (1975) also noted that the large responses to phosphorus supplementation, which occurred in Africa, were from areas where the soil had a high concentration of calcium.

2.4.2 Energy and protein

It has been shown that under conditions of energy (Benzie *et al*., 1960) and protein (Sykes *et al*., 1973) deficiencies, bone mineralization may be restricted even though phosphorus intake is adequate. This is due to the fact that there is not enough protein and energy available for the formation of organic matrix for normal mineralization (Cohen, 1980). Wadsworth & Cohen (1976) found that energy intake is restricted by a phosphorus deficiency and therefore the response to phosphorus supplementation can only be predicted to a level where other nutrients restrict energy intake. Also the protein and phosphorus contents of pastures tend to be correlated (Cohen, 1975), so to obtain any significant response with phosphorus supplementation, it is recommended that both a protein and phosphorus supplement be given (Cohen, 1975).

2.5 PHOSPHORUS STATUS INDICATORS

The phosphorus requirements of grazing cattle, early detection of phosphorus deficiency and the correct level of supplementation have important economic consequences. If supplementation is undersupplied then animal growth and reproduction are affected and if supplementation is oversupplied financial returns are compromised. It is therefore necessary to accurately determine the animal's phosphorus status (De Waal & Koekemoer, 1997). Recommendations for phosphorus supplementation are often based on speculation and although clinical symptoms like aphosphorosis may be used to diagnose a deficiency, often by the time these symptoms appear, the deficiency is usually advanced (Little, 1972). It is therefore necessary to find other methods of assessing the animal's phosphorus status. Blood samples are easily obtained and have formed the basis of diagnostic tests (Cohen, 1975), although they can provide little information about the status of the animal's mineral reserves and are influenced by several factors (De Waal *et al*., 1997). A more sensitive and reliable phosphorus status indicator seems to be phosphorus levels in rib bones (Little, 1972), which have been shown to identify phosphorus deficiencies in reproducing cattle (Read *et al*., 1986b, c).

2.5.1 Mineral levels and specific gravity of rib bone

Several experiments have shown that bone phosphorus is the most reliable phosphorus status indicator (Cohen, 1973a, b; Little, 1984; Read *et al*., 1986c). Read (1984) found that skeletal phosphorus content is directly dependent on phosphorus intake and concluded that bone tissue is the most accurate method of determining phosphorus status of the animal. De Waal *et al*. (1997) found that mineral concentrations are more sensitive when expressed per unit volume (mg/cm^3) of fresh bone, than when expressed as percentage of dry bone (mg/mg). This is in agreement with previous experiments conducted by Little (1972), Little and McMeniman (1973), De Waal (1979) and Read *et al*. (1986a, c). Judkins *et al*. (1982) also found that phosphorus in dry 12^{th} rib bone samples was not indicative of phosphorus status, but when phosphorus was expressed as mgP/cm^3 fresh bone, it did prove to be a sensitive indicator of phosphorus status.

De Waal *et al*. (1997) and Read *et al*. (1986c) took biopsies on the same rib, on the same side, at a specific sampling occasion. Comparisons between treatments are therefore valid between treatments for a specific sampling occasion, and not necessarily between different occasions. This is because the degree of mineralization of one rib may differ from that of another (Little & Minson, 1977). Little (1984) also suggested that in living cattle, a compact rib bone thickness of 3mm from bone biopsy samples of the 12th rib were indicative of a phosphorus adequate diet. Bortolussi *et al*. (1996) however reported a compact rib bone thickness of only 2.4mm in phosphorus-supplemented steers while phosphorus deficient steers had a rib bone thickness of less than 2mm. This difference could possibly be explained by an experiment done by Winter (1988), who reported that younger animals have thinner bones than older animals, suggesting that the animals in the trial conducted by Little (1984) may have been older than the animals in the Bortolussi *et al*. (1996) trial (Karn, 2000). Little (1984) suggested that a 5% concentration in the total fresh ribs of slaughtered cattle is an indicator of adequate phosphorus reserves. Little (1972) proposed a threshold deficiency of 120mgP/cm3 of fresh bone, below which deficiency symptoms would occur. An acceptable level would be 140-150mgP/cm^3 fresh bone. Read *et al*. (1986c) reported that at Armoedsvlakte in the North West Province, severely phosphorus deficient cows showed rib bone levels of less than 100mgP/cm^3.

De Waal *et al*. (1997) found that bone phosphorus more accurately reflects the animal's mineral reserves than blood plasma phosphorus levels. These results support those of Moir (1966) and Read *et al*. (1986c, d). However Hoey *et al*. (1982) showed that age, physiological state, protein and energy intake, calcium deficiency status, rib bone sampled, rib biopsy position and length of time from last sampling can all affect phosphorus levels of rib bone. Therefore, levels of phosphorus in rib bones should not be considered alone and should be evaluated along with other criteria to be considered a sensitive guide to the animal's phosphorus status (Karn, 2000).

Specific gravity of bone can also be used as a status indicator. Bone density seems to follow the same trends as individual bone minerals, with a loss of minerals leading to an increased bone porosity, which is reflected in a reduced specific gravity (de Waal *et al*., 1997). Shupe *et al*. (1988) found that cows on a phosphorus adequate diet had a higher bone specific gravity than those on a phosphorus deficient diet. Specific gravity of bone is however, not as sensitive an indicator of mineral status as single mineral is. It also does not supply information about the bone reserves of a specific mineral (De Waal *et al*., 1997). It has been shown to provide conclusive evidence of a phosphorus deficiency in an experiment conducted at Armoedsvlakte in the Northern Cape. There Read *et al*. (1986c) suggested that in severe cases of phosphorus deficiency, specific gravity of bone could be as conclusive of phosphorus deficiency as phosphorus content of bone.

2.5.2 Mineral levels in blood plasma

In Karn (2000) it is suggested that the use of serum phosphorus or inorganic plasma as an indicator of phosphorus status has shown mixed results, with some indicating it is of little value. De Waal *et al*. (1997) found that, in agreement with Moir (1966) and Read *et al*. (1986d), plasma phosphorus levels did however reflect the animal's dietary phosphorus intake.

Read *et al*. (1986d) found that plasma phosphorus levels above 40mgP/l were of little value in determining an animal's phosphorus level. A phosphorus deficiency can then be indicated by a level below 20mgP/l. De Waal *et al*. (1997) found that as the level of phosphorus supplementation increased, there was a clear trend for plasma phosphorus levels to increase. Milk production requires a high level of phosphorus, and plasma phosphorus levels tend to be low at this time (Ternouth & Coates 1997). This is in agreement with De Waal *et al*. (1997), who found that at any given sampling time, the average plasma inorganic phosphorus levels were lower for pregnant and lactating cows than non-pregnant or dry cows. Read *et al*. (1986d) also showed that one has to be careful when handling whole blood samples, as erythrocytes contain high concentrations of organically bound phosphorus, which may cause an increase in plasma inorganic phosphorus.

Factors such as length of time on a phosphorus deficient diet, age, and stage of production, all have an effect on an animal's phosphorus status, and therefore have an effect on blood phosphorus levels. Therefore blood may have more use as an indicator of dietary phosphorus levels rather than as an indicator of the animal's phosphorus status (Karn, 2000).

2.5.3 Phosphorus in rumen fluid, faeces and saliva

There are many factors, which affect the level of phosphorus in rumen fluid. These factors are, sampling site within the rumen, distribution effect depending on when the animal last drank water, the animal's ability to select parts of plants with a higher phosphorus concentration therefore affecting the composition of the digesta and also the extent to which the gut is filled (De Waal *et al*., 1997). Other influences are factors such as rainfall, which cause seasonal variation in phosphorus concentration of herbage, increased phosphorus circulation of plasma inorganic phosphorus to the rumen via saliva and the time elapsed since the animal's last phosphorus supplementation (de Waal *et al*., 1997). With all these influencing factors, inorganic phosphorus levels of rumen fluid can be used to distinguish between supplemented and unsupplemented animals, but it is not sensitive enough to distinguish between different levels of supplementation (De Waal 1997).

Cohen (1978) reported varying levels, 150-183mgP/l, of inorganic phosphorus in the rumen fluid. It has however, also been reported that concentrations of water-soluble phosphorus in rumen fluid do not fall below 200mgP/l, even when there is clinical phosphorus deficiency (Clark, 1953). It has also been shown that when animals on a phosphorus deficient diet are given phosphorus supplementation, it has no affect on digestion in the rumen (Cohen, 1975).

Moir (1966) showed that faecal levels below 0.2% phosphorus on a DM basis could indicate a phosphorus deficiency low enough to produce deficiency symptoms. Other studies have shown that faecal levels of phosphorus have a varied response to supplementation and therefore should not be used alone as a status indicator (Karn, 2000). Read *et al*. (1986d) found that at Armoedsvlakte, faecal phosphorus was not at all sensitive to phosphorus supplementation. This was especially true when dry matter intake was depressed by the phosphorus deficiency. Faecal phosphorus levels are probably a better indicator of dietary phosphorus concentration than the animal's phosphorus status (Karn, 2000).

Varying results have been obtained using saliva phosphorus as a status indicator. Gartner *et al*. (1982) found that blood inorganic phosphorus was a better indicator of the animal's phosphorus status. It has also been reported that phosphorus concentration in saliva varies in response to the amount of saliva secreted daily, and therefore might not be a good indicator of phosphorus status (Loxton *et al*., 1983). Added to this, Challa *et al*. (1988) and Challa *et al*. (1989) showed that even on a phosphorus deficient diet, animals must maintain a certain rate of salivary phosphorus secretion. Therefore, especially at low phosphorus intakes, when animals have an obligatory salivary phosphorus level, salivary phosphorus is an unreliable phosphorus status indicator (Karn, 2000).

2.6 PHOSPHORUS SUPPLEMENTATION IN GRAZING CATTLE

Parent material low in phosphorus is the source of many of the world's soils (Cohen, 1980). These soils support early maturing, grass dominant pastures with a lengthy period of senescence and a short summer growth period. Such pastures are common in Africa, America and Australia (Cohen, 1980). The phosphorus content of these grasses may reach levels as low as 0.2gP/kg organic matter (Robinson & Sagemen, 1967). In South Africa it was found that as grasses mature, their phosphorus content drops from 0.13-0.18% in the summer to 0.05-0.07% in the winter (Underwood, 1981). Other factors also influence the phosphorus contents of plants. These factors include, the phosphorus content of soil, as well as the effect of drought, with the degree and length of the drought playing a part (Underwood, 1981). Animals are able to mobilise phosphorus reserves from their skeleton, but this only temporarily stops a deficiency from occurring, which is why the length of a drought is so important. It would therefore appear to be beneficial to provide phosphorus supplementation to grazing cattle. Experiments have however, shown mixed results.

It is regarded good practice to give grazing cattle phosphorus supplementation with the belief that it improves growth, reproduction and milk production. Cohen (1976) however, indicated that cows grazing on a low phosphorus pasture showed no improvement in live weight, weight of calves or fertility when given a phosphorus supplement. The number of cows in this experiment was however small, so a further experiment was done with similar results, except calf weaning weights were slightly higher following supplementation of the cows (84kg vs. 95kg respectively). This however was attributed to a stimulation of milk production due to the presence of nitrogen and crude protein in the supplement (Cohen, 1976). In another case using Hereford heifers, no differences were found in terms of growth, intake or the age at which puberty was reached between a group fed 66% of the NRC recommended phosphorus levels and a group fed 174% of the recommended levels (Call *et al*., 1978). Pregnancy percentages also did not vary much and after nine months blood serum levels and rib bone samples showed the same results for both groups. An experiment done in the Western Highveld region of South Africa showed no differences in calving and weaning percentages between phosphorus supplemented and unsupplemented groups (de Brouwer *et al*., 2000). Condition score in the summer was also similar, all cows gained in condition score, although the unsupplemented group did improve the least, resulting in a lower condition score than the supplemented group in autumn.

In America, Karn (1995b) reported that with Hereford and Hereford-Angus crossbred replacement heifers, weight gains were not affected by phosphorus supplementation. He also found that yearling steers grazing northern plains responded inconsistently to phosphorus (Karn, 1995a). These results are in agreement with the results of Cohen (1972), Leche (1977), Winks (1990) and McLean *et al*. (1990) who found that yearling steers in Australia, grazing on pasture low in phosphorus, did not respond to phosphorus supplementation in either the wet or dry season, as well as with Leche (1977) who obtained no response with steers in New Guinea. The reason reported for this was probably due to the fact that protein, and not phosphorus, was the first limiting factor. In other reports from Australia, Winks (1990) and McLean *et al*. (1990) found that weight in growing cattle was not affected by phosphorus supplementation. Ternouth (1990) proposed that the reason for lack of response to phosphorus supplementation be due to skeletal reabsorption of phosphorus as well as gastro-intestinal recycling of phosphorus. This allows the animal to go for months before experiencing a phosphorus deficiency. There also seems to be no effect on milk phosphorus concentration. It has been found that even in severely phosphorus deficient cows, there was little difference in the phosphorus concentration of milk between the milk of phosphorus deficient cows and the milk of cows without a phosphorus deficiency (Theiler *et al*., 1927; Read *et al*., 1986a).

Cohen (1978) conducted a five-year experiment where heifers were allowed to graze on fertilized pasture from the age of 6-7 months till a year later when oestrus was detected. There was a significant, but small, increase in growth and oestrus of the heifers on fertilized pastures compared to those on unfertilized pasture, but not as much as would have been expected. Cohen (1978) also recorded an increase in diet digestibility and digestible organic matter due to the fertilized pasture. According to Rees & Minson (1976) this could account for the increase in animal production. Cohen (1978) therefore concluded that the increased production was due more to a secondary effect rather then from an increase in phosphorus intake. This is in agreement with a number of other experiments such as Teleni *et al*. (1977) who came to the conclusion that phosphorus supplementation had only an indirect effect on reproduction. As well as Little (1972) and Gartner *et al*. (1982) who found that phosphorus supplementation increased the digestibility of the plant cell wall attributing to favourable conditions for rumen flora. At Armoedsvlakte, improvement of animals on phosphorus supplementation was attributed to an increase in feed intake (Read *et al*., 1986b).

In the United States, Black *et al*. (1943) found that heifers were 57kg heavier at 18 months of age when given phosphorus supplementation, and Karn (1995a) found immediate weight gain response when Simmentaler crossbred heifers where given phosphorus supplementation. Phosphorus supplementation had a positive effect in South Africa, where even young cattle were suffering from ‘styfsiekte’, by alleviating symptoms of aphosphorosis and increasing weight gains (Theiler *et al*., 1927). Coates (1995), Hendricksen and Punter (1990), McLean *et al*. (1990) and Coates (1996) found that if phosphorus supplement or fertilizer phosphorus was given to growing cattle during the wet season, weight gain was achieved. However, there have been cases where only fertilizer phosphorus and not phosphorus as a supplement has given a response (McLean *et al*., 1994). Cohen (1972) and McLean *et al*. (1990) suggested that the reason behind phosphorus supplementation in the wet season not showing a response in the dry season, even though forage phosphorus is lower, might be due to phosphorus not being the limiting factor. The real limiting factor could be another mineral, or even protein or energy. This is in agreement with Grant *et al*. (1996) who found that only when protein concentrations were correct, did phosphorus supplementation cause an increase in weight gains. Miller *et al*. (1990) however, found that even when phosphorus is not the limiting factor, it may still prove to be beneficial in alleviating the symptoms of aphosphorosis. Inconsistent results in response of growing cattle to phosphorus supplementation indicates that if phosphorus is not the first limiting factor, then animals may not respond to phosphorus supplementation, even in a phosphorus deficient situation (Karn, 2000). Results have shown that phosphorus supplementation may result in no response, may improve weight gains and can even result in weight loss depending on other nutrients availability, on the animal’s phosphorus status and on whether phosphorus is the first or second limiting factor (Karn, 2000).

Black *et al*. (1943) found that both calving percentage and calf weaning weights improved with phosphorus supplementation. He also found that both phosphorus fertilization and supplementation improved both dietary phosphorus levels and the animal’s production performance (Black *et al*., 1949). Karn (1997) also found an increase in calf weaning weights after phosphorus supplementation was provided. Judkins *et al*., (1985) found however, that grazing cattle only responded to phosphorus supplementation during drought. Studies in South Africa have shown that phosphorus supplementation improves herd reproduction. Early studies showed a significant improvement in fertility (Theiler *et al*., 1924; Du Toit and Bisschop, 1929). Read *et al*. (1986b) found varying results. Phosphorus supplementation caused no response in cow or calf performance at Glen, but at Armoedsvlakte there was an increase in cow weights, reproductive performance, calving percentage and calf weaning weights. Read *et al*., (1986b) also noted that the phosphorus deficiency at Armoedsvlakte had caused a decrease in feed intake, and that this was probably the primary reason for their poor production state. These results were reinforced by De Waal *et al*. (1996) who found the same response, but with no increase in weaning weights. An increase in milk production has also been recorded for cows grazing phosphorus fertilized pastures (Davison *et al*., 1997; Walker *et al*., 1997). Davison *et al*. (1997) attributed this to an increase in feed intake as well as an increase in forage production. Research shows that phosphorus supplementation does indeed improve milk production in phosphorus deficient cows, but there is still confusion around whether this is due to the increase in the actual mineral, or due to the secondary effect of increased feed intake (Karn, 2000).

It has been said that sub-clinical phosphorus deficiencies are more important than acute deficiencies as they are difficult to quantify and cause a decrease in production, leading to loss in income (Heard, 1971). In an experiment by Groenewald (1986), it was found that cows tend to calve only once every two years when phosphorus supplementation is not provided. De Brouwer *et al*. (2000) had to terminate one winter trial, as the cows that were not receiving phosphorus supplementation were in such poor condition. This occurred even though there had been a good rainfall season resulting in ample roughage being available to the animals in this group. Supplementation is obviously beneficial in such areas. De Brouwer *et al*. (2000) also had results agreeing with Read *et al*. (1986b) and De Waal *et al*. (1996) in that cows on phosphorus supplementation gained more weight than the unsupplemented cows. De Brouwer *et al*. (2000) also noted a difference in condition score. Both unsupplemented and phosphorus supplemented cows gained condition, but the unsupplemented group had a very small improvement compared to the supplemented group. It was also found that with decreasing levels of phosphorus supplementation there was a tendency for lower weight gain in calves from birth to weaning (De Brouwer *et al*., 2000). In the same experiment, unsupplemented cows showed the greatest change in skeletal phosphorus reserves, and were not able to avoid a phosphorus deficiency during lactation. This even resulted in death for some animals due to complications associated with aphosphorosis. As soon as phosphorus supplementation was given to these animals their condition improved dramatically. In contradiction to Jacobs (1991), De Brouwer *et al*. (2000) suggested that cows receive supplementary phosphorus during the time when they are not lactating i.e. the winter months.

Karn (1997) found that during calving and lactation, control cows lost less weight than the phosphorus supplemented cows, but during the following gestation period, control cows gained less weight than supplemented cows. In a second study conducted by Karn (1997), the phosphorus supplemented cows gained more weight during their calving and lactation period and the following gestation period than did the unsupplemented cows. However the year after that, it was once again the control cows that gained more weight. There was also no effect on conception rate due to phosphorus supplementation. Both Call *et al*. (1978) and Fishwick *et al*. (1977) reported that long periods of phosphorus inadequacy had no effect on reproduction of grazing cows. Karn (1997) also had results agreeing with Fishwick *et al*. (1977) which showed that phosphorus supplemented cows did not return to oestrus quicker and therefore did not calve earlier than unsupplemented cows. Karn (1997) did however record higher weaning weights for calves from phosphorus supplemented cows. This was attributed to an increase in milk production from these cows, which is in agreement with the results of both Fishwick *et al*. (1977) and Read *et al*. (1986a).

Phosphorus supplementation as well as phosphorus fertilization has shown positive results in animal production, but for both results have been varying. Reasons for these results may be due to protein or energy being the first limiting factor or it may be due to the fact that phosphorus supplementation has an effect on feed intake (Karn, 2000).

2.7 SUMMARY OF PHOSPHORUS SUPPLEMENTATION

The importance of phosphorus has been highlighted and its role in many physiological processes in the animal body cannot be denied. It is therefore important to consider supplementation when a deficiency in the mineral is suspected. Experiments have shown varying results with regard to whether phosphorus supplementation is necessary or not, with phosphorus supplementation for bovines being less controversial than that of phosphorus supplementation in sheep, that tend to be more selective feeders. These varying results are largely due to the fact that the exact mechanisms of phosphorus homeostasis in ruminants are not known as well as varying results from the various phosphorus status indicators. Interactions of phosphorus with other nutrients also have to be taken into account. (Karn, 2000).

It has been shown that in areas that have a very small phosphorus deficiency, it is not always economical to provide phosphorus supplementation. In areas with a severe deficiency in phosphorus, it seems to be recommended for grazing ruminants, more so for bovines. In these deficient areas, phosphorus may not have a marked effect on growth and reproduction, but does seem to have a positive effect, even if it is indirect. This is due to phosphorus supplementation having a positive effect on feed intake, and therefore possibly having a positive effect on weight, as well as alleviating the symptoms of aphosphorosis. The symptoms of aphosphorosis are often not noticed straight away, and animals may be experiencing a decrease in feed intake and severe phosphorus reabsorption from the skeleton. This all leads to economic losses that are potentially not necessary. (Karn, 2000).

It is clear however, that more research needs to be done as far as phosphorus supplementation in grazing cattle is concerned. On a whole, more experiments, as well as longer experiments with more trial animals, need to be done in order to justify phosphorus supplementation in areas with small deficiencies. The benefits of phosphorus supplementation have however already been proved in areas of severe phosphorus deficiency.

CHAPTER 3: MATERIALS AND METHODS

The experiment can be divided into two phases consisting of three separate trials. Phase one involved the first two trials and consisted of one breed type on a predominantly *Combretum appiculatum* veld with a small portion of transitional veld made up of a mixture of *Terminalia sp.* and *A. tortilis*, while the third trial, which was part of phase two, consisted of four different breed types on a predominantly *Acacia tortilis veld*. The arrangement of these trials is summarised in Figure 1.

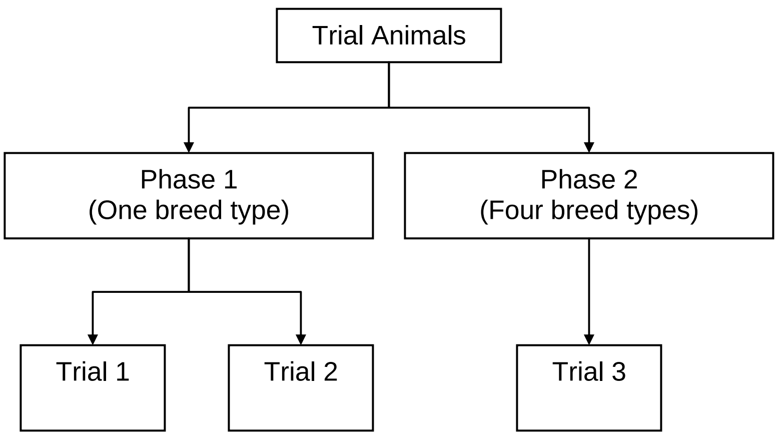


Figure 1: Arrangement of trials and experimental animals

3.1 PHASE 1: Effect of phosphorus supplementation in one breed type

3.1.1 Trial area

The first two trials were done on 2448ha of land on the western portion of the Mara Research Station. The Mara Research Station is situated in the arid sweet bushveld (Acocks, 1988) of the Limpopo Province (29° 25' E, 23° 05' S) and is 961m above sea level. The average minimum and maximum temperatures are 12.7 °C and 25.1 °C respectively. The long term average rainfall measured at Mara Research station over 48 years was 449.3mm per year of which 92.65% of that rain occurred in the months of October to April

(Lademann, 1992). During this trial, the mean annual rainfall was 480mm, ranging from 232mm to 846mm (Du Plessis *et al*., 2006). The veld type, which occurs in this area, is a transitional veld, with a mixture of *Terminalia sp.* and *Acacia tortilis* commonly occurring.

3.1.2 Trial animals and techniques

Two trials were carried out during this phase. Trial 1 took place from 1995 through to the end of 1997. Trial 2 took place from 1998 through to the end of 2002. A Bonsmara breeding herd was used. The age of the cows varied from 2 years to 13 years old. For Trial 1, the cows of the respective herds were block selected for age and weight and randomly allocated to one of four phosphorus supplementation groups, which received the following treatments: control group (C), phosphorus supplementation all year round (T1), phosphorus supplementation during the summer months (T2), and phosphorus supplementation in the summer months with a winter lick (T3). For Trial 2, the cows were selected in the same manner and randomly allocated to one of two groups: control group (C) and phosphorus supplementation all year round (T1).

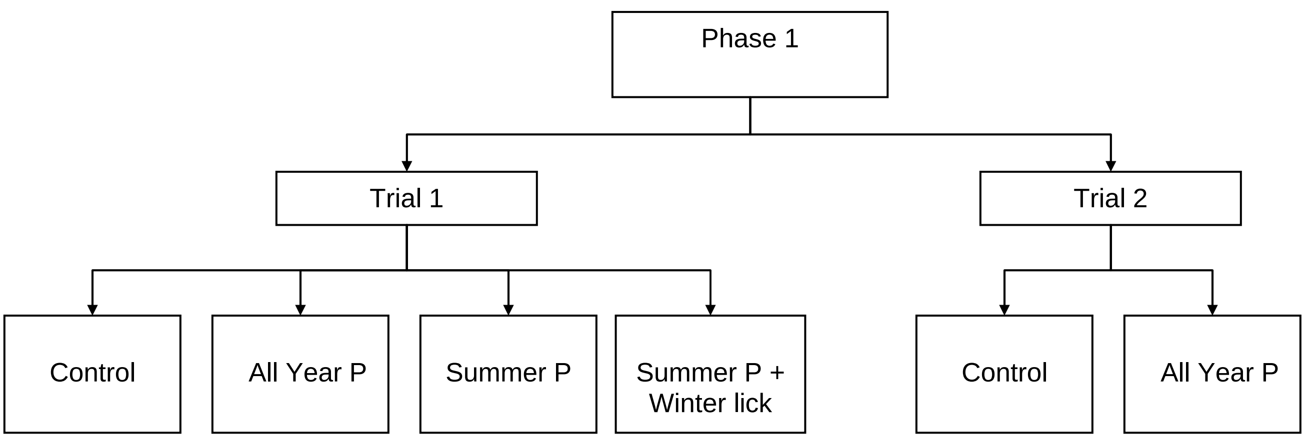


Figure 2: Experimental design for Phase 1 (P= phosphorus supplementation)

Treatment 1: This group, in both Trial 1 and Trial 2, received a phosphorus-salt (P-NaCl) supplement throughout the entire year. The phosphorus supplement, which was provided by Kynoch Feeds, was dicalciumphosphate. The supplement consisted of 140g calcium per kg and 80g phosphorus per kg after it had been mixed in a 1:1 ratio with salt. Various other micro-minerals such as magnesium, aluminium, fluoride, iron and manganese were also present in the supplement. An average intake of approximately 75g per animal per day was provided for.

Treatment 2: This group of Trial 1 received the above-mentioned P-NaCl-supplement during the summer months only. This group also received a winter lick during the first winter of the trial.

Treatment 3: The last treatment group of Trial 1 received the above-mentioned P-NaCl-supplement throughout the summer months, as well as a winter lick during the winter months. Kynoch Feeds provided veld-lick 50, which was composed of 500g protein per kg, 135g urea per kg, 80g per kg of other non-protein nitrogen, 40g calcium per kg and 20g phosphorus per kg. An intake of approximately 300g per animal per day was provided for.

The various supplements were provided roughly every two weeks in order to monitor intakes. All cows were kept together in the same camp to eliminate camp effects. Cows had continuous access to the supplements. Cows were weighed once a month. Birth weights of calves were recorded and calves were then weighed once a month up until weaning (between 195 and 200 days old). Calving interval (number of days between two consecutive calves) and the reproductive rate (total number of calves produced divided by the total number of years the cow was in the system for) of cows was calculated.

3.2 PHASE 2: Effect of phosphorus supplementation in four breed types

3.2.1 Trial area

Trial 3 took place on the eastern portion of the Mara Research Station (23° 05’ S, 29° 25’ E), which is also 961m above sea level. The Una official rainfall station, which is situated in this area, recorded an average of 423.4mm per year from 1945 to 2002, with the rainfall being concentrated in the summer months. This portion of the Mara Research Station is also situated in the arid sweet bushveld (Acocks, 1988) with the vegetation being comprised of a short, shrubby structure varying from open to closed woodland. The prominent woody species include*, Acacia tortilis, Commiphora pyracanthoides, Bosica albitrunca* and *Grewia* species, with the herbaceous layer including *Eragrostis rigidior, Panicum maximum, P. coloratum, Urochloa mosambicensis* and gramenoid and forbs species.

3.2.2 Trial animals and techniques

In Trial 3, cows representative of four different breed types were used. These were Afrikaner type, Simmentaler type (Simmentaler x Afrikaner x Simmentaler), Nguni type and a Bonsmara type (Afrikaner x Simmentaler x Bonsmara). The age of the cows varied from 2 to 13 years. The cows were block selected for age, weight and breed and randomly allocated to one of two dietary supplemented groups that received the following treatments: the first group served as a control group while the second group was fed a supplement of Kimtrafos 12 P all year round. Kimtrafos 12 P contains 75g phosphorus per kg of the mixture and no salt.

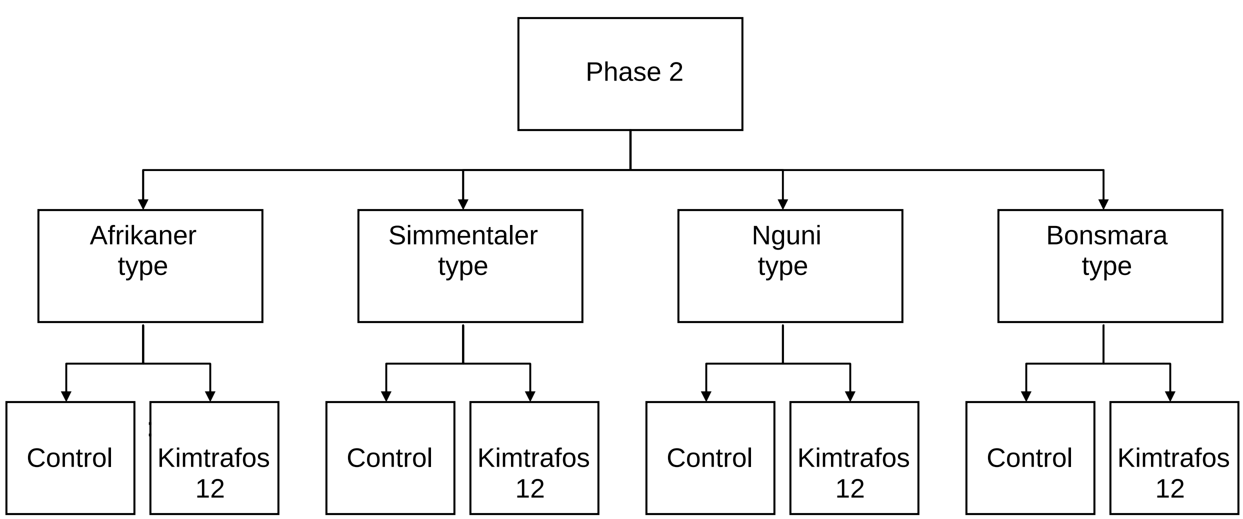


Figure 3: Experimental design for Phase 2 (P= phosphorus supplementation)

Cows grazed on adjacent camps to minimize camp effects and to allow the treatment group full access to the supplement. Calves were again weaned at 195 to 200 days old and removed from the herd. They were returned to the trial after two months. This trial took place from 1998 to 2002.

The data collected in both trials consisted of mass of cows and calves every 28 days, number of animals pregnant, number of calves born, number of calves weaned and birth weights and weaning weights of calves.

3.3 STATISTICAL ANALYSES

Data was captured in Microsoft Excel and double-checked before continuing with statistical analysis procedures. Statistical analyses included normal descriptive statistics such as means ± standard deviations (least square means, LSM), standard errors, frequency distributions and elimination of out layers. Cow weight was the first dependent variable used in the statistical analyses. Means and standard deviations for treatment, year and reproductive status were calculated on a monthly basis using ANOVA procedures. Scheffe's test was done for significance with $p \leq 0.05$ showing significance. This test controls the Type I experimentwise error rate, but it generally has a higher Type II error rate than Tukey's test for all pairwise comparisons. The General Linear Model (GLM) procedure of Least Squares Means (LSM) was also used to evaluate the significance of the interactions and to correct for unbalanced numbers of observations. Other dependant variables were treated in the same way. These included heifer weights, birth weights of calves, weaning weight of calves, weight gain of calves as well as breed. Where calving interval was concerned, the GLM procedure was used to compare the dependant variables of total numbers of calves and average calving interval against the number of years the cow was in the system for.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 PHASE 1

4.1.1 Cows

In this section the effects of various factors on the growth of cows were quantified in terms of weight of the cows.

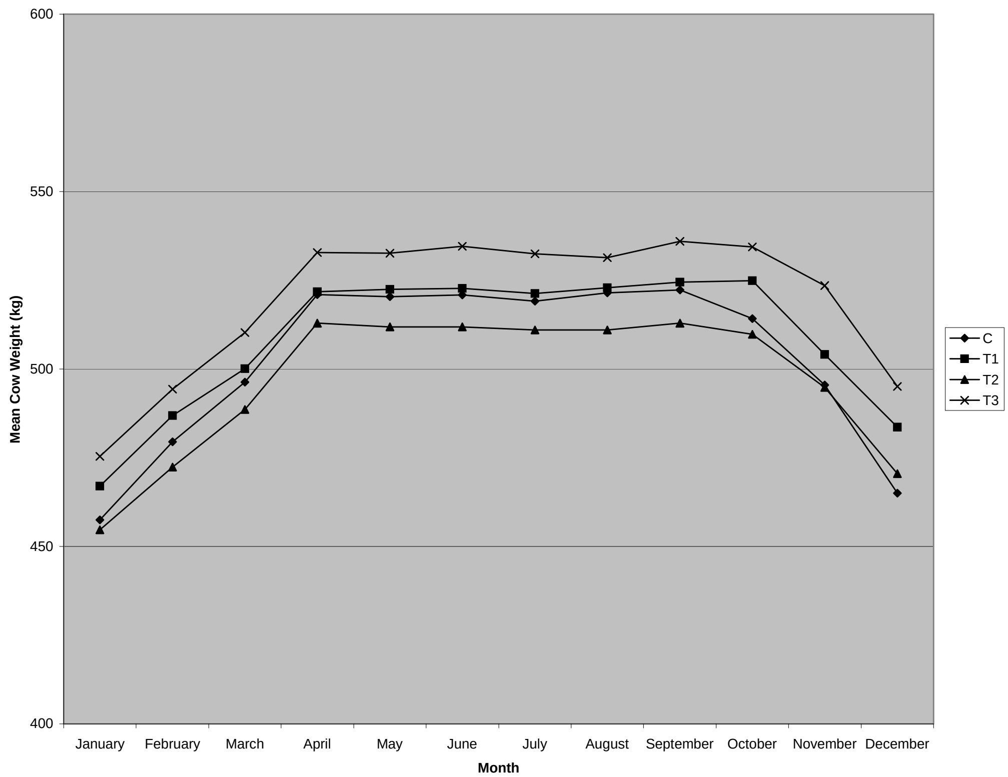
Table 1a: Trial 1- Summary statistics (mean ± std dev) for the effect of control diet and different dietary phosphorus supplementation treatments on cow weights (kg)

Month	C	T1	T2	T3
n= 149	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**
January	457.5 ± 65.3	467.0 ± 82.3	454.7 ± 72.1	475.4 ± 75.8
February	479.5 ± 77.7	486.9 ± 92.4	472.4 ± 81.6	494.3 ± 81.1
March	496.3 ± 69.2	500.1 ± 87.4	488.6 ± 72.9	510.3 ± 73.6
April	521.0 ± 71.2	521.8 ± 88.6	512.9 ± 73.8	532.8 ± 73.1
May	520.4 ± 70.5	522.5 ± 86.5	511.9 ± 75.7	532.6 ± 71.1
June	520.9 ± 67.1	522.7 ± 81.9	511.9 ± 74.0	534.6 ± 68.1
July	519.1 ± 60.9	521.3 ± 73.6	511.0 ± 66.2	532.5 ± 60.4
August	521.5 ± 55.1	522.9 ± 70.6	511.0 ± 68.3	531.4 ± 57.2
September	522.3 ± 53.0	524.5 ± 67.3	512.9 ± 65.6	536.0 ± 56.8
October	514.2 ± 49.5	524.9 ± 64.6	509.8 ± 63.2	534.4 ± 54.5
November	495.5 ± 55.7	504.1 ± 65.1	494.8 ± 62.7	523.5 ± 55.1
December	465.0 ± 54.3	483.6 ± 63.1	470.5 ± 62.0	495.1 ± 55.2
Average	**502.8 ± 62.5**	**508.5 ± 77.0**	**496.9 ± 69.8**	**519.4 ± 65.2**

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 1b: Effect of treatments (ANOVA results) in different months on cow weights (for Table 1a)

Month	p value	F value
January	0.3367	1.13
February	0.3134	1.19
March	0.4419	0.90
April	0.6098	0.61
May	0.5635	0.68
June	0.4461	0.89
July	0.5662	0.68
August	0.5630	0.73
September	0.2994	1.23
October	0.0927	2.17
November	0.1466	1.81
December	0.1308	1.90



Graph 1: Trial 1- Effect of treatment and month on mean cow weights (kg)

Tables 1a and 1b (and Graph 1) show that there was no significant difference between any of the groups, treatments or control. There was however a tendency towards significance in the month of October. This lack of significance could be due to the smaller amount of trial animals and the fewer years that the trial ran for. A numerical difference can however be seen between the groups, with both T1 and T3 resulting in higher average cow weights over the months than the control group. The T2 group however had a lower average weight than all the other treatment groups and the control group.

The fact that the cows in the T1 and T3 groups on average weighed more than the control group cows (5.7 ± 14.5kg and 16.6 ± 2.7kg respectively) could be an indication that the cows that received phosphorus supplementation grew more, as well as maintained a better body condition score. Supplemented cows therefore maintained a better weight during lactation. The results suggest this as treatment is the only factor that differs between the groups, with other factors like veld type and climate being the same for all four groups. These results agree with De Brouwer *et al* (2000), Read *et al* (1986b) and De Waal (1996) who all found that cows on phosphorus supplementation gained more weight than unsupplemented cows. It is also important to note that cows in the T3 group (phosphorus supplementation in the summer months and winter lick in the winter months) performed better than those in T1 group (phosphorus supplementation all year round). This could be attributed to the fact that the T3 group received protein in the winter lick. This finding is in agreement with Benzie *et al*. (1960) and Sykes *et al*. (1973) who both showed that if there are energy and protein deficiencies, bone mineralization may be restricted even though phosphorus intake is adequate. Cohen (1975) also recommended that a protein supplement be given for there to be any significant response to phosphorus supplementation. This was especially true during the months of calving and lactation, showing that the supplemented animals maintained a better body condition score. The numerical difference between the T1 and T3 groups compared to the control group can especially be seen in the months of calving (October, November and December) with the mean weights differing to a greater degree than during the rest of the year. This is in agreement with the findings of De Brouwer *et al*. (2000) that both supplemented and unsupplemented cows gained condition score but more so the cows receiving phosphorus supplementation.

Phosphorous supplementation is generally not required during the winter months in South Africa. Supplementation is usually needed during the rainy months of October through to March. The T2 group performed slightly worse than the control group (496.9 ± 69.8 and 502.8 ± 62.5 respectively). This difference however was very small and when considering the months of October, November and December the difference between the two groups was even smaller, with the T2 group weighing more than the control group in December. This difference could again be attributed to the T3 group receiving protein in the winter lick.

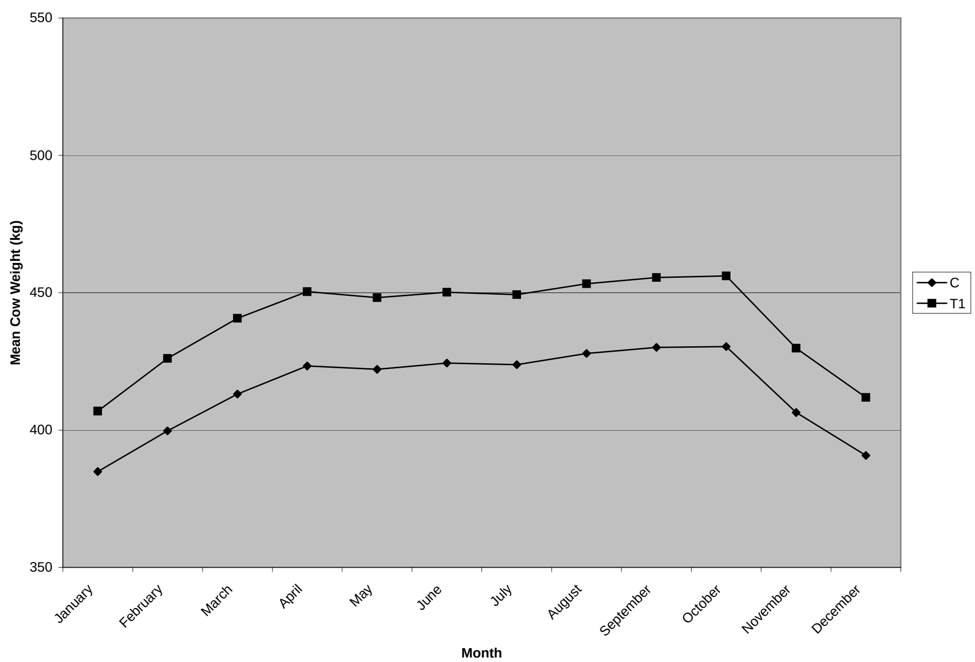
Table 2a: Trial 2 - Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on cow weights (kg)

Month	C	T1
n=157	**Mean ± Std Dev**	**Mean ± Std Dev**
January	384.9 ± 92.7 [a]	406.9 ± 92.2 [b]
February	399.7 ± 90.7 [a]	426.1 ± 91.1 [b]
March	413.1 ± 90.3 [a]	440.7 ± 90.6 [b]
April	423.3 ± 90.2 [a]	450.4 ± 89.9 [b]
May	422.1 ± 88.4 [a]	448.2 ± 88.6 [b]
June	424.4 ± 88.7 [a]	450.2 ± 87.9 [b]
July	423.8 ± 90.0 [a]	449.3 ± 88.8 [b]
August	427.9 ± 90.5 [a]	453.3 ± 90.4 [b]
September	430.1 ± 90.3 [a]	455.5 ± 89.3 [b]
October	430.4 ± 90.6 [a]	456.1 ± 88.9 [b]
November	406.4 ± 85.3 [a]	429.8 ± 82.7 [b]
December	390.7 ± 72.8 [a]	411.9 ± 67.5 [b]
Average	**414.7 ± 88.4**	**439.9 ± 87.3**

[a, b, c] Row means with different superscripts differ ($p < 0.001$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 2b: Effect of treatments (ANOVA results) in different months on cow weights (for Table 2a)

Month	p value	F value
January	0.0034	8.67
February	0.0003	13.2
March	0.0001	15.2
April	0.0001	14.69
May	<0.0001	17.69
June	0.0006	12.07
July	0.0004	12.87
August	0.0008	11.36
September	0.0005	12.26
October	0.0003	13.02
November	0.0005	12.27
December	0.0003	13.51



Graph 2: Trial 2- Effect of treatment and month on mean cow weights (kg)

In Tables 2a and 2b (and Graph 2) it can be seen that there was a significant difference between weights of the control group and the T1 (phosphorus supplementation all year round) group of cows. The phosphorus supplemented group performed better than the control group did. This means that on average the cows that received phosphorus supplementation weighed about 25kg more than the unsupplemented cows. This weight difference was fairly constant throughout the year and is in agreement with the results of De Brouwer *et al* (2000), Read *et al* (1986b) and De Waal (1996) who all, reported that cows receiving phosphorus supplementation gained more weight than cows that received no supplementation. This weight gain was particularly important during the months of calving and lactation, allowing the cows to maintain a better body condition score and therefore hopefully increasing their chances of conceiving again. The reason that treatment was significant in this trial as opposed to the first trial could be attributed to the fact that there were more trial animals over a longer trial period. Trial animals were also more homogenous in Trial 2, resulting in lower standard deviations between treatment groups in Trial 2 compared to Trial 1.

It is important to note that cow weight was also influenced by seasonal differences. It can be seen in both Table 1a (as well as Graph 1) and Table 2a (as well as Graph 2) that the average cow weight increased from January to April, which can be explained by the availability of good summer pasture. Cow weight then tended to level off or even declined marginally during the months of April to September which was due to the winter months providing a pasture of lesser quality. Weight increased slowly from September to October, which can be explained by an increase in the weight of the fetus. The sudden weight loss from October to December can be attributed to the fact that these months coincided with the calving season. Cows not only calved, but were also lactating during these months.

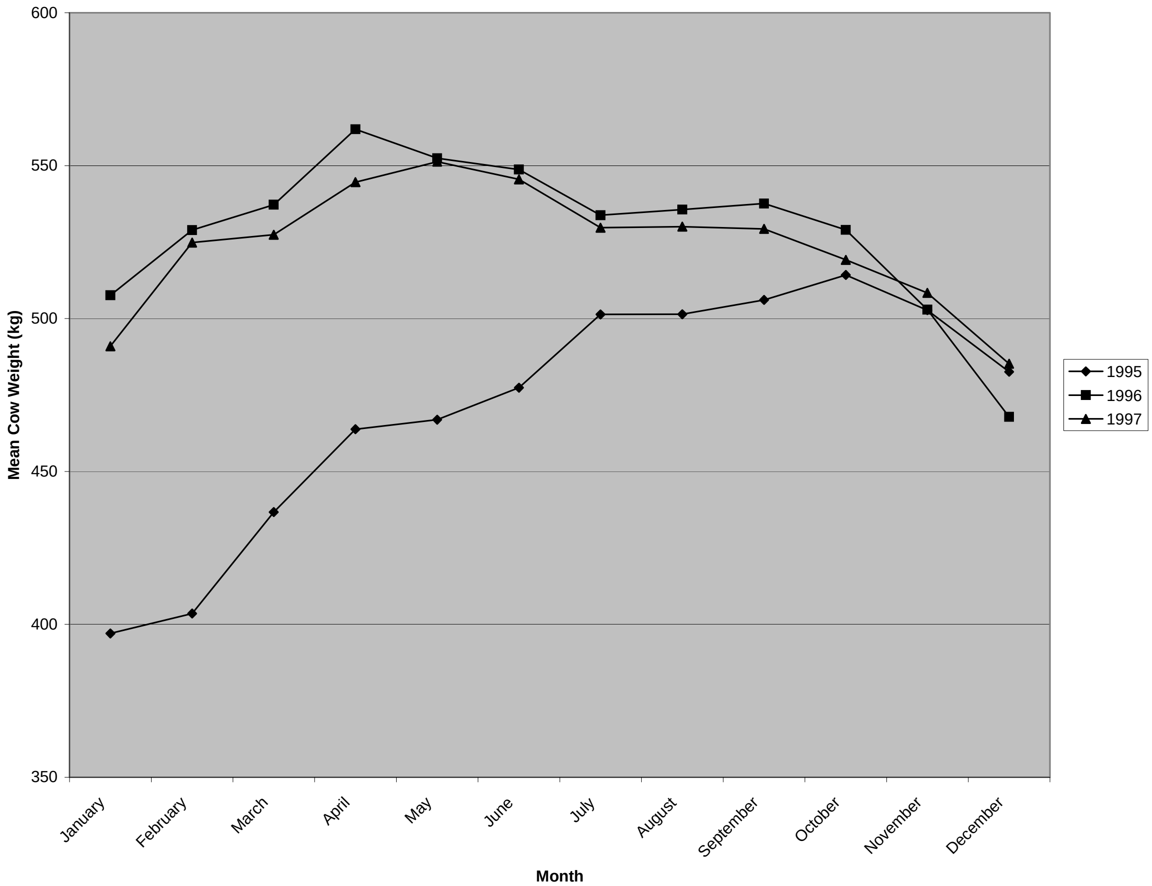
Table 3a: Trial 1- Summary statistics (mean ± std dev) for the effect of year of the trial on cow weights (kg)

Month	Year		
n= 149	1995	1996	1997
	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	397.0 ± 48.4 ^{A}	507.6 ± 58.5 ^{B}	490.9 ± 58.4 ^{B}
February	403.5 ± 49.3 ^{A}	528.9 ± 61.3 ^{B}	524.8 ± 65.8 ^{B}
March	436.7 ± 54.8 ^{A}	537.2 ± 64.3 ^{B}	527.4 ± 63.2 ^{B}
April	463.8 ± 61.6 ^{A}	561.9 ± 66.6 ^{B}	544.6 ± 62.4 ^{B}
May	466.9 ± 62.3 ^{A}	552.4 ± 67.6 ^{B}	551.3 ± 63.9 ^{B}
June	477.4 ± 64.1 ^{A}	548.7 ± 69.8 ^{B}	545.5 ± 60.5 ^{B}
July	501.3 ± 64.7 ^{a}	533.8 ± 67.6 ^{b}	529.7 ± 59.2 ^{b}
August	501.4 ± 62.3 ^{a}	535.6 ± 64.1 ^{b}	530.0 ± 57.1 ^{b}
September	506.1 ± 60.0 ^{a}	537.6 ± 61.9 ^{b}	529.3 ± 56.7 ^{ab}
October	514.2 ± 61.1	529.0 ± 59.3	519.2 ± 54.0
November	502.7 ± 64.6	502.9 ± 60.7	508.4 ± 55.8
December	482.6 ± 65.3	467.8 ± 60.6	485.2 ± 49.0
Average	**471.1 ± 59.9**	**528.6 ± 63.5**	**523.9 ± 58.8**

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
$^{A, B, C}$ Row means with different superscripts differ ($P < 0.001$)

Table 3b: Effect of year (ANOVA results) in different months on cow weights (for Table 3a)

Month	p value	F value
January	<0.0001	30.6
February	<0.0001	28.58
March	<0.0001	33.45
April	<0.0001	35.26
May	<0.0001	30.76
June	<0.0001	22.15
July	0.0169	4.17
August	0.0040	5.70
September	0.0063	5.21
October	0.4235	0.86
November	0.3168	1.16
December	0.4655	0.77



Graph 3: Trial 1- Effect of year and month on mean cow weights (kg)

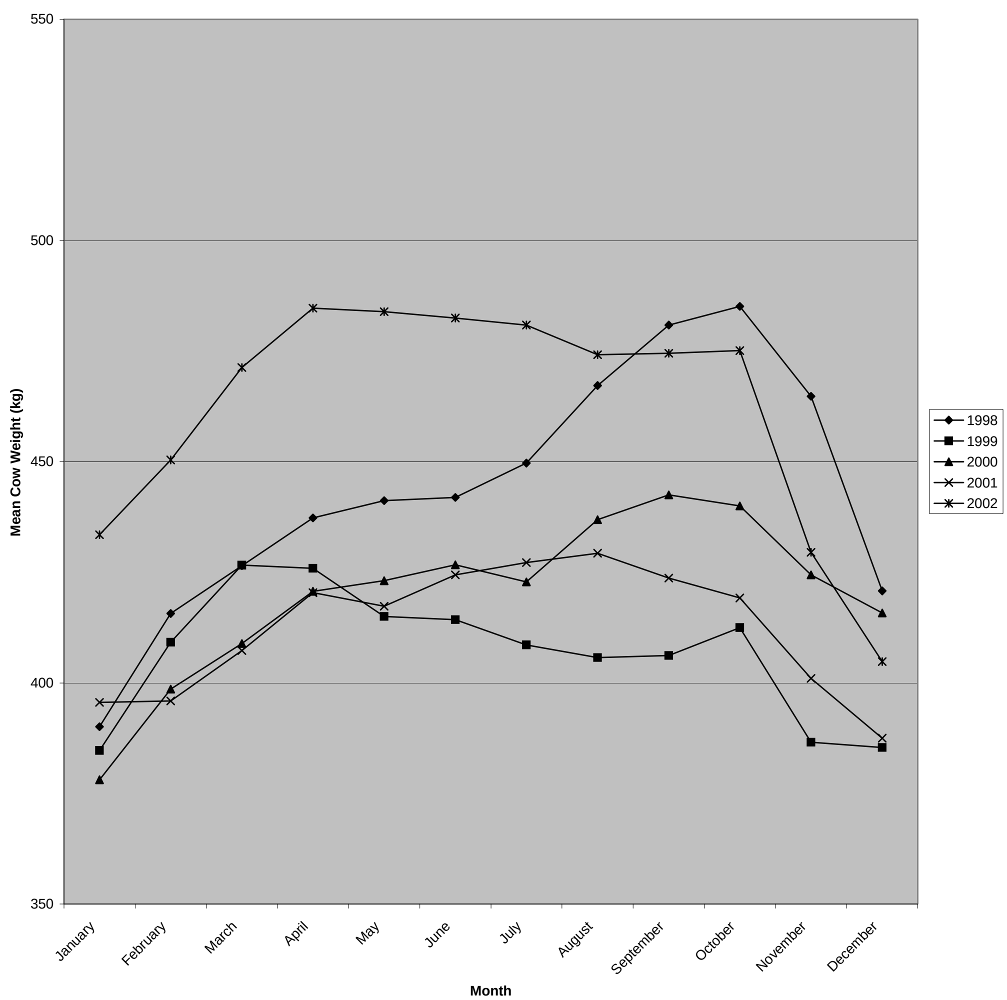
Table 4a: Trial 2- Summary statistics (mean ± std dev) for the effect of year of the trial on cow weights (kg)

Month	Year				
n= 157	**1998**	**1999**	**2000**	**2001**	**2002**
	Mean ± Std Dev	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**
January	390.1 ± 91.0 [a]	384.7 ± 105.8 [a]	378.1 ± 91.5 [a]	395.6 ± 93.5 [a]	433.5 ± 71.5 [b]
February	415.7 ± 93.5 [ab]	409.2 ± 102.3 [b]	398.6 ± 88.4 [b]	395.9 ± 90.6 [b]	450.4 ± 74.3 [a]
March	426.5 ± 90.7 [a]	426.6 ± 98.5 [a]	408.9 ± 87.9 [a]	407.3 ± 91.1 [a]	471.3 ± 73.7 [b]
April	437.3 ± 87.1 [a]	425.9 ± 98.7 [a]	420.7 ± 89.2 [a]	420.4 ± 87.0 [a]	484.7 ± 75.7 [b]
May	441.2 ± 87.3 [a]	415.0 ± 91.9 [a]	423.1 ± 86.9 [a]	417.3 ± 85.8 [a]	483.9 ± 76.8 [b]
June	441.9 ± 88.4 [a]	414.3 ± 89.0 [a]	426.7 ± 87.0 [a]	424.4 ± 88.8 [a]	482.5 ± 77.0 [b]
July	449.7 ± 87.3 [ab]	408.6 ± 87.3 [c]	422.8 ± 87.6 [bc]	427.2 ± 90.5 [bc]	480.9 ± 80.8 [a]
August	467.2 ± 87.4 [ab]	405.7 ± 86.2 [d]	436.9 ± 86.3 [bc]	429.3 ± 96.2 [cd]	474.2 ± 80.2 [a]
September	480.9 ± 88.4 [a]	406.2 ± 85.8 [c]	442.5 ± 87.0 [b]	423.7 ± 92.9 [bc]	474.5 ± 78.6 [a]
October	485.1 ± 89.1 [a]	412.5 ± 86.6 [b]	440.0 ± 88.6 [b]	419.2 ± 91.3 [b]	475.1 ± 76.5 [a]
November	464.8 ± 85.3 [a]	386.6 ± 79.1 [c]	424.4 ± 83.7 [b]	401.0 ± 87.4 [bc]	429.5 ± 70.7 [b]
December	420.8 ± 65.9 [a]	385.4 ± 68.7 [b]	415.8 ± 76.7 [a]	387.5 ± 71.7 [b]	404.8 ± 62.8 [ab]
Average	**443.4 ± 86.8**	**406.7 ± 90.0**	**419.9 ± 86.7**	**412.4 ± 88.9**	**462.1 ± 74.9**

[a, b, c] Row means with different superscripts differ ($p < 0.001$)

Table 4b: Effect of year (ANOVA results) in different months on cow weights (for Table 4a)

Month	p value	F value
January	<0.0001	10.42
February	<0.0001	8.38
March	<0.0001	10.63
April	<0.0001	12.38
May	<0.0001	16.26
June	<0.0001	11.26
July	<0.0001	11.65
August	<0.0001	9.68
September	<0.0001	11.87
October	<0.0001	11.36
November	<0.0001	9.40
December	0.0006	4.98



Graph 4: Trial 2- Effect of year and month on mean cow weights (kg)

As seen in Tables 3a, 3b and Tables 4a and 4b (as well as Graphs 3 and 4), the year of the trail had a significant influence on cow weight in both Trial 1 and Trial 2. In Trial 1 year effects were significant for cow weights during the months January through to September. Year effect was not however significant in October, November and December. The months of October through to December are important, as they are the last few months of pregnancy as well as being the months the cows calved down in. The lack of significance could therefore have been due to reproductive status having a stronger influence on weight than year effect did. Reproductive status did have a significant effect on cow weights during these three months with $p = 0.0027$, $p = 0.0004$ and $p < 0.0001$ respectively. This was expected, as a cow is usually heavier when she is pregnant than when she is not, and lactating cows tend to lose condition and therefore weight. In Trial 2 the year effect was significant throughout. In Trial 1 (Graph 3) it can be seen that the average weights in 1996 and 1997 were higher than in 1995. These 2 years produced cow weights that were roughly 55kg heavier than the ones in 1995.

Here any differences in cow weight will be due mostly to rainfall. Underwood (1981) showed that the length and degree of drought reduced the phosphorus contents of plants. In years with high rainfall, the grazing would be better and therefore animals would tend to take in less supplemental feeding. This would result in improved weights due to better and more available pasture but would also result in less of an effect due to supplementation. In years with poor rainfall, there would be less pasture available for grazing and live weights would drop, but intake of the supplemented animals would increase. The results suggest that this is what happened in these trials, as cow weights were higher for supplemented cows than unsupplemented cows (refer to Tables 1a and 2a).This is in agreement with Judkins *et al*. (1985) who found that grazing cattle only responded to phosphorus supplementation during drought. In years of extreme rainfall, weight may also be affected due to camps becoming muddy and flooded resulting in decreased feed intake.

In both the trials the seasonal effects were noted (Graph 3 and Graph 4), with weight gain in the late summer months, to a levelling off, or even slight decrease in weight in the winter months and a severe drop during the calving season.

Table 5a: Trial 1- Summary statistics (mean ± std dev) for the interaction between control diet, different dietary phosphorus supplementation treatments and the year of the trial on cow weights (kg)

Treatment	Month	Year		
n= 149		1995	1996	1997
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	January	389.4 ± 32.3	499.7 ± 48.7	485.0 ± 47.1
T1	January	397.8 ± 58.6	511.1 ± 72.1	493.5 ± 67.1
T2	January	398.2 ± 50.7	493.8 ± 58.3	481.6 ± 67.0
T3	January	402.9 ± 51.9	525.9 ± 51.6	502.3 ± 56.6
C	February	394.7 ± 35.0	525.3 ± 54.7	520.9 ± 53.8
T1	February	403.3 ± 60.4	531.1 ± 76.1	528.5 ± 76.2
T2	February	402.9 ± 53.4	515.0 ± 61.9	514.1 ± 73.3
T3	February	413.5 ± 47.5	544.4 ± 50.8	534.2 ± 65.4
C	March	429.3 ± 39.8	534.7 ± 57.7	526.5 ± 51.4
T1	March	431.9 ± 63.7	539.4 ± 80.5	530.6 ± 75.4
T2	March	439.6 ± 60.4	520.9 ± 64.5	514.5 ± 65.7
T3	March	446.6 ± 55.7	553.8 ± 51.6	534.6 ± 63.7
C	April	456.1 ± 48.1	562.0 ± 61.7	546.2 ± 51.5
T1	April	457.8 ± 70.6	564.8 ± 84.3	544.1 ± 73.9
T2	April	468.5 ± 66.4	544.8 ± 66.0	532.3 ± 66.5
T3	April	473.5 ± 62.8	575.6 ± 51.4	552.9 ± 61.6
C	May	459.2 ± 48.6	553.1 ± 63.9	550.6 ± 54.3
T1	May	461.7 ± 69.7	556.7 ± 84.3	550.9 ± 72.7
T2	May	470.9 ± 68.4	534.1 ± 69.9	540.9 ± 72.9
T3	May	476.5 ± 64.5	565.6 ± 48.8	560.7 ± 61.8
C	June	469.4 ± 53.1	550.8 ± 67.4	543.8 ± 47.5
T1	June	473.1 ± 71.3	552.8 ± 83.1	543.5 ± 69.1
T2	June	479.4 ± 70.6	530.6 ± 74.9	533.2 ± 65.3
T3	June	488.2 ± 64.2	560.3 ± 52.0	559.6 ± 63.5
C	July	493.1 ± 52.3	538.8 ± 72.9	527.1 ± 48.4
T1	July	498.6 ± 76.1	536.1 ± 74.4	529.7 ± 68.3
T2	July	502.4 ± 70.1	516.5 ± 70.2	515.9 ± 57.9
T3	July	511.8 ± 62.1	543.8 ± 53.5	543.9 ± 63.5
C	August	495.0 ± 50.4	541.1 ± 62.2	528.8 ± 42.4
T1	August	498.1 ± 69.0	542.8 ± 71.9	528.2 ± 67.0
T2	August	503.0 ± 72.4	515.3 ± 71.5	516.8 ± 61.5
T3	August	510.0 ± 60.1	542.4 ± 49.1	543.9 ± 59.2
C	September	498.3 ± 48.1	542.5 ± 58.9	526.2 ± 43.2
T1	September	504.4 ± 68.5	541.7 ± 67.6	527.6 ± 64.1
T2	September	505.9 ± 65.5	519.4 ± 68.2	513.6 ± 66.9
T3	September	516.5 ± 59.9	546.2 ± 53.4	547.5 ± 54.5

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 5a (continued): Trial 1- Summary statistics (mean ± std dev) for the interaction between control diet, different dietary phosphorus supplementation treatments and the year of the trial on cow weights (kg)

Treatment	Month	Year		
N=149		1995	1996	1997
		Mean ± Std Dev	**Mean ± Std Dev**	**Mean ± Std Dev**
C	October	498.1 ± 46.0	528.1 ± 57.2	516.5 ± 41.6
T1	October	514.4 ± 70.9	538.3 ± 62.4	521.8 ± 61.3
T2	October	512.6 ± 64.4	510.0 ± 64.8	505.0 ± 64.7
T3	October	532.6 ± 61.1	539.1 ± 52.8	530.7 ± 51.8
C	November	479.7 ± 51.8	495.6 ± 64.0	513.1 ± 47.4
T1	November	506.7 ± 77.3	508.3 ± 57.6	496.8 ± 62.0
T2	November	493.2 ± 65.1	496.9 ± 60.9	494.1 ± 67.6
T3	November	532.4 ± 53.8	510.6 ± 64.0	528.6 ± 44.9
C	December	465.8 ± 65.6	460.3 ± 56.9	469.6 ± 35.0
T1	December	497.2 ± 72.2	467.4 ± 65.1	485.3 ± 49.4
T2	December	469.1 ± 64.6	462.1 ± 66.1	481.8 ± 57.4
T3	December	498.2 ± 55.5	482.5 ± 58.6	504.6 ± 52.9

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 5b: Effect of the interaction (ANOVA results) between treatment and year in different months on cow weights (for Table 5a)

Month	p value	F value
January	0.9911	0.14
February	0.9967	0.10
March	0.9938	0.12
April	0.9919	0.13
May	0.9884	0.15
June	0.9917	0.13
July	0.9917	0.13
August	0.9833	0.17
September	0.9815	0.18
October	0.9690	0.22
November	0.9172	0.34
December	0.9928	0.13

Table 6a: Trial 2- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and the year of the trial on cow weights (kg)

Treatment	Month	Year				
n= 157		1998	1999	2000	2001	2002
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	January	382.1 ± 99.5	382.5 ± 107.1	365.9 ± 92.2	379.9 ± 88.9	418.0 ± 68.5
T1	January	398.3 ± 81.9	386.9 ± 105.6	386.8 ± 89.9	408.8 ± 9.8	446.6 ± 71.9
C	February	404.2 ± 99.6	403.2 ± 102.2	379.7 ± 85.9	380.9 ± 85.6	434.1 ± 72.7
T1	February	427.6 ± 86.5	415.0 ± 103.2	415.8 ± 87.9	408.3 ± 93.3	464.3 ± 73.4
C	March	414.3 ± 95.8	419.6 ± 98.5	390.8 ± 85.4	389.9 ± 86.8	454.7 ± 71.7
T1	March	438.9 ± 84.6	433.1 ± 98.9	425.2 ± 87.6	421.4 ± 92.7	485.2 ± 73.1
C	April	425.4 ± 94.2	417.8 ± 97.9	403.9 ± 87.8	402.8 ± 82.9	469.5 ± 74.2
T1	April	449.5 ± 78.6	433.5 ± 99.8	435.8 ± 88.5	434.7 ± 88.2	497.4 ± 75.2
C	May	430.7 ± 95.6	405.3 ± 91.5	407.2 ± 86.4	402.4 ± 79.3	469.3 ± 74.3
T1	May	452.0 ± 77.8	424.2 ± 92.1	437.5 ± 85.5	430.2 ± 89.7	496.1 ± 77.1
C	June	431.7 ± 97.1	405.2 ± 89.7	411.0 ± 88.2	407.8 ± 80.1	469.7 ± 75.9
T1	June	452.3 ± 78.4	423.0 ± 88.2	441.1 ± 84.0	438.8 ± 94.0	493.3 ± 76.9
C	July	439.5 ± 95.6	397.4 ± 89.4	407.0 ± 90.3	412.3 ± 81.4	468.4 ± 78.6
T1	July	460.1 ± 77.8	419.3 ± 84.8	437.0 ± 83.2	439.9 ± 96.5	491.3 ± 81.8
C	August	457.9 ± 94.7	393.3 ± 87.4	420.4 ± 90.9	415.8 ± 88.0	460.8 ± 77.3
T1	August	476.6 ± 79.5	417.3 ± 84.2	451.8 ± 85.9	440.7 ± 102.0	485.3 ± 81.4
C	September	471.2 ± 95.3	394.1 ± 87.6	425.7 ± 87.5	409.2 ± 85.4	461.8 ± 77.2
T1	September	490.8 ± 80.9	417.7 ± 83.2	457.5 ± 84.5	436.1 ± 97.8	485.1 ± 78.8
C	October	476.4 ± 96.9	399.8 ± 88.0	423.4 ± 88.5	403.5 ± 84.6	461.8 ± 75.0
T1	October	494.1 ± 80.6	424.4 ± 84.4	455.1 ±86.7	432.7 ± 95.3	486.2 ± 76.5
C	November	460.4 ± 94.5	376.3 ± 80.1	409.3 ± 86.3	386.1 ± 81.1	413.7 ± 65.8
T1	November	469.3 ± 75.7	396.1 ± 77.6	438.0 ± 79.6	414.2 ± 91.2	442.9 ± 72.4
C	December	420.5 ± 74.4	371.7 ± 69.1	402.2 ± 80.1	373.8 ± 70.5	392.1 ± 60.4
T1	December	421.1 ± 56.8	397.8 ± 66.6	428.3 ± 71.8	399.5 ± 71.1	415.3 ± 63.4

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 6b: Effect of the interaction (ANOVA results) between treatment and year in different months on cow weights (for Table 6a)

Month	p value	F value
January	0.7536	0.48
February	0.5351	0.79
March	0.5232	0.80
April	0.5412	0.78
May	0.7011	0.55
June	0.7649	0.46
July	0.7898	0.43
August	0.7082	0.54
September	0.7254	0.51
October	0.7157	0.53
November	0.6566	0.61
December	0.8726	0.31

In Tables 5a, 5b, 6a and 6b it can be seen that the treatment-year interaction was not significant in either Trial 1 or 2. This shows that any differences between the treatment groups compared in the previous tables was due either to treatment effect or year effect and that no interaction complicated the result.

4.1.2 Heifers

In this section the effects of various factors on the growth of heifers were quantified in terms of weight of the heifers.

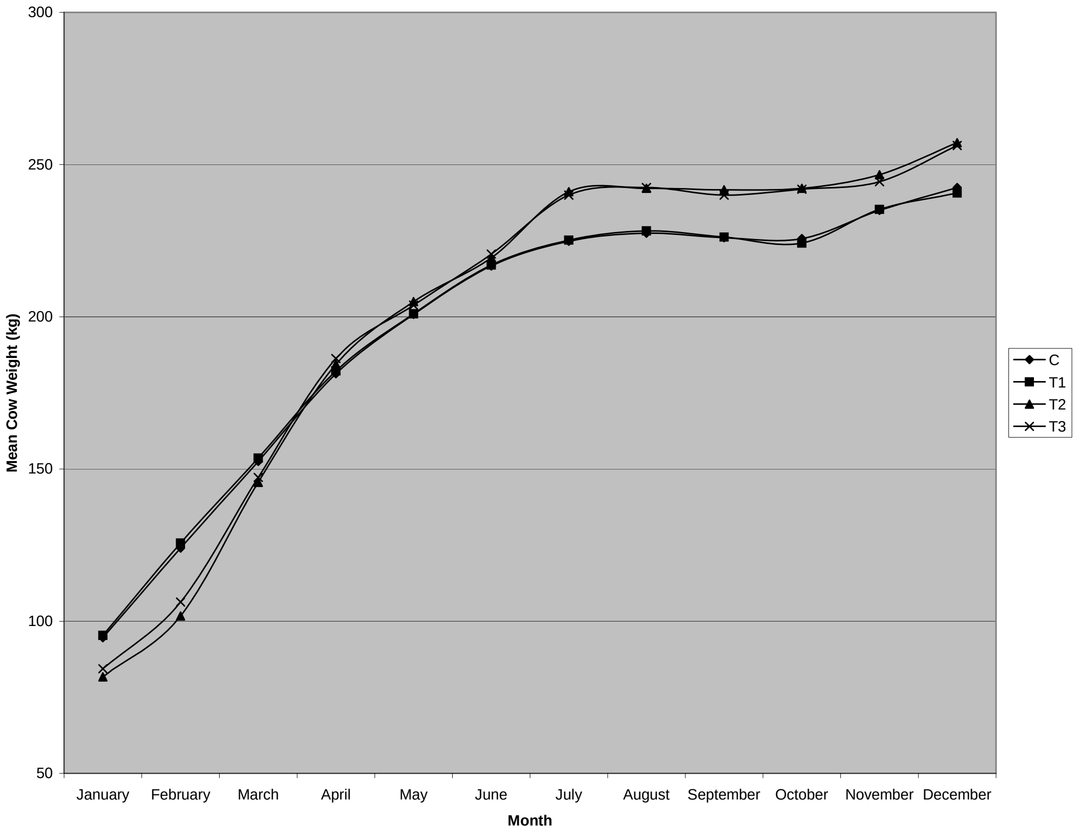
Table 7a: Trial 1- Summary statistics (mean ± std dev) for the effect of control diet and different dietary phosphorus supplementation treatments on heifer weights (kg)

Month	C	T1	T2	T3
n= 77	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**
January	94.6 ± 21.9	95.3 ± 22.4	81.7 ± 12.5	84.4 ± 14.5
February	124.0 ± 31.5	125.7 ± 30.2	101.7 ± 12.0	106.3 ± 16.6
March	152.5 ±28.2	153.6 ± 28.1	145.6 ± 14.0	147.2 ± 20.4
April	181.3 ± 27.8	182.2 ± 27.6	184.4 ± 17.0	186.3 ± 21.7
May	200.8 ± 28.4	201.0 ± 28.2	205.0 ± 13.5	203.8 ± 20.8
June	216.7 ± 30.4	217.0 ± 30.8	219.4 ± 15.1	220.6 ± 20.3
July	224.8 ± 28.2	225.2 ± 27.3	241.1 ± 17.3	240.0 ± 19.1
August	227.5 ± 29.2	228.2 ± 29.2	242.2 ± 16.0	242.5 ± 18.9
September	226.0 ± 27.4	226.2 ± 28.8	241.7 ± 16.0	240.0 ± 18.1
October	225.7 ± 29.4	224.2 ± 27.5	242.2 ± 19.1	241.9 ± 17.7
November	235.0 ± 30.1	235.3 ± 28.9	246.7 ± 20.5	244.4 ± 19.5
December	242.5 ± 28.2	240.7 ± 30.5	257.2 ± 21.4	256.3 ± 21.5
Average	**196.0 ± 28.4**	**196.2 ± 28.3**	**200.74 ± 16.2**	**201.1 ± 19.1**

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 7b: Effect of treatment (ANOVA results) in different months on heifer weights (for Table 7a)

Month	p value	F value
January	0.9653	0.09
February	0.9521	0.11
March	0.9703	0.08
April	0.9666	0.09
May	0.9868	0.05
June	0.9829	0.06
July	0.9926	0.03
August	0.9750	0.07
September	0.9859	0.05
October	0.9997	0.00
November	0.9982	0.01
December	0.9950	0.02



Graph 5: Trial 1- Effect of treatment and month on mean heifer weights (kg)

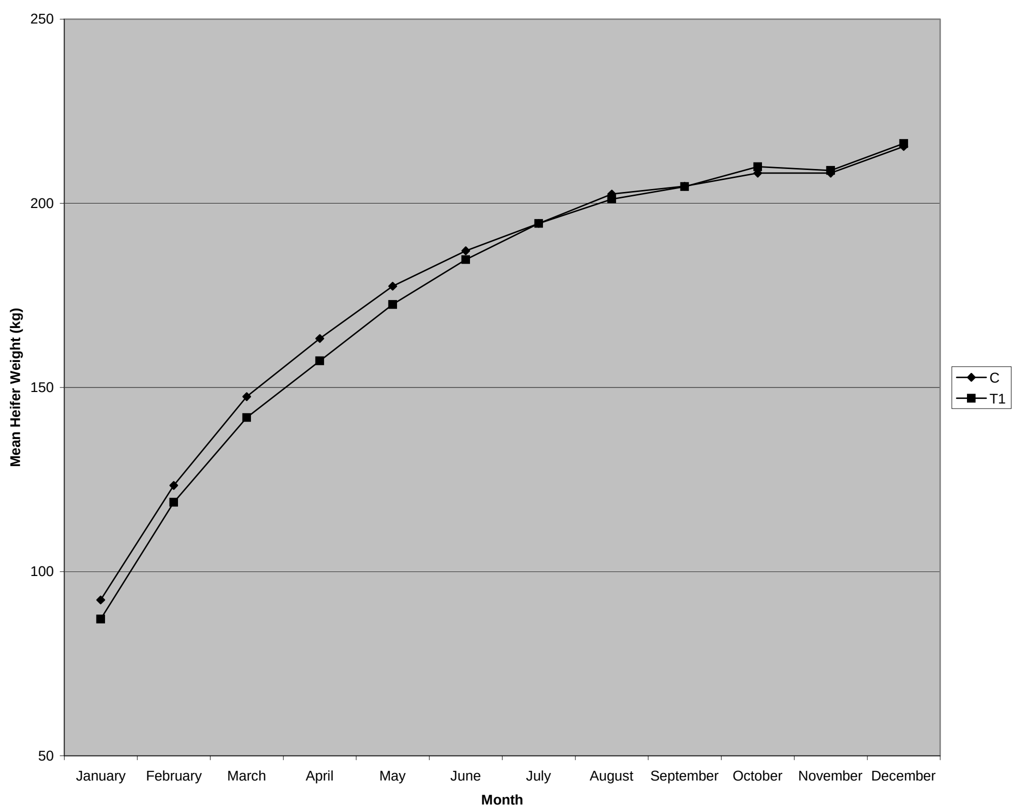
Table 8a: Trial 2- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on heifer weights (kg)

Month	C	T1
n= 77	Mean ± Std Dev	Mean ± Std Dev
January	92.3 ± 21.0	87.1 ± 21.5
February	123.4 ± 23.2	118.8 ± 20.4
March	147.5 ± 24.9	141.8 ± 23.0
April	163.3 ± 27.3	157.2 ± 26.9
May	177.5 ± 27.3	172.5 ± 27.3
June	187.1 ± 26.8	184.7 ± 28.5
July	194.5 ± 26.2	194.5 ± 28.1
August	202.5 ± 25.2	201.1 ± 26.4
September	204.6 ± 24.3	204.5 ± 26.3
October	208.2 ± 26.7	209.9 ± 26.1
November	208.2 ± 26.6	208.9 ± 25.8
December	215.4 ± 26.0	216.2 ± 26.4
Average	**177.0 ± 25.5**	**174.8 ± 25.6**

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 8b: Effect of treatment (ANOVA results) in different months on heifer weights (for Table 8a)

Month	p value	F value
January	0.2501	1.35
February	0.4557	0.56
March	0.2770	1.20
April	0.3499	0.89
May	0.4158	0.67
June	0.7120	0.14
July	0.9563	0.00
August	0.8189	0.05
September	0.9806	0.00
October	0.7839	0.08
November	0.9865	0.00
December	0.8323	0.05



Graph 6: Trial 2- Effect of treatment and month on mean heifer weights (kg)

In Tables 7a and 7b it can be seen that treatment had no significant effect on heifer weight. Numerical differences were however noted. When the average weight was calculated over the months the treatment groups showed a higher weight than the control group. These differences were however very small. In Trial 2 (Tables 8a and 8b) the control group showed bigger increases in weight than the phosphorus supplemented group, but these differences are also very small and even more so during the months of October to December. These results differ from Cohen (1978) who found that heifers had a small, but significant, increase in growth. These heifers did not however receive a lick but grazed fertilized pasture. The increase in growth was therefore concluded to be due to a secondary effect of an increased diet digestibility. McLean & Ternouth (1994) found that fertilizer phosphorus, and not phosphorus as a supplement, gave a positive response.

Karn (1995a), Winks (1990) and McLean *et al*. (1990) found that weight gain was not affected by supplementation in heifers. The lack of response was thought to be due to skeletal reabsorption and gastro-intestinal recycling of phosphorus. Another explanation could be that young animals are able to adjust their rate of bone deposition in response to nutritional changes, whereas older animals lose this ability, resulting in a higher phosphorus turnover on a low phosphorus diet (Braithwaite, 1975). Supplementation would therefore have little or no effect.

It can also be noted in Graph 5 and Graph 6 that the heifers weight increased continuously throughout the year with a slight leveling off in the winter months. This was expected as the heifers were still growing to reach mature weight.

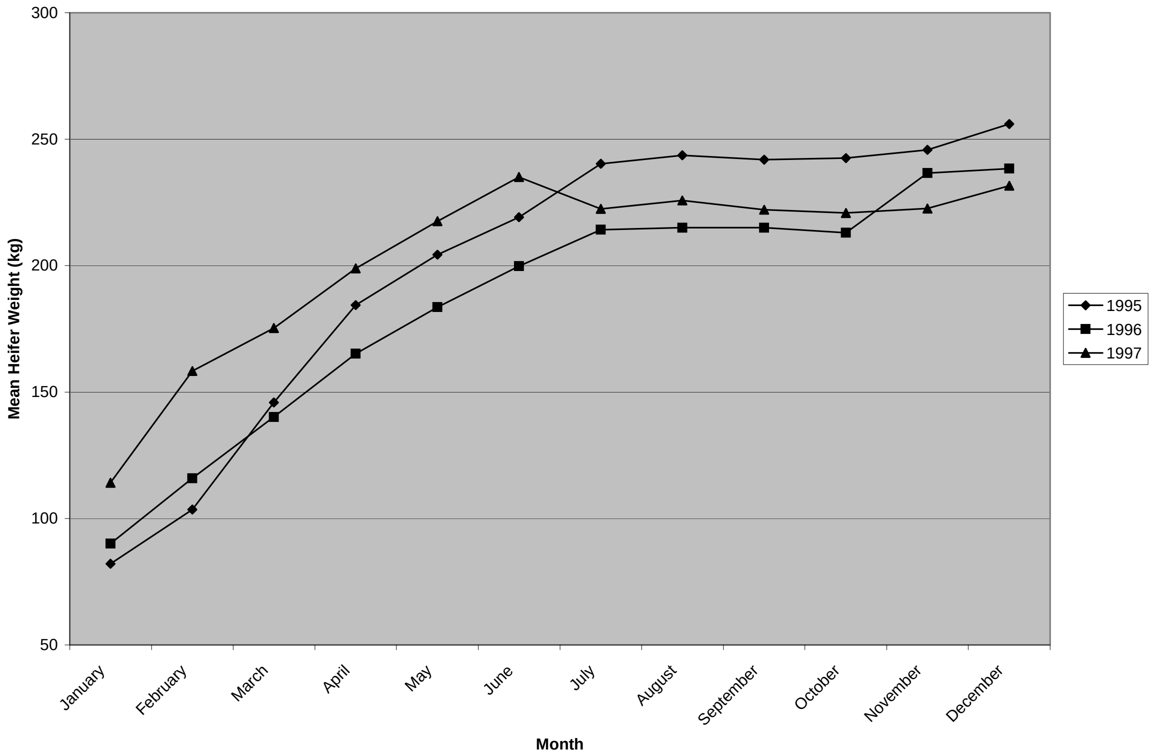
Table 9a: Trial 1- Summary statistics (mean ± std dev) for the effect of year of the trial on heifer weights (kg)

Month	Year		
n= 77	1995	1996	1997
	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	82.1 ± 15.5 [A]	90.1 ± 18.7 [A]	114.2 ± 15.6 [B]
February	103.6 ± 18.2 [A]	115.9 ± 18.1 [A]	158.3 ± 22.2 [B]
March	145.9 ± 21.7 [A]	140.2 ± 19.7 [A]	175.3 ± 25.7 [B]
April	184.4 ± 24.3 [A]	165.2 ± 19.9 [B]	198.9 ± 23.4 [A]
May	204.3 ± 24.3 [A]	183.6 ± 20.5 [B]	217.6 ± 22.8 [A]
June	219.2 ± 26.9 [A]	199.8 ± 22.7 [B]	235.0 ± 23.7 [A]
July	240.3 ± 26.5 [a]	214.2 ± 21.4 [b]	222.4 ± 21.9 [b]
August	243.6 ± 27.2 [a]	215.0 ± 21.3 [bc]	225.8 ± 22.9 [ac]
September	241.9 ± 25.2 [a]	215.0 ± 22.7 [b]	222.1 ± 22.1 [b]
October	242.5 ± 25.6 [A]	213.0 ± 22.7 [B]	220.8 ± 22.1 [B]
November	245.8 ± 28.2 [a]	236.6 ± 23.0 [ab]	222.6 ± 26.1 [b]
December	256.0 ± 28.6 [a]	238.4 ± 22.7 [ab]	231.6 ± 25.8 [b]
Average	**200.8 ± 24.4**	**185.6 ± 21.1**	**203.7 ± 22.9**

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
[A, B, C] Row means with different superscripts differ ($p < 0.001$)

Table 9b: Effect of year (ANOVA results) in different months on heifer weights (for Table 9a)

Month	p value	F value
January	<0.0001	19.04
February	<0.0001	39.0
March	<0.0001	13.38
April	0.0001	10.43
May	<0.0001	10.77
June	0.0002	9.52
July	0.0057	5.58
August	0.0016	7.04
September	0.0019	6.86
October	0.0010	7.70
November	0.0341	3.55
December	0.0279	3.77



Graph 7: Trial 1- Effect of year and month on mean heifer weights (kg)

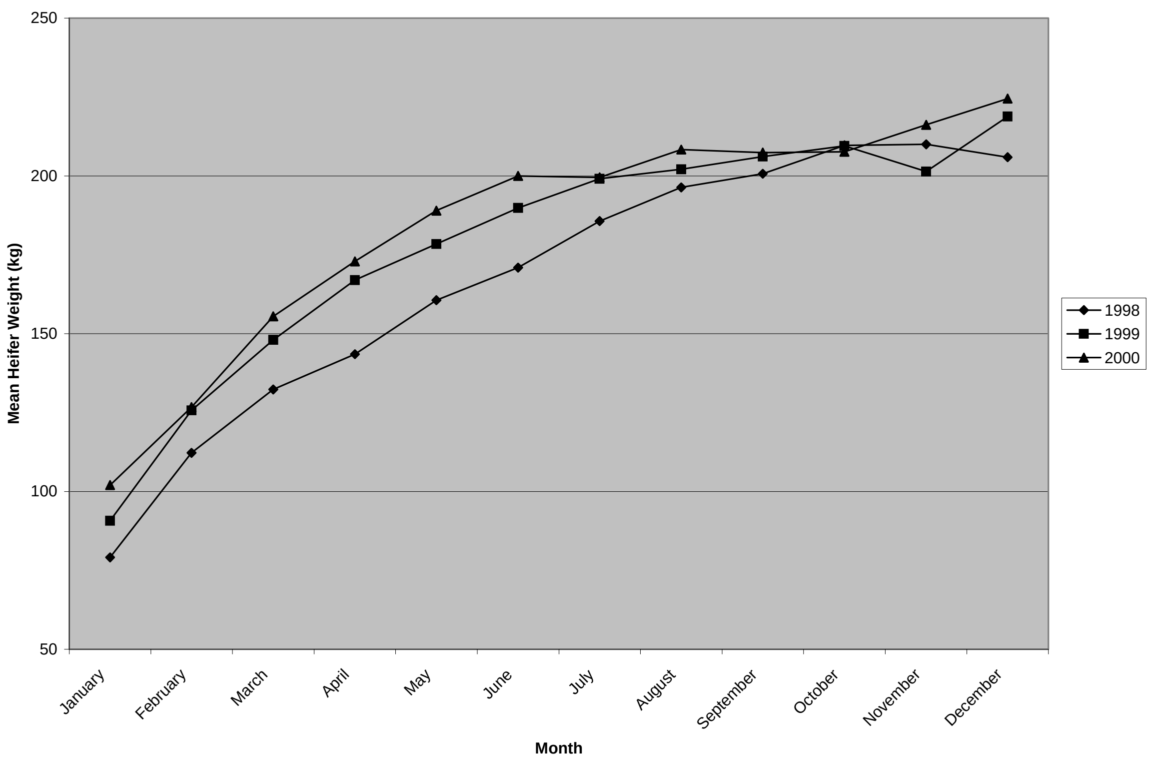
Table 10a: Trial 2- Summary statistics (mean ± std dev) for the effect of year of the trial on heifer weights (kg)

Month	**Year**		
n= 77	**1998**	**1999**	**2000**
	Mean ± Std Dev	**Mean ± Std Dev**	**Mean ± Std Dev**
January	79.1 ± 15.1 [A]	90.7 ± 16.7 [AB]	102.0 ± 26.7 [B]
February	112.2 ± 19.2 [a]	125.7 ± 20.4 [a]	126.7 ± 24.1 [a]
March	132.3 ± 22.0 [a]	148.0 ± 21.0 [b]	155.5 ± 24.3 [b]
April	143.5 ± 23.5 [A]	167.0 ± 21.6 [B]	172.9 ± 28.4 [B]
May	160.6 ± 24.6 [A]	178.4 ± 21.0 [B]	189.0 ± 29.9 [B]
June	170.9 ± 24.6 [A]	189.8 ± 22.0 [B]	200.0 ± 29.2 [B]
July	185.7 ± 26.1	199.1 ± 23.9	199.5 ± 30.2
August	196.3 ± 25.9	202.1 ± 21.1	208.3 ± 30.1
September	200.7 ± 26.4	206.1 ± 21.9	207.4 ± 28.1
October	209.7 ± 28.1	209.5 ± 22.3	207.6 ± 29.7
November	210.0 ± 28.4	201.4 ± 17.9	216.2 ± 30.4
December	205.9 ± 27.1 [a]	218.8 ± 9.8 [a]	224.5 ± 28.8 [a]
Average	**167.2 ± 24.3**	**178.1 ± 20.0**	**184.1 ± 28.3**

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
[A, B, C] Row means with different superscripts differ ($p < 0.001$)

Table 10b: Effect of year (ANOVA results) in different months on heifer weights (for Table 10a)

Month	p value	F value
January	0.0007	8.06
February	0.0337	3.56
March	0.0023	6.63
April	0.0002	9.88
May	0.0009	7.82
June	0.0007	8.15
July	0.1201	2.18
August	0.2929	1.25
September	0.6368	0.45
October	0.9574	0.04
November	0.1502	1.95
December	0.0411	3.34



Graph 8: Trial 2- Effect of year and month on mean heifer weights (kg)

In Tables 9a and 9b it can be seen that in Trial 1, year of the trial was significant regarding heifer weight. In Trial 2 however, the year of the trial was only significant in the months of December to June and not during the months of July to November (Tables 10a and 10b).

It was expected that the year of the trial would be significant, with differences in rainfall having an effect on weight. Years with lower rainfall would result in poorer grazing and therefore lower average weights. Temperature differences over the years would also play a role, with extremes in temperature resulting in a decrease in average weight. In both Trial 1 and Trial 2, the average weights over the years were similar. This was probably due to there being no extreme climate differences between the years i.e. the years of the trial were similar. This can be seen in Graph 7 and Graph 8.

4.1.3 Calves

In this section the effects of various factors on the reproductive characteristics of cows were quantified in terms of calf birth weight, calf weaning weight and weight gain of calves.

Table 11a: Trial 1- Summary statistics (mean ± std dev) for the effect of control diet and different dietary phosphorus supplementation treatments on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Birth Weight	Weaning Weight	Weight Gain
n= 247	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	37.0 ± 6.8	195.4 ± 30.8	158.3 ± 28.6
T1	37.3 ± 6.8	193.4 ± 32.3	155.5 ± 29.4
T2	39.1 ± 5.8	197.1 ± 30.9	157.9 ± 29.0
T3	38.0 ± 5.9	197.6 ± 29.8	160.0 ± 27.8

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 11b: Effect of treatment (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 11a)

	p value	F value
Birth weight	0.5349	0.73
Weaning weight	0.7893	0.35
Weight gain	0.8065	0.33

Table 12a: Trial 2- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Birth Weight	Weaning Weight	Weight Gain
n= 318	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	35.5 ± 5.5	178.8 ± 27.8 [a]	142.8 ± 26.4 [a]
T1	35.7 ± 5.9	187.9 ± 27.2 [b]	151.6 ± 26.0 [b]

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 12b: Effect of treatment (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 12a)

	p value	F value
Birth weight	0.7003	0.15
Weaning weight	0.0272	4.95
Weight gain	0.0524	3.81

Tables 11a, 11b, 12a and 12b show the effect that control and various phosphorus supplementation treatments had on the birth weight, weaning weight and weight gain of the treated cows' calves. In both Trial 1 and Trial 2, treatment was not significant for birth weight**.** Numerical differences were noted, these were however very small. In Trial 2, the phosphorus supplemented group and control group had almost identical birth weights.

In Trial 1 it was found that treatment did not significantly influence weaning weight. In Trial 2 the effect of treatment on weaning weight was significant, with the treatment group having a higher average weaning weight than the control group. This was in agreement with Black *et al*. (1943), and Karn (1997), who both found that calf weaning weights improved with phosphorus supplementation. De Brouwer *et al*. (2000) also found that with decreasing levels of phosphorus supplementation there was a tendency for lower weight gains in calves from birth to weaning. This showed that cows on phosphorus supplementation produced more milk than those that were not supplemented.

This was probably due to an increased feed intake. Karn (1997), Fishwick *et al*. (1977) and Read *et al*. (1986a) all found that phosphorus supplemented cows had an increase in milk production. Karn (2000) however, showed that there is still confusion as to whether the increase is due to phosphorus itself or due to the secondary effect, which is increased feed intake.

Treatment had no significant effect on weight gain in Trial 1. In Trial 2 however, treatment was significant, with the phosphorus supplemented cows producing calves that gained more weight from birth to weaning than the calves from the control group cows. This could be due to supplemented cows (possibly due to increased feed intake) having a higher milk yield, which then leads to higher weaning weights of their calves.

Table 13a: Trial 1- Summary statistics (mean ± std dev) for the effect of sex on birth weight, weaning weight and weight gain of calves (kg)

Sex	**Birth Weight**	**Weaning Weight**	**Weight Gain**
n= 247	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**
B	39.3 ± 6.3	205.9 ± 30.3 [a]	166.4 ± 28.8 [a]
H	36.0 ± 6.0	183.7 ± 27.1 [b]	147.7 ± 24.9 [b]

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B= bull calf, H= heifer

Table 13b: Effect of sex (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 13a)

	p value	**F value**
Birth weight	0.2867	0.73
Weaning weight	0.0302	4.76
Weight gain	0.0316	4.69

Table 14a: Trial 2- Summary statistics (mean ± std dev) for the effect of sex on birth weight, weaning weight and weight gain of calves (kg)

Sex	Birth Weight	Weaning Weight	Weight Gain
n= 318	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B	36.9 ± 5.8 [a]	185.3 ± 30.4	149.0 ± 29.1
H	34.6 ± 5.4 [b]	181.5 ± 25.3	146.3 ± 23.9

[a, b, c] Column means with different superscripts differ ($p < 0.001$)
B= bull calf, H= heifer

Table 14b: Effect of sex (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 14a)

	p value	F value
Birth weight	0.0006	12.07
Weaning weight	0.1559	2.03
Weight gain	0.2653	1.25

In general bull calves are expected to be born heavier, grow faster and therefore reach higher weaning weights than heifers. In Trial 1 there was no significant difference between bull and heifer birth weights. There was however a significant difference for both weight gain and weaning weight, with the bull claves gaining more weight and therefore reaching significantly heavier weaning weights. In Trial 2, sex had a significant influence on birth weight, with bull claves being heavier than the heifers. Sex however, had no significant influence on weaning weight or weight gain.

Table 15a: Trial 1- Summary statistics (mean ± std dev) for the interaction between control diet, different dietary phosphorus supplementation treatments and sex on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Birth Weight	Weaning Weight	Weight Gain
n=247		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	B	38.0 ± 6.6	202.0 ± 29.7	163.7 ± 28.8
C	H	35.6 ± 6.9	186.5 ± 30.5	151.0 ± 27.3
T1	B	39.1 ± 6.1	205.0 ± 29.3	165.2 ± 27.8
T1	H	35.2 ± 7.1	179.5 ± 30.5	144.0 ± 27.5
T2	B	40.0 ± 6.4	203.1 ± 37.7	162.9 ± 35.0
T2	H	38.2 ± 4.9	189.8 ± 17.9	151.8 ± 18.2
T3	B	40.3 ± 6.3	215.9 ± 21.8	175.9 ± 21.6
T3	H	35.5 ± 4.2	180.7 ± 26.3	145.4 ± 24.8

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)
B= bull calf, H= heifer

Table 15b: Effect of interaction (ANOVA results) between treatment and sex on birth weight, weaning weight and weight gain of calves (for Table 15a)

	p value	F value
Birth weight	0.4644	0.86
Weaning weight	0.1935	1.59
Weight gain	0.1968	1.57

Table 16a: Trial 2- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and sex on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Birth Weight	Weaning Weight	Weight Gain
n= 318		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	B	36.2 ± 5.9	182.4 ± 31.8	147.4 ± 30.6
C	H	35.0 ± 5.1	174.3 ± 23.8	139.1 ± 22.0
T1	B	37.4 ± 5.8	187.5 ± 29.3	150.2 ± 28.1
T1	H	34.2 ± 5.7	188.3 ± 25.1	153.1 ± 23.8

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)
B= bull calf, H= heifer

Table 16b: Effect of interaction (ANOVA results) between treatment and sex on birth weight, weaning weight and weight gain of calves (for Table 16a)

	p value	F value
Birth weight	0.1522	2.06
Weaning weight	0.5492	0.36
Weight gain	0.3452	0.90

Tables 15a, 15b, 16a and 16b show the interaction between control and the various phosphorus supplements on birth weight, weaning weight and weight gain between the two sexes. This was shown not to be significant i.e. there was no interaction between the two factors. This shows that any effect treatment may have had on these three parameters was not complicated by an interaction with sex of the calf.

Table 17a: Trial 1- Summary statistics (mean ± std dev) for the effect of birth year of a calf on its birth weight, weaning weight and weight gain (kg)

Year	Birth Weight	Weaning Weight	Weight Gain
n= 247	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
1995	37.4 ± 6.5	205.8 ± 21.5 [a]	167.7 ± 19.9 [a]
1996	37.1 ± 5.0	206.8 ± 30.9 [a]	169.8 ± 28.2 [a]
1997	38.6 ± 7.6	175.1 ± 26.9 [b]	136.7 ± 22.6 [b]
1998	44.7 ± 0.6	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.001$)

Table 17b: Effect of birth year of a calf (ANOVA results) on birth weight, weaning weight and weight gain (for Table 17a)

	p value	F value
Birth weight	0.1831	1.63
Weaning weight	<0.0001	18.07
Weight gain	<0.0001	25.27

Table 18a: Trial 2- Summary statistics (mean ± std dev) for the effect of birth year of a calf on its birth weight, weaning weight and weight gain (kg)

Year	Birth Weight	Weaning Weight	Weight Gain
n= 318	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
1998	36.5 ± 5.4 [a]	185.4 ± 30.1 [A]	148.8 ± 28.9 [A]
1999	35.2 ± 5.2 [ab]	191.6 ± 28.8 [A]	156.1 ± 27.7 [AC]
2000	36.7 ± 5.0 [a]	186.1 ± 24.0 [A]	149.4 ± 22.5 [AD]
2001	34.0 ± 6.5 [b]	167.5 ± 23.0 [B]	133.6 ± 21.9 [B]
2002	35.5 ± 6.2 [a]	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
[A, B, C] Column means with different superscripts differ ($p < 0.001$)

Table 18b: Effect of birth year of a calf (ANOVA results) on its birth weight, weaning weight and weight gain (for Table 18a)

	p value	F value
Birth weight	0.0337	2.65
Weaning weight	<0.0001	10.88
Weight gain	<0.0001	9.67

Tables 17a, 17b, 18a and 18b show the differences between birth weight, weaning weight and weight gain over the different birth years. In Trial 1, the level of birth year was not significant where birth weight was concerned. The cow has the ability to buffer bad years i.e. years with poor grazing and therefore the birth weight of a calf is seldom affected. Year of birth was however significant for birth weight in Trial 2 with a significance level of p= 0.0337. The year of birth also had a significant effect on both weaning weight and weight gain in both trials. Both weaning weight and weight gain are dependant on the cow's milk yield. Different years, with different amounts of rainfall and temperature ranges, will produce different levels of grazing. In years with poor grazing, the cow will have a lower milk yield which means less milk available to the calf and therefore the calf will grow slower and reach a lower weight when weaned.

Table 19a: Trial 1- Summary statistics (mean ± std dev) for the interaction between control diet, different dietary phosphorus supplementation treatments and the birth year of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Year	Birth Weight	Weaning Weight	Weight Gain
n= 247		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	1995	35.4 ± 6.9	197.9 ± 17.9	161.2 ± 18.3
C	1996	37.2 ± 4.6	211.8 ± 29.9	175.5 ± 27.2
C	1997	37.8 ± 8.7	176.7 ± 28.9	138.4 ± 23.4
T1	1995	37.0 ± 7.5	209.6 ± 14.9	171.4 ± 14.3
T1	1996	36.9 ± 5.7	205.6 ± 30.7	168.2 ± 27.6
T1	1997	37.4 ± 7.6	171.7 ± 30.7	134.0 ± 25.5
T1	1998	44.5 ± 0.7	-	-
T2	1995	38.6 ± 6.1	207.2 ± 25.9	168.1 ± 23.5
T2	1996	37.4 ± 5.7	202.8 ± 35.1	165.4 ± 31.8
T2	1997	41.4 ± 5.4	178.9 ± 24.6	137.6 ± 22.0
T2	1998	45.0	-	-
T3	1995	38.3 ± 5.8	208.4 ± 25.2	170.1 ± 22.5
T3	1996	37.1 ± 4.3	206.6 ± 30.2	169.4 ± 27.7
T3	1997	38.9 ± 7.8	175.0 ± 20.5	137.6 ± 18.5

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 19b: Effect of interaction (ANOVA results) between treatment and birth year on birth weight, weaning weight and weight gain (for Table 19a)

	p value	F value
Birth weight	0.7650	0.59
Weaning weight	0.6041	0.78
Weight gain	0.5890	0.8

Table 20a: Trial 2- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and the birth year of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Year	Birth Weight	Weaning Weight	Weight Gain
n= 318		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C	1998	37.2 ± 5.3	179.4 ± 30.5	142.2 ± 29.7
C	1999	35.3 ± 4.9	187.7 ± 24.5	152.5 ± 24.2
C	2000	36.1 ± 5.4	179.6 ± 27.4	143.9 ± 25.9
C	2001	32.7 ± 7.1	161.6 ± 23.2	130.2 ± 21.1
C	2002	35.8 ± 4.6	-	-
T1	1998	35.9 ± 5.5	190.7 ± 29.2	154.9 ± 27.3
T1	1999	35.1 ± 5.5	194.9 ± 31.9	158.9 ± 30.4
T1	2000	37.3 ± 4.5	191.7 ± 19.3	154.3 ± 18.2
T1	2001	35.0 ± 6.0	172.0 ± 22.3	136.2 ± 22.6
T1	2002	35.3 ± 7.6	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 20b: Effect of interaction (ANOVA results) between treatment and birth year on birth weight, weaning weight and weight gain (for Table 20a)

	p value	F value
Birth weight	0.4647	0.90
Weaning weight	0.9931	0.03
Weight gain	0.9799	0.06

Tables 19a, 19b, 20a and 20b show the interaction between control and the various phosphorus supplementations with the birth year of the calf. There were no significant interactions between the two for birth weight, weaning weight and weight gain in either of the trials. This showed that any effect treatment may have had on birth weight, weaning weight and weight gain was not complicated by birth year of the calf.

Table 21a: Trial 1- Summary statistics (mean ± std dev) for the interaction between birth year of the calf and sex on birth weight, weaning weight and weight gain of calves (kg)

Sex n= 247	Year	Birth Weight Mean ± Std Dev	Weaning Weight Mean ± Std Dev	Weight Gain Mean ± Std Dev
B	1995	37.7 ± 6.6 [bc]	215.0 ± 19.9	176.5 ± 16.7
B	1996	38.4 ± 5.1 [b]	217.6 ± 29.9	179.1 ± 27.2
B	1997	41.6 ± 7.0 [a]	183.6 ± 26.6	141.9 ± 23.9
B	1998	44.0	195.0	151.0
H	1995	36.9 ± 6.6 [bc]	193.0 ± 17.0	155.5 ± 17.7
H	1996	35.5 ± 4.4 [c]	193.9 ± 27.3	158.5 ± 25.3
H	1997	35.5 ± 6.9 [c]	166.3 ± 24.5	131.1 ± 20.0
H	1998	45.0 ± 0.0	180.0 ± 14.1	135.0 ± 14.1

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B= bull calf, H= heifer

Table 21b: Effect of interaction (ANOVA results) between birth year and sex on birth weight, weaning weight and weight gain (for Table 21a)

	p value	F value
Birth weight	0.0409	2.8
Weaning weight	0.8827	0.22
Weight gain	0.5225	0.75

Table 22a: Trial 2- Summary statistics (mean ± std dev) for the interaction between birth year of the calf and sex on birth weight, weaning weight and weight gain of calves (kg)

Sex n= 318	Year	Birth Weight Mean ± Std Dev	Weaning Weight Mean ± Std Dev	Weight Gain Mean ± Std Dev
B	1998	37.3 ± 5.6	183.4 ± 37.6	145.8 ± 36.1
B	1999	35.6 ± 5.2	192.3 ± 31.8	157.0 ± 30.7
B	2000	38.0 ± 5.2	193.3 ± 27.1	155.6 ± 25.5
B	2001	35.2 ± 6.8	172.6 ± 21.1	137.7 ± 21.1
B	2002	38.2 ± 5.9	-	-
H	1998	36.0 ± 5.3	186.8 ± 23.9	150.8 ± 23.3
H	1999	34.8 ± 5.3	191.0 ± 26.1	155.2 ± 25.2
H	2000	35.6 ± 4.6	180.2 ± 19.7	144.5 ± 18.7
H	2001	32.1 ± 5.7	159.4 ± 24.2	127.1 ± 22.3
H	2002	33.7 ± 5.7	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B= bull calf, H= heifer

Table 22b: Effect of interaction (ANOVA results) between birth year and sex on birth weight, weaning weight and weight gain (for Table 22a)

	p value	F value
Birth weight	0.3119	1.20
Weaning weight	0.3317	1.15
Weight gain	0.2855	1.27

Tables 21a, 21b, 22a and 22b show the interaction between the sex of the calf and the year the calf was born in. In Trial 1, the interaction was significant for birth weight. This shows that there was an interaction between birth year and sex of the calf. This interaction is probably due to sex as in general bull calves are born heavier than heifers. In both trials there was no significant interaction for weaning weight or weight gain.

Table 23a: Trial 1- Summary statistics (mean ± std dev) for the effect of birth month on birth weight, weaning weight and weight gain of calves (kg)

Month	Birth Weight	Weaning Weight	Weight Gain
n= 247	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	44.2 ± 0.8	186.3 ± 11.1	142.0 ± 11.6
October	36.6 ± 7.0	204.3 ± 33.5	167.3 ± 29.8
November	38.2 ± 6.3	193.0 ± 30.9	154.9 ± 29.1
December	38.2 ± 5.6	189.7 ± 25.8	151.3 ± 23.4

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.05$)

Table 23b: Effect of birth month (ANOVA results) on birth weight, weaning weight and weight gain (for Table 23a)

	p value	F value
Birth weight	0.3799	1.07
Weaning weight	0.0214	2.95
Weight gain	0.0017	4.51

Table 24a: Trial 2- Summary statistics (mean ± std dev) for the effect of birth month on birth weight, weaning weight and weight gain of calves (kg)

Month	Birth Weight	Weaning Weight	Weight Gain
n= 318	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	32.0 ± 1.4	145.0	112.0
October	35.3 ± 5.2	188.3 ± 23.2	153.2 ± 22.1
November	36.3 ± 6.5	184.8 ± 28.4	148.3 ± 26.6
December	35.0 ± 4.6	173.2 ± 31.0	137.2 ± 30.2

[a, b, c] Column means with different superscripts differ ($p < 0.05$)

Table 24b: Effect of birth month (ANOVA results) on birth weight, weaning weight and weight gain (for Table 24a)

	p value	F value
Birth weight	0.4934	0.85
Weaning weight	0.0013	5.42
Weight gain	0.0007	5.90

Tables 23a, 23b, 24a and 24b show the effect of the month in which the calf was born in, on its birth weight, weaning weight and weight gain. In both trials, the month in which the calf was born had no significant effect on its birth weight. This, as explained previously, was due to the buffering effect of the cow. It did however have a significant effect on weight gain and therefore weaning weight in both trials. In general, calves born in the normal calving season of October, November and December should have better weight gain and weaning weights than those born outside of the normal calving season. Within the calving season there were also differences, with those calves born in October and November (October being more optimum) having better weight gain and weaning weights than those calves born in December. This is due to the cow having access to good pasture throughout most of lactation. Cows who calve later graze on pasture of lesser quality towards the end of lactation due to seasonal changes. Cows who calve down in optimum months of October, November and December are also in a better condition at conception (January, February and March) leading to the production of healthier calves with higher weaning weights (Taylor, 2006).

4.1.4 Reproduction

In this section the effects of various factors on reproductive characteristics of cows quantified in terms of the total amount of calves produced per cow, the average calving intervals of cows and the reproduction rate of cows was considered.

Table 25a: Trial 1- Summary statistics (mean ± std dev) for the effect of control diet and different dietary phosphorus supplementation treatments on the total amount of calves produced per cow (with total amount of years that the cow was in the system)

Treatment	Total Calves	Years in System
n= 149	Mean ± Std Dev	Mean ± Std Dev
C	1.4 ± 1.1	2.1 ± 0.9
T1	1.7 ± 1.2	2.2 ± 0.9
T2	1.8 ± 1.0	2.4 ± 0.7
T3	1.9 ± 1.0	2.5 ± 0.7

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 25b: Effect of treatment (ANOVA results) on the total amount of calves produced per cow (for Table 25a)

	p value	F value
Treatment	0.4039	0.98
Years in system	<0.0001	218.63

Table 26a: Trial 2- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on the total amount of calves produced per cow (with total amount of years that the cow was in the system)

Treatment	Total Calves	Years in System
n= 157	Mean ± Std Dev	Mean ± Std Dev
C	1.9 ± 1.2	3.2 ± 1.2[a]
T1	2.1 ± 1.4	3.5 ± 1.2[b]

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 26b: Effect of treatment (ANOVA results) on the total amount of calves produced per cow (for Table 26a)

	p value	F value
Treatment	0.8803	0.02
Years in system	<0.0001	304.88

Tables 25a, 25b, 26a and 26b show the effect of control and the various phosphorus supplementation treatments on the total amount of calves a cow produced while in the trial. In both trials, treatment had no significant effect on the number of calves a cow produced. This is in agreement with Karn (1997), Call *et al*. (1978) and Fishwick *et al*. (1977), who all found that phosphorus supplementation had no effect on conception rate, and that long periods of phosphorus inadequacy had no effect on reproduction. What was significant was the total number of years the cow was in the system for. This was due to the fact that, the longer the cow was in the system for, the more chances she had to produce a calf. Therefore, in general, the longer the cow was in the system for, the more calves she produced. Here treatment had no effect because some cows were in the trial from year one, while others came in later and were possibly only in the system for one or two years. These cows could therefore not be compared to each other on a level of treatment.

Table 27a: Trial 1- Summary statistics (mean ± std dev) for the effect of control diet and different dietary phosphorus supplementation treatments on the average calving interval of the cow (with total amount of years that the cow was in the system)

Treatment	Average CI	Years in System
n= 149	Mean ± Std Dev	Mean ± Std Dev
C	365.9 ±15.7	3.0 ± 0.2
T1	370.5 ± 30.7	2.9 ± 0.3
T2	388.7 ± 83.9	2.7 ± 0.5
T3	379.9 ± 48.9	2.8 ± 0.4

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 27b: Effect of treatment (ANOVA results) on the average calving interval of the cow (for Table 27a)

	p value	F value
Treatment	0.8153	0.31
Years in system	0.5740	0.32

Table 28a: Trial 2- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on the average calving interval of the cow (with total amount of years that the cow was in the system)

Treatment	Average CI	Years in System
n= 157	Mean ± Std Dev	Mean ± Std Dev
C	471.1 ± 134.7	4.0 ± 0.9
T1	456.2 ± 126.4	4.1 ± 0.9

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation**)**

Table 28b: Effect of treatment (ANOVA results) on the average calving interval of the cow (for Table 28a)

	p value	F value
Treatment	0.7485	0.10
Years in system	0.2089	1.60

Tables 27a, 27b, 28a and 28b show the effects that control and the various treatment groups had on average calving interval of the cow. Calving interval is defined as the number of days between the births of two consecutive calves of a cow. Here treatment was not significant in either of the trials. This is in agreement with Fishwick *et al*. (1977) who found that supplemented cows did not return to oestrus quicker than unsupplemented cows. Groenewald (1986) did however find that cows that did not receive phosphorus supplementation tended to calve only once every two years. In Trial 2 the cows that received phosphorus supplementation had a better average calving interval than the control group. This may be due to the cow being in better condition after lactation, allowing her to recover quicker. This can either be due to the phosphorus supplementation itself, or to the increased feed intake which results as a secondary effect from phosphorus supplementation.

The number of years the cow was in the system for did not significantly influence average calving interval of the cow. It can however be seen, that the cows that were in the system for longer had lower, and therefore better, calving intervals than those that were in for fewer years. This can be explained by the fact that the cows that were in for longer were probably older, and more mature animals tend to have better calving intervals than cows that have only produced one calf. Often when a heifer has her first calf, especially if the heifer is small, she may have distocia and may lose condition during lactation. This often results in her not conceiving in her second breeding season resulting in a very long calving interval. Calving interval generally then improves, as the cow gets older. In Trial 1, cows could only be in the trial for a maximum of three years and a large portion of the trial animals would have only had one or no calving intervals, making the results difficult to interpret.

Table 29a: Trial 1- Summary statistics (mean ± std dev) for the interaction between control diet, different dietary phosphorus supplementation treatments and cow age on the reproductive rate of cows

Treatment	Reproductive Rate	Age of cow
n= 149	Mean ± Std Dev	Mean ± Std Dev
C	0.59 ± 0.40	4.90 ± 3.35
T1	0.67 ± 0.41	5.09 ± 3.46
T2	0.69 ± 0.33	6.06 ± 3.14
T3	0.69 ± 0.34	6.06 ± 3.16

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year, T2= P in summer, T3= P in summer + winter lick
(P= phosphorus supplementation)

Table 29b: Effect of interaction (ANOVA results) between treatment and age of cow on the reproductive rate of cows (for Table 29a)

	p value	F value
Treatment	0.6810	0.50
Age of cow	<0.0001	23.82

Table 30a: Trial 2- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and cow age on the reproductive rate of cows

Treatment	Reproductive Rate	Age of cow
n= 157	Mean ± Std Dev	Mean ± Std Dev
C	0.55 ± 0.25	5.74 ± 3.01[a]
T1	0.56 ± 0.27	6.22 ± 3.52[b]

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T1= P all year
(P= phosphorus supplementation)

Table 30b: Effect of interaction (ANOVA results) between treatment and age of cow on the reproductive rate of cows (for Table 30a)

	p value	F value
Treatment	0.9490	0.00
Age of cow	<0.0001	57.59

Tables 29a, 29b, 30a and 30b show the reproduction rate of the cow. This was calculated by, the number of calves the cow produced, divided by the number of years the cow was in the system for. Treatment had no significant effect on reproduction rate in either of the trials. Age of the cow was however significant in both trials. This is due to, the more mature the cow, the easier she recovers from parturition and lactation, and the sooner she is able to conceive again. This is true up until a certain age, after which she will be too old and once again struggle to recover.

4.2 PHASE 2

4.2.1 Cows

In this section the effects of various factors on the growth of cows were quantified in terms of weight of the cows. Four different breed types were used in this trial namely Afrikaner type, Simmentaler type, Nguni type and Bonsmara type cows.

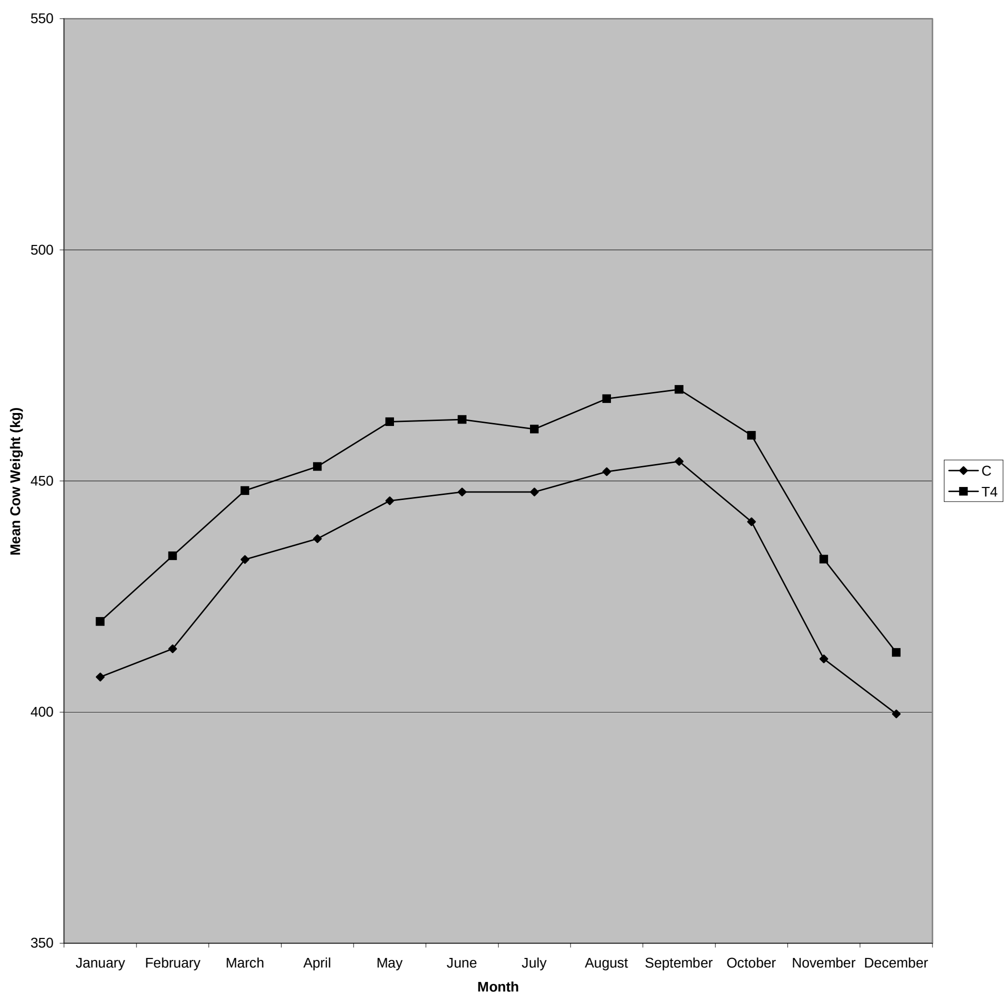
Table 31a: Trial 3- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on cow weights (kg)

Month	C	T4
n= 226	Mean ± Std Dev	Mean ± Std Dev
January	407.6 ± 102.7	419.6 ± 107.0
February	413.7 ± 96.8	433.8 ± 108.7
March	433.0 ± 99.4	447.9 ± 104.3
April	437.5 ± 99.1	453.1 ± 103.0
May	445.7 ± 98.0	462.8 ± 100.8
June	447.6 ± 98.8 [a]	463.3 ± 101.1 [b]
July	447.6 ± 97.8 [a]	461.2 ± 104.5 [b]
August	452.0 ± 99.2 [a]	467.8 ± 100.7 [b]
September	454.2 ± 99.7 [a]	469.8 ± 101.7 [b]
October	441.2 ± 93.9 [a]	459.9 ± 98.5 [b]
November	411.5 ± 84.1 [A]	433.1 ± 93.8 [B]
December	399.6 ± 83.3	412.9 ± 80.6
Average	**432.6 ± 96.1**	**448.8 ± 100.4**

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
[A, B, C] Row means with different superscripts differ ($p < 0.001$)
C= control, T4= Kimtrafos 12 P all year

Table 31b: Effect of treatments (ANOVA results) in different months on cow weights (for Table 31a)

Month	p value	F value
January	0.1803	1.80
February	0.2721	1.21
March	0.1151	2.49
April	0.1219	2.40
May	0.0611	3.52
June	0.0354	4.45
July	0.0576	3.62
August	0.0497	3.87
September	0.0381	4.32
October	0.0093	6.83
November	0.0010	11.04
December	0.0738	3.22



Graph 9: Trial 3- Effect of treatment and month on mean cow weights (kg)

Tables 31a and 31b shows the effect that control and a phosphorus supplementation had on cow weight over the twelve months of the various years. Treatment is shown to have no significant effect during the months of December through to January. This is in agreement with Cohen (1976), who indicated that cows grazing on a low phosphorus pasture showed no improvement in liveweight when given a phosphorus supplement. This could be due to the poor quality of this particular supplement. Another reason could be that, often phosphorus is not the limiting factor. The real limiting factor could be another mineral, protein or energy. Grant *et al*. (1996) found that phosphorus supplementation could only cause an increase in weight gains when protein concentrations were correct.

There was however a significant difference in the months of June through to November (with May and December tending towards significance). These months are roughly the months of the last trimester of pregnancy as well as the months that the cows usually calve down in. Numerical differences can also be noted in all months with the phosphorus-supplemented group having higher weights than the control group and on average weighing more. This is also in agreement with the fact that phosphorus supplementation is most needed during the months of October through to March and would therefore have its greatest effect during these months.

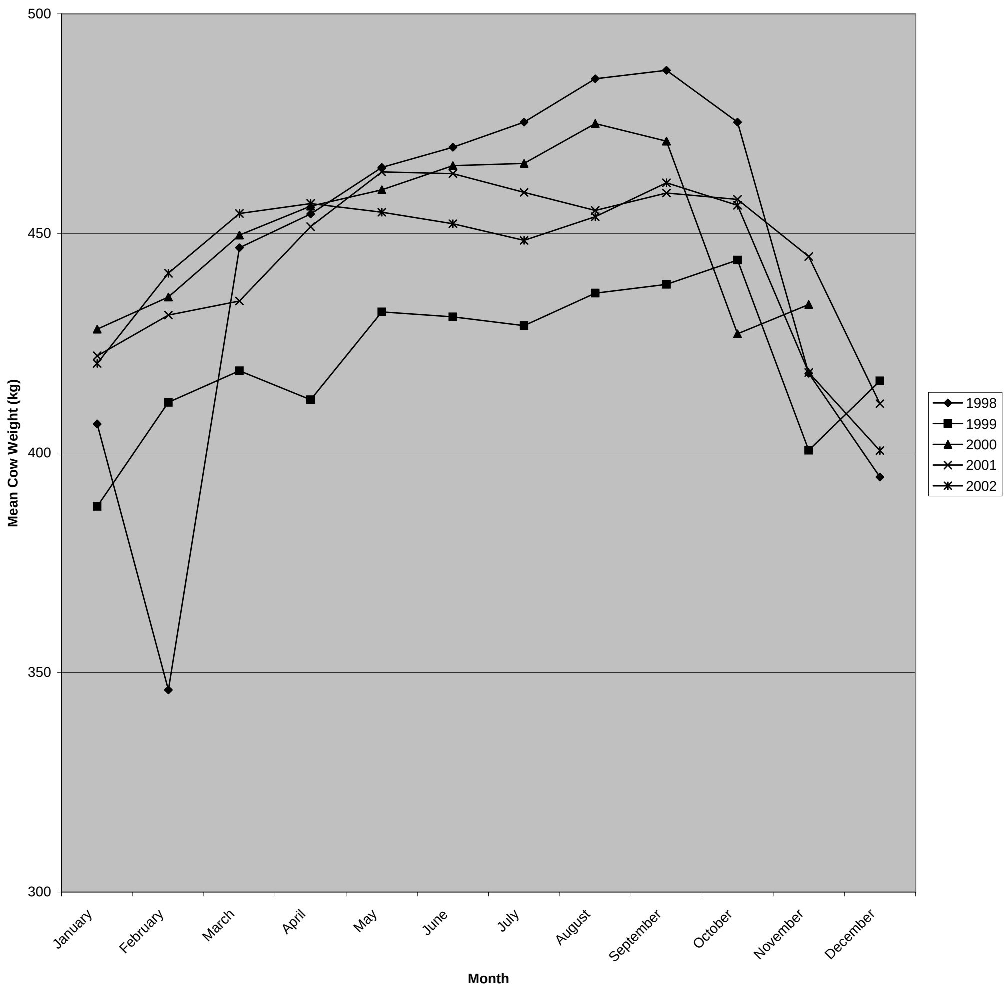
Table 32a: Trial 3- Summary statistics (mean ± std dev) for the effect of year of the trial on cow weights (kg)

Month	Year				
n= 226	1998	1999	2000	2001	2002
	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	406.6 ± 100.5 ^{AB}	387.8 ± 108.7^{A}	428.2 ± 105.0^{B}	422.1 ± 106.0 ^{B}	420.4 ± 99.1 ^{B}
February	446.0 ± 62.2 ^{a}	411.5 ± 104.6 ^{b}	435.5 ± 99.7 ^{bc}	431.4 ± 107.5 ^{bc}	440.9 ± 101.4 ^{c}
March	446.7 ± 100.2 ^{AB}	418.7 ± 102.6 ^{A}	449.6 ± 99.0 ^{B}	434.6 ± 104.5 ^{AB}	454.5 ± 101.4 ^{B}
April	454.4 ± 97.7 ^{B}	412.1 ± 100.1 ^{A}	456.2 ± 97.6 ^{B}	451.5 ± 103.8 ^{B}	456.8 ± 101.0 ^{B}
May	465.0 ± 102.1 ^{b}	432.1 ± 95.1 ^{a}	459.9 ± 95.4 ^{ab}	464.0 ± 104.8 ^{b}	454.8 ± 100.4^{ab}
June	469.6 ± 101.8 ^{B}	431.0 ± 95.5 ^{A}	465.4 ± 95.3 ^{B}	463.6 ± 104.7 ^{B}	452.2 ± 101.8 ^{AB}
July	475.3 ± 103.0 ^{B}	429.0 ± 93.5 ^{A}	465.9 ± 104.0 ^{B}	459.3 ± 101.9 ^{B}	448.4 ± 100.9 ^{AB}
August	485.2 ± 102.2 ^{B}	436.4 ± 93.3 ^{A}	475.0 ± 95.9 ^{B}	455.2 ± 101.2 ^{AB}	453.8 ± 104.4 ^{AB}
September	487.1 ± 102.4 ^{B}	438.4 ± 94.3 ^{A}	471.0 ± 96.7 ^{B}	459.2 ± 100.5 ^{AB}	461.5 ± 107.8 ^{AB}
October	475.3 ± 87.0 ^{A}	443.9 ± 93.8 ^{BC}	427.1 ± 89.8 ^{B}	457.7 ± 99.2 ^{AC}	456.4 ± 107.5 ^{ABC}
November	418.1 ± 85.4 ^{AB}	400.6 ± 87.5 ^{A}	433.8 ± 90.9 ^{B}	444.7 ± 91.5 ^{B}	418.3 ± 88.3 ^{AB}
December	394.5 ± 72.6	416.4 ± 86.8	-	411.2 ± 80.9	400.5 ± 85.0
Average	**443.7 ± 93.1**	**421.5 ± 96.3**	**451.6 ± 97.2**	**446.2 ± 100.5**	**443.2 ± 99.9**

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
$^{A, B, C}$ Row means with different superscripts differ ($p < 0.001$)

Table 32b: Effect of year (ANOVA results) in different months on cow weights (for Table 32a)

Month	p value	F value
January	<0.0001	8.85
February	0.0041	3.89
March	0.0002	5.59
April	<0.0001	10.75
May	0.0017	4.38
June	0.0010	4.68
July	0.0001	5.90
August	<0.0001	6.66
September	<0.0001	6.22
October	<0.0001	6.08
November	<0.0001	8.05
December	0.0700	2.37



Graph 10: Trial 3- Effect of year and month on mean cow weights (kg)

Tables 32a and 32b show that year had a significant effect on the average weight of cows in the months of January through to November, with December tending towards significance. This would again be due to the differences in rainfall and temperature that occur over the years. A year with a good rainfall will result in better pastures and therefore better grazing (better availability and quality). This will result in improved weight gain and maintenance of weight. Years with a poor rainfall will result in poor pastures and therefore poor grazing. This will result in decreased weight gain or even weight loss. Temperatures also have an effect on weight gain, with moderate temperatures being optimum and extreme temperatures being detrimental. Extreme cold would be the biggest problem as the animal requires a lot of energy to maintain body temperature, and most breeds in South Africa are adapted for heat rather than cold.

Table 33a: Trial 3- Summary statistics (mean ± std dev) for the effect of the different breed types on cow weights (kg)

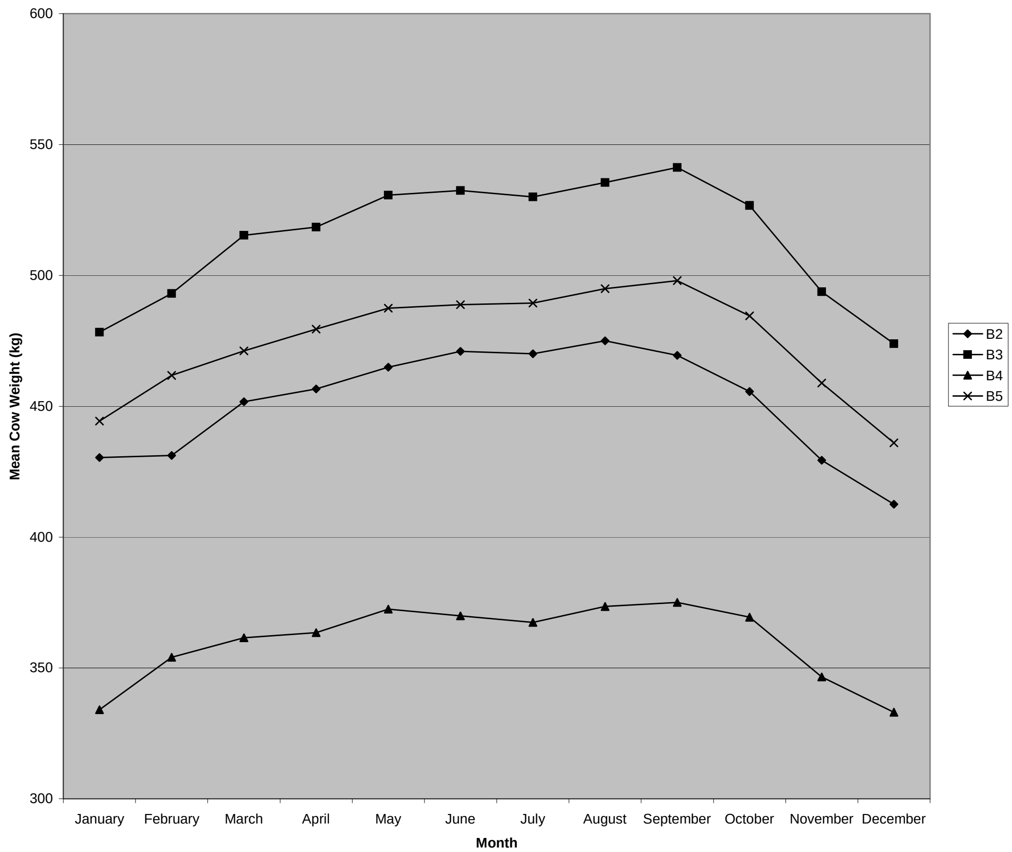
Month	Breed type			
n= 226	B2	B3	B4	B5
	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	430.4 ± 87.8 [c]	478.3 ± 103.2 [a]	334.0 ± 65.5 [b]	444.3 ± 97.1 [c]
February	431.2 ± 95.5 [c]	493.1 ± 101.8 [a]	354.1 ± 63.3 [b]	461.8 ± 95.2 [c]
March	451.7 ± 85.7 [c]	515.3 ± 96.5 [a]	361.5 ± 61.5 [b]	471.2 ± 89.4 [c]
April	456.6 ± 85.5 [c]	518.5 ± 92.9 [a]	363.5 ± 58.7 [b]	479.5 ± 88.1 [c]
May	464.9 ± 81.2 [c]	530.7 ± 90.7 [a]	372.5 ± 57.3 [b]	487.5 ± 85.2 [c]
June	471.0 ± 83.0 [c]	532.4 ± 89.2 [a]	369.9 ± 55.1 [b]	488.8 ± 84.2 [c]
July	470.0 ± 82.0 [c]	530.0 ± 91.7 [a]	367.4 ± 57.8 [b]	489.4 ± 83.7 [c]
August	475.0 ± 82.4 [c]	535.5 ± 91.5 [a]	373.5 ± 52.6 [b]	494.9 ± 83.1 [c]
September	469.4 ± 82.7 [c]	541.2 ± 92.0 [a]	375.0 ± 51.6 [b]	498.0 ± 83.0 [c]
October	455.6 ± 83.8 [a]	526.7 ± 88.4 [b]	369.4 ± 50.8 [c]	484.5 ± 78.5 [d]
November	429.4 ±75.5 [a]	493.8 ± 77.0 [b]	346.6 ± 47.8 [c]	458.9 ± 76.2 [d]
December	412.5 ± 64.4 [c]	473.9 ± 67.3 [a]	333.1 ± 45.5 [b]	436.0 ± 65.6 [c]
Average	**451.5 ± 82.5**	**514.1 ± 90.2**	**360.0 ± 55.6**	**474.6 ± 84.1**

[a, b, c] Row means with different superscripts differ ($p < 0.001$)

B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 33b: Effect of breed (ANOVA results) in different months on cow weights (for Table 33a)

Month	p value	F value
January	<0.0001	123.36
February	<0.0001	48.61
March	<0.0001	146.59
April	<0.0001	157.22
May	<0.0001	133.47
June	<0.0001	143.05
July	<0.0001	147.82
August	<0.0001	154.74
September	<0.0001	158.05
October	<0.0001	142.58
November	<0.0001	142.70
December	<0.0001	116.02



Graph 11: Trial 3- Effect of breed and month on mean cow weights (kg)

Table 33a and 33b (as well as Graph 11) show the effect that breed type had on cow weight. Breed type had a significant effect on cow weight. In this trial there were four different breed types with varying frame sizes. The four breed types were Simmentaler type, Bonsmara type, Afrikaner type and Nguni type beef cattle. Average cow weights for these breed types (1993- 1998) at calving were 543kg (Simmentaler), 486kg (Bonsmara), 444kg (Afrikaner) and 353kg (Nguni). (Beef breeding in South Africa, ARC- Animal Improvement Institute).

We would therefore have expected the Nguni type cows to have the lowest weight, which was confirmed in this trial. If looking at weights from lowest to highest, we would have expected the Afrikaner group to be next, followed by the Bonsmara group and finally the Simmentaler group. This was again confirmed (see Graph 11). Seasonal effects can also be noted with an increase in weight up until May, then a smaller increase or levelling off over the winter months and a drop in weight over the calving season of October, November and December.

Table 34a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and the year of the trial on cow weights (kg)

Treatment	Month	Year				
n= 226		1998	1999	2000	2001	2002
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	January	407.3 ± 108.0 [c]	398.0 ± 108.7 [c]	427.3 ± 107.2 [c]	406.9 ± 97.2 [c]	395.2 ± 92.0 [c]
T4	January	405.9 ± 93.7 [c]	378.3 ± 108.7 [a]	429.1 ± 103.4 [c]	436.8 ± 112.7 [b]	447.0 ± 100.2 [b]
C2	February	343.2 ± 70.8 [b]	420.4 ± 104.7 [abc]	429.7 ± 94.7 [ac]	413.4 ± 97.7 [bc]	412.4 ± 90.3 [bc]
T4	February	349.0 ± 53.6 [b]	403.5 ± 104.7 [bc]	441.1 ± 104.9 [ac]	449.0 ± 114.5 [ac]	470.9 ± 104.5 [a]
C2	March	449.0 ± 111.0 [c]	429.9 ± 108.6 [b]	446.1 ± 91.9 [c]	416.8 ± 94.7 [b]	425.6 ± 91.6 [b]
T4	March	444.3 ± 89.3 [c]	408.1 ± 96.2 [b]	453.0 ± 105.9 [c]	452.0 ± 111.4 [c]	485.1 ± 103.2 [a]
C2	April	457.2 ± 106.0 [abc]	420.0 ± 105.9 [ac]	449.8 ± 94.2 [abc]	433.8 ± 97.3 [abc]	431.2 ± 92.5 [ac]
T4	April	451.7 ± 89.7 [abc]	404.9 ± 94.8 [a]	462.1 ± 101.1 [bc]	469.3 ± 108.1 [bc]	483.7 ± 103.5 [b]
C2	May	469.9 ± 111.4 [a]	435.3 ± 102.1 [a]	453.9 ± 91.1 [a]	446.2 ± 93.1 [a]	428.7 ± 92.2 [a]
T4	May	460.0 ± 92.8 [a]	429.3 ± 88.9 [a]	465.6 ± 99.7 [a]	480.8 ± 113.0 [a]	482.4 ± 102.0 [a]
C2	June	474.4 ± 110.9 [ab]	436.6 ± 103.7 [ab]	432.1 ± 88.1 [ab]	442.9 ± 94.2 [ab]	424.7 ± 93.9 [ab]
T4	June	464.8 ± 92.9 [ab]	425.7 ± 87.6 [a]	468.4 ± 102.3 [ab]	483.0 ± 111.0 [b]	480.4 ± 102.8 [ab]
C2	July	480.7 ± 112.0 [a]	434.5 ± 101.3 [a]	463.2 ± 87.4 [a]	437.6 ± 86.5 [a]	425.8 ± 95.9 [a]
T4	July	470.0 ± 94.2 [a]	423.9 ± 86.3 [a]	468.4 ± 118.1 [a]	479.7 ± 111.4 [a]	471.5 ± 101.6 [a]
C2	August	491.0 ± 110.8 [a]	439.3 ± 100.4 [ab]	470.7 ± 86.7 [ab]	434.8 ± 89.9 [ab]	428.4 ± 99.1 [b]
T4	August	479.4 ± 93.9 [ab]	433.7 ± 86.9 [ab]	479.0 ± 104.4 [ab]	474.5 ± 108.2 [ab]	479.7 ± 104.3 [ab]
C2	September	491.8 ± 111.5 [a]	440.2 ± 100.5 [a]	466.5 ± 92.9 [a]	437.5 ± 85.4 [a]	440.3 ± 101.8 [a]
T4	September	482.4 ± 93.5 [a]	436.7 ± 88.8 [a]	475.4 ± 100.9 [a]	479.7 ± 109.8 [a]	482.8 ± 110.5 [a]

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 34a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and the year of the trial on cow weights (kg)

Treatment	Month	Year				
n= 226		1998	1999	2000	2001	2002
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	October	473.1 ± 91.4 ^{ab}	446.4 ± 99.3 ^{ab}	420.7 ± 85.3 ^{a}	436.5 ± 84.0 ^{ab}	434.5 ± 103.5 ^{ab}
T4	October	477.4 ± 83.4 ^{ab}	441.6 ± 89.3 ^{ab}	433.1 ± 94.2 ^{ab}	477.6 ± 108.6 ^{b}	479.2 ± 107.9 ^{b}
C2	November	419.0 ± 83.8 ^{abc}	398.6 ± 91.8 ^{b}	412.6 ± 77.4 ^{abc}	428.9 ± 75.6 ^{abc}	401.0 ± 89.1^{bc}
T4	November	417.1 ± 88.1^{abc}	402.5 ± 84.0 ^{b}	451.8 ± 98.1^{ac}	460.5 ± 103.4 ^{a}	435.6 ± 84.9 ^{abc}
C2	December	396.3 ± 75.7 ^{a}	419.3 ± 92.9 ^{a}		396.1 ± 70.4 ^{a}	384.7 ± 88.7 ^{a}
T4	December	392.7 ± 70.4 ^{a}	413.7 ± 81.8 ^{a}		425.1 ± 87.9 ^{a}	416.7 ± 78.6 ^{a}

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 34b: Effect of the interaction (ANOVA results) between treatment and year in different months on cow weights (for Table 34a)

Month	p value	F value
January	0.0744	2.14
February	0.0996	1.96
March	0.0092	3.41
April	0.0426	2.49
May	0.0052	3.74
June	0.0012	4.61
July	0.0025	4.16
August	0.0042	3.87
September	0.0055	3.71
October	0.0128	3.22
November	0.0233	2.86
December	0.0066	4.15

Table 34a and 34b show the interaction between control and the phosphorus supplementation treatment groups with the year of the trial. The interaction was significant for the months March through to December, and tended towards significance in January and February. This shows that in certain months phosphorus supplementation would have had an effect on cow weights and in other months cow weights would have been affected only by the year of the trial.

Table 35a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and breed on cow weights (kg)

Treatment	Month	Breed type			
n= 226		B2	B3	B4	B5
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	January	415.1 ± 77.7	471.9 ± 104.9	334.9 ± 67.9	440.4 ± 97.3
T4	January	445.0 ± 95.1	484.4 ± 101.9	333.0 ± 63.1	448.1 ± 97.4
C2	February	421.2 ± 87.5	480.5 ± 96.3	353.8 ± 65.6	446.7 ± 90.2
T4	February	441.3 ± 103.6	504.6 ± 106.0	354.3 ± 61.2	475.7 ± 98.1
C2	March	443.5 ±77.8	505.8 ± 96.9	360.1 ± 64.7	463.5 ± 87.5
T4	March	459.5 ± 93.2	524.5 ± 96.0	362.9 ± 58.2	478.3 ± 91.1
C2	April	448.9 ± 77.5	514.8 ± 92.3	359.9 ± 60.6	469.2 ± 85.5
T4	April	464.0 ± 93.2	522.0 ± 94.2	367.3 ± 56.8	489.0 ± 89.9
C2	May	455.0 ± 73.7	524.1 ± 88.2	369.7 ± 60.7	476.8 ± 87.2
T4	May	474.5 ± 87.7	536.7 ± 93.3	375.5 ± 53.7	497.2 ± 82.7
C2	June	458.9 ± 75.7	525.4 ± 88.3	367.2 ± 59.7	480.2 ± 85.4
T4	June	482.8 ± 89.0	538.9 ± 90.3	372.6 ± 50.2	496.7 ± 82.8
C2	July	460.2 ± 76.0	523.3 ± 89.3	367.6 ± 56.0	480.8 ± 85.1
T4	July	479.6 ± 87.5	536.0 ± 94.1	367.2 ± 59.1	497.4 ± 82.2
C2	August	463.0 ± 77.0	530.9 ± 90.5	370.6 ± 56.7	485.5 ± 84.7
T4	August	486.7 ± 86.9	539.6 ± 93.0	376.4 ± 48.7	503.6 ± 81.1
C2	September	455.1 ± 79.2	537.8 ± 90.2	372.8 ± 54.7	487.1 ± 84.6
T4	September	483.3 ± 84.8	544.3 ± 94.2	377.2 ± 48.5	508.2 ± 80.8
C2	October	441.4 ± 82.8	522.6 ± 85.0	366.7 ± 51.7	470.6 ± 76.7
T4	October	469.8 ± 83.6	530.5 ± 91.9	372.2 ± 50.1	497.4 ± 78.4
C2	November	409.1 ± 67.4	490.5 ± 68.3	342.2 ± 47.3	447.0 ± 68.8
T4	November	449.1 ± 78.7	496.4 ± 83.8	351.1 ± 48.1	470.6 ± 81.7
C2	December	395.5 ± 56.5	475.4 ± 68.5	329.6 ± 43.5	429.4 ± 72.0
T4	December	428.0 ± 68.3	472.7 ± 67.0	336.8 ± 47.5	442.2 ± 58.8

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 35b: Effect of the interaction (ANOVA results) between treatment and breed in different months on cow weights (for Table 35a)

Month	p value	F value
January	0.0747	2.32
February	0.6929	0.48
March	0.2912	1.25
April	0.3228	1.16
May	0.2106	1.55
June	0.2282	1.45
July	0.2042	1.54
August	0.1708	1.68
September	0.1023	2.08
October	0.1192	1.96
November	0.1456	1.80
December	0.1323	1.88

In Table 35a and 35b the interaction between control and phosphorus supplementation with breed of the cow can be seen. No significant interaction was observed for the months of February through to December. January did however tend towards significance. This shows that any effect treatment may have had was not complicated by differences in breed type.

Table 36a: Trial 3- Summary statistics (mean ± std dev) for the interaction between breed type and the year of the trial on cow weights (kg)

Breed type n= 226	Month	Year 1998 Mean ± Std Dev	1999 Mean ± Std Dev	2000 Mean ± Std Dev	2001 Mean ± Std Dev	2002 Mean ± Std Dev
B2	January	414.1 ± 83.4	401.7 ± 110.9	448.3 ± 66.1	462.2 ± 68.2	
B3	January	503.6 ± 66.6	430.3 ± 120.5	493.6 ± 109.9	488.3 ± 102.8	485.1 ± 85.5
B4	January	314.8 ± 61.7	325.9 ± 65.7	341.3 ± 70.7	337.4 ± 65.0	341.8 ± 62.9
B5	January	434.3 ± 83.1	404.2 ± 109.0	457.0 ± 94.0	446.9 ± 106.1	469.1 ± 78.2
B2	February	283.3 ± 17.0	413.6 ± 104.7	468.1 ± 64.5	-	-
B3	February	362.0	456.4 ± 110.7	500.8 ± 103.4	504.5 ± 97.7	518.2 ± 86.6
B4	February	355.6 ± 63.5	349.1 ± 64.7	346.7 ± 65.1	357.0 ± 65.4	360.4 ± 60.7
B5	February	303.0 ± 9.9	437.1 ± 106.3	469.7 ± 79.4	462.7 ± 103.0	483.2 ± 81.5
B2	March	454.9 ±78.7	421.7 ± 100.4	480.2 ± 65.2	-	-
B3	March	538.2 ± 63.7	481.7 ± 114.7	520.8 ± 100.9	510.7 ± 98.9	531.0 ± 87.2
B4	March	354.2 ± 97.3	355.5 ± 58.4	361.9 ± 66.3	357.7 ± 61.2	373.3 ± 57.0
B5	March	479.2 ± 84.6	432.3 ± 97.5	478.5 ± 77.4	466.6 ± 92.4	498.4 ± 83.2
B2	April	464.7 ± 81.1	425.5 ± 99.8	482.2 ± 63.4	-	-
B3	April	545.4 ± 61.2	467.6 ± 109.0	529.3 ± 96.5	524.0 ± 92.1	537.4 ± 75.4
B4	April	363.5 ± 58.5	342.9 ± 54.8	366.2 ± 62.0	368.9 ± 61.4	371.6 ± 55.4
B5	April	483.6 ± 84.0	426.2 ± 92.7	486.8 ± 76.8	493.1 ± 86.9	502.5 ± 82.2
B2	May	476.4 ± 82.2	440.4 ± 94.2	480.8 ± 59.9	-	-
B3	May	561.3 ± 62.8	486.5 ± 105.4	531.6 ± 95.0	549.0 ± 92.1	536.7 ± 74.7
B4	May	364.2 ± 55.8	369.9 ± 53.2	372.7 ± 61.0	381.9 ± 60.6	371.0 ± 56.4
B5	May	501.0 ± 83.0	446.2 ± 88.7	492.5 ± 76.4	499.1 ± 87.8	498.0 ± 81.7
B2	June	484.5 ± 81.6	441.1 ± 95.2	490.9 ± 62.1	-	-
B3	June	564.0 ± 62.6	489.1 ± 102.3	534.7 ± 91.8	543.7 ± 93.6	540.0 ± 75.0
B4	June	366.9 ± 54.0	361.9 ± 51.3	375.4 ± 59.4	380.3 ± 58.7	362.8 ± 51.4
B5	June	506.7 ± 81.6	449.1 ± 86.7	499.3 ± 75.2	502.8 ± 87.7	489.9 ± 79.7
B2	July	487.5 ± 78.8	435.8 ± 92.6	491.2 ± 61.6	-	-
B3	July	575.7 ± 65.9	482.7 ± 98.1	537.8 ± 94.9	534.6 ± 97.3	536.2 ± 75.5
B4	July	370.6 ± 51.6	360.8 ± 51.6	368.1 ± 79.7	378.8 ± 50.5	358.5 ± 49.3
B5	July	512.4 ± 81.4	448.7 ± 85.8	507.4 ± 76.0	498.5 ± 87.2	486.7 ± 76.2
B2	August	496.9 ± 78.6	440.9 ± 95.0	492.3 ± 59.8	-	-
B3	August	585.8 ± 67.7	489.5 ± 98.5	542.4 ± 96.7	534.0 ± 91.6	543.4 ± 76.3
B4	August	381.3 ± 50.8	369.1 ± 51.3	385.7 ± 59.1	373.4 ± 50.6	360.4 ± 49.5
B5	August	521.4 ± 78.1	457.6 ± 83.4	518.7 ± 73.1	493.7 ± 85.9	494.7 ± 81.4

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 36a (continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between breed type and the year of the trial on cow weights (kg)

Breed	Month	Year				
type		1998	1999	2000	2001	2002
n= 226		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B2	September	490.3 ± 80.0	437.4 ± 92.7	485.4 ± 64.8	-	-
B3	September	588.1 ± 64.7	494.7 ± 97.7	536.0 ± 99.5	547.1 ± 93.0	556.2 ± 77.3
B4	September	383.4 ± 50.6	365.6 ± 51.2	385.4 ± 54.6	379.9 ± 50.4	361.8 ± 49.5
B5	September	530.9 ± 76.5	464.4 ± 82.1	518.8 ± 81.5	489.5 ± 83.2	502.9 ± 80.0
B2	October	482.4 ± 71.0	445.1 ± 96.4	443.7 ± 77.2	-	-
B3	October	557.4 ± 56.3	495.2 ± 97.2	490.3 ± 85.6	545.7 ± 95.8	555.0 ± 75.1
B4	October	386.4 ± 48.7	374.8 ± 50.0	351.3 ± 51.9	380.6 ± 48.6	358.6 ± 49.2
B5	October	512.3 ± 57.9	471.3 ± 84.0	459.1 ± 75.1	485.6 ± 81.2	498.5 ± 79.8
B2	November	431.7 ± 64.6	411.4 ± 86.1	447.6 ± 70.3	-	-
B3	November	505.0 ± 55.9	449.0 ± 86.4	521.4 ± 69.4	516.0 ± 87.9	492.5 ± 63.5
B4	November	333.1 ± 39.6	329.1 ± 43.2	349.6 ± 52.4	378.7 ± 45.5	334.5 ± 38.9
B5	November	440.9 ± 70.6	430.7 ± 80.2	475.1 ± 70.8	481.5 ± 84.0	457.6 ± 63.4
B2	December	411.4 ± 52.9	413.4 ± 72.9	-	-	-
B3	December	458.2 ± 47.0	476.6 ± 82.3	-	476.4 ± 61.8	480.2 ± 70.6
B4	December	318.1 ± 40.7	343.3 ± 45.7	-	343.4 ± 52.1	324.5 ± 37.5
B5	December	419.0 ± 57.0	449.9 ± 80.8	-	441.2 ± 63.6	428.4 ±56.8

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)

B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 36b: Effect of the interaction (ANOVA results) between breed type and year in different months on cow weights (for Table 36a)

Month	p value	F value
January	0.3479	1.11
February	0.0995	1.61
March	0.7247	0.70
April	0.6100	0.82
May	0.7562	0.67
June	0.7552	0.67
July	0.4512	0.99
August	0.5574	0.88
September	0.6728	0.75
October	0.7807	0.64
November	0.8678	0.53
December	0.8475	0.48

Table 36a and 36b shows the interaction between the year of the trial and the breed type of the cow. There was no significant interaction between these two factors except for a tendency towards significance in February. Again changes in weight over the various years can be attributed to changes in rainfall and temperature. A reason for there being no interaction could be due to the breeds being adapted to the climate and therefore being less affected by changes in temperature.

Table 37a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on cow weights (kg)

Treatment	Breed type	Month	Year				
n= 226			1998	1999	2000	2001	2002
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	January	394.2 ± 83.3	397.8 ± 98.1	431.4 ± 58.6	439.0 ± 60.3	-
T4	B2	January	434.0 ± 82.8	405.3 ± 125.3	465.3 ± 71.2	483.3 ± 70.7	-
C2	B3	January	515.9 ± 69.5	440.7 ± 126.4	496.1 ± 123.9	464.0 ± 96.6	452.8 ± 75.5
T4	B3	January	491.3 ± 65.1	419.8 ± 118.1	491.0 ± 98.2	510.8 ± 107.0	512.8 ± 86.3
C2	B4	January	315.1 ± 69.8	337.8 ± 62.6	351.1 ± 73.7	335.7 ± 66.0	330.0 ± 68.7
T4	B4	January	314.5 ± 54.4	315.4 ± 68.3	331.0 ± 67.7	339.2 ± 65.6	356.6 ± 52.6
C2	B5	January	451.8 ± 93.6	420.9 ± 118.7	454.6 ± 102.9	432.5 ± 101.6	444.6 ± 73.2
T4	B5	January	418.3 ± 73.1	388.5 ± 100.1	459.2 ± 87.3	460.7 ± 111.1	493.6 ± 77.2
C2	B2	February	283.0 ± 24.0	412.8 ± 98.4	452.5 ± 55.3	-	-
T4	B2	February	284.0	414.3 ± 114.3	483.7 ± 71.4	-	-
C2	B3	February	-	461.7 ± 117.6	498.3 ± 103.1	479.2 ± 91.4	484.3 ± 75.3
T4	B3	February	362.0	451.4 ± 108.2	503.3 ± 108.4	527.8 ± 101.0	547.3 ± 87.5
C2	B4	February	355.1 ± 72.4	367.0 ± 61.3	350.9 ± 68.0	351.1 ± 64.8	349.1 ± 67.3
T4	B4	February	356.0 ± 55.2	332.2 ± 65.1	342.4 ± 63.6	363.1 ± 67.1	374.6 ± 49.4
C2	B5	February	296.0	449.4 ± 118.6	458.1 ± 76.9	440.6 ± 95.2	450.2 ± 70.1
T4	B5	February	310.0	426.9 ± 97.5	479.8 ± 82.7	483.7 ± 108.0	516.1 ± 80.3

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 37a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on cow weights (kg)

Treatment	Breed type	Month	Year				
n= 226			1998	1999	2000	2001	2002
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	March	441.6 ± 80.7	423.3 ± 93.6	465.3 ± 55.7	-	-
T4	B2	March	468.2 ± 78.6	420.2 ± 110.1	495.0 ± 72.9	-	-
C2	B3	March	552.9 ± 62.7	490.8 ± 124.3	516.5 ± 101.8	478.3 ± 88.6	503.3 ± 87.8
T4	B3	March	523.6 ± 64.8	471.8 ± 108.0	525.2 ± 104.4	540.6 ± 101.7	554.7 ± 82.3
C2	B4	March	351.1 ± 81.0	358.3 ± 56.8	374.4 ± 70.2	352.0 ± 61.4	362.4 ± 60.9
T4	B4	March	357.5 ± 51.8	352.8 ± 61.4	349.4 ± 61.5	363.7 ± 62.0	387.0 ± 49.9
C2	B5	March	500.0 ± 97.0	458.7 ± 112.0	466.4 ± 72.8	449.6 ± 88.7	459.7 ± 71.8
T4	B5	March	460.4 ± 70.9	409.1 ± 79.0	488.4 ± 81.8	482.7 ± 95.1	537.1 ± 77.0
C2	B2	April	452.2 ± 84.7	426.2 ± 92.9	469.0 ± 50.1		
T4	B2	April	477.2 ± 79.8	424.9 ± 109.5	495.3 ± 74.3		
C2	B3	April	564.2 ± 60.5	482.0 ± 121.5	523.8 ± 96.3	497.7 ± 86.3	521.2 ± 70.2
T4	B3	April	526.7 ± 59.1	454.3 ± 98.7	534.8 ± 100.6	548.3 ± 93.8	551.3 ± 79.4
C2	B4	April	363.1 ± 67.2	344.3 ± 53.0	364.0 ± 63.8	362.1 ± 62.2	363.2 ± 61.0
T4	B4	April	363.8 ± 50.2	341.6 ± 58.1	368.2 ± 62.0	376.0 ± 61.3	382.0 ± 46.9
C2	B5	April	497.6 ± 91.9	442.3 ± 104.4	480.1 ± 75.2	472.6 ± 87.4	463.9 ± 72.3
T4	B5	April	470.8 ± 78.3	412.0 ± 81.6	492.2 ± 79.9	513.5 ± 83.7	541.1 ± 74.4

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 37a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on cow weights (kg)

Treatment	Breed type	Month	Year				
n= 226			1998	1999	2000	2001	2002
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	May	465.4 ± 85.3	431.4 ± 84.8	469.8 ± 47.1	-	-
T4	B2	May	487.4 ± 82.0	448.6 ± 104.9	491.8 ± 70.9	-	-
C2	B3	May	578.7 ± 61.3	501.4 ± 116.0	522.0 ± 95.1	512.0 ± 75.1	520.1 ± 67.7
T4	B3	May	544.0 ± 62.9	471.5 ± 95.9	541.2 ± 98.1	577.4 ± 96.4	550.9 ± 79.9
C2	B4	May	365.3 ± 63.9	370.4 ± 54.4	374.4 ± 66.0	377.0 ± 61.8	361.8 ± 61.8
T4	B4	May	363.1 ± 48.1	369.4 ± 53.8	371.1 ± 57.7	386.0 ± 60.7	382.6 ± 48.0
C2	B5	May	523.0 ± 96.8	451.3 ± 107.2	484.0 ± 75.4	483.8 ± 84.6	459.1 ± 73.0
T4	B5	May	480.9 ± 66.4	442.0 ± 73.3	499.4 ± 78.8	514.4 ± 90.5	536.9 ± 72.0
C2	B2	June	474.0 ± 84.7	427.0 ± 84.2	478.2 ± 49.8	-	-
T4	B2	June	495.0 ± 81.4	454.2 ± 106.0	503.7 ± 72.3	-	-
C2	B3	June	581.1 ± 63.9	504.3 ± 115.1	524.9 ± 88.3	505.8 ± 83.7	523.5 ± 67.9
T4	B3	June	546.9 ± 59.9	472.7 ± 88.4	544.5 ± 98.1	572.8 ± 93.2	554.1 ± 80.3
C2	B4	June	368.3 ± 62.4	362.5 ± 52.3	384.2 ± 63.0	374.8 ± 66.4	348.4 ± 53.2
T4	B4	June	365.4 ± 45.8	361.4 ± 52.0	367.2 ± 56.2	385.8 ± 51.1	379.7 ± 44.9
C2	B5	June	527.4 ± 94.5	464.8 ± 104.6	494.7 ± 74.3	481.6 ± 81.3	450.6 ± 66.1
T4	B5	June	487.8 ± 66.8	435.2 ± 67.4	503.1 ± 78.0	523.9 ± 90.9	529.1 ± 73.9

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 37a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on cow weights (kg)

Treatment	Breed type	Month	Year				
n= 226			1998	1999	2000	2001	2002
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	July	478.6 ± 82.1	425.2 ± 85.1	480.0 ± 50.0	-	-
T4	B2	July	496.3 ± 78.7	445.7 ± 101.5	502.3 ± 72.0	-	-
C2	B3	July	593.6 ± 64.7	498.6 ± 109.2	520.0 ± 89.6	490.0 ± 81.0	528.3 ± 67.8
T4	B3	July	557.8 ± 65.8	467.9 ± 88.1	555.5 ± 100.5	568.9 ± 97.5	542.9 ± 83.4
C2	B4	July	371.6 ± 57.3	360.5 ± 54.8	386.9 ± 61.6	376.2 ± 53.5	345.6 ± 50.0
T4	B4	July	369.5 ± 47.1	361.1 ± 50.0	350.2 ± 91.7	381.3 ± 48.6	373.4 ± 45.4
C2	B5	July	533.9 ± 94.7	465.3 ± 100.3	498.3 ± 76.1	474.7 ± 80.6	454.0 ± 66.8
T4	B5	July	492.9 ± 65.5	434.0 ± 70.7	514.9 ± 77.4	522.3 ± 89.1	519.4 ± 72.4
C2	B2	August	488.1 ± 83.9	427.8 ± 87.7	477.2 ± 46.9	-	-
T4	B2	August	505.7 ± 76.4	452.9 ± 103.3	507.5 ± 69.0	-	-
C2	B3	August	605.8 ± 65.1	503.7 ± 109.0	527.8 ± 89.3	501.6 ± 84.8	531.8 ± 69.3
T4	B3	August	565.8 ± 67.8	476.3 ± 89.6	557.0 ± 105.5	558.9 ± 91.8	553.3 ± 83.0
C2	B4	August	383.6 ± 56.7	368.0 ± 54.2	398.3 ± 63.9	367.5 ± 52.7	343.2 ± 46.2
T4	B4	August	378.8 ± 45.8	370.1 ± 50.1	373.7 ± 53.1	379.2 ± 49.2	380.4 ± 46.6
C2	B5	August	541.0 ± 88.9	468.8 ± 97.6	512.0 ± 75.3	470.5 ± 78.5	462.5 ± 71.3
T4	B5	August	503.6 ± 66.1	447.6 ± 70.3	524.1 ± 73.3	516.9 ± 88.6	526.9 ± 80.0

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 37a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on cow weights (kg)

Treatment	Breed type	Month	Year				
n= 226			1998	1999	2000	2001	2002
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	September	479.8 ± 85.2	419.6 ± 83.0	470.0 ± 61.8	-	-
T4	B2	September	500.8 ± 77.6	453.7 ± 101.3	500.8 ± 66.8	-	-
C2	B3	September	607.1 ± 64.4	512.0 ± 106.7	530.7 ± 96.8	509.4 ± 80.0	544.7 ± 71.4
T4	B3	September	569.1 ± 62.7	478.7 ± 89.3	541.8 ± 106.8	576.2 ± 94.7	566.1 ± 83.4
C2	B4	September	384.7 ± 56.3	367.4 ± 52.2	388.8 ± 58.6	376.8 ± 54.3	351.1 ± 50.1
T4	B4	September	382.0 ± 46.1	363.8 ± 51.9	382.4 ± 52.1	382.9 ± 47.4	373.8 ± 47.3
C2	B5	September	550.0 ± 86.0	472.0 ± 96.6	508.8 ± 82.4	463.5 ± 73.9	473.5 ± 71.0
T4	B5	September	513.5 ± 65.9	457.8 ± 69.4	527.4 ± 82.8	515.6 ± 85.7	532.4 ± 79.5
C2	B2	October	475.4 ± 78.9	425.5 ± 87.7	429.0 ± 79.3	-	-
T4	B2	October	489.4 ± 65.7	463.2 ± 104.0	459.8 ± 75.1	-	-
C2	B3	October	560.9 ± 56.7	518.8 ± 106.7	487.7 ± 86.0	506.0 ± 90.2	546.3 ± 65.6
T4	B3	October	554.0 ± 59.1	475.0 ± 87.0	492.8 ± 89.0	576.2 ± 91.6	563.1 ± 84.8
C2	B4	October	384.1 ± 54.3	381.3 ± 50.6	352.1 ± 46.5	378.5 ± 51.5	344.5 ± 48.2
T4	B4	October	388.8 ± 43.9	368.3 ± 50.2	350.5 ± 57.5	382.6 ± 46.7	375.1 ± 46.2
C2	B5	October	516.2 ± 59.5	476.9 ± 97.9	442.7 ± 69.5	461.1 ± 70.1	468.8 ± 73.8
T4	B5	October	508.7 ± 59.2	466.7 ± 73.4	473.1 ± 79.4	510.1 ± 85.9	528.3 ± 76.4

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 37a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on cow weights (kg)

Treatment	Breed type	Month	Year				
n= 226			1998	1999	2000	2001	2002
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	November	418.2 ± 69.1	387.5 ± 72.2	424.4 ± 59.9	-	-
T4	B2	November	445.2 ± 60.3	433.5 ± 94.5	470.9 ± 74.7	-	-
C2	B3	November	511.3 ± 55.8	481.8 ± 91.2	499.6 ± 75.5	479.6 ± 67.5	486.7 ± 60.3
T4	B3	November	498.7 ± 58.7	423.7 ± 76.4	531.3 ± 67.8	548.8 ± 94.3	497.4 ± 68.0
C2	B4	November	339.7 ± 39.8	324.9 ± 41.8	347.6 ± 45.0	377.2 ± 48.7	318.1 ± 37.2
T4	B4	November	326.0 ± 39.7	333.3 ± 45.5	351.5 ± 60.3	380.1 ± 43.3	352.7 ± 33.0
C2	B5	November	447.6 ± 60.8	430.5 ± 87.5	454.2 ± 61.0	461.1 ± 71.2	440.4 ± 61.2
T4	B5	November	434.2 ± 82.0	430.9 ± 75.3	493.2 ± 75.7	503.2 ± 93.0	474.8 ± 62.6
C2	B2	December	393.3 ± 50.8	397.2 ± 62.6	-	-	-
T4	B2	December	427.6 ± 51.9	428.3 ± 80.9	-	-	-
C2	B3	December	472.7 ± 41.0	489.8 ± 90.6	-	457.3 ± 54.1	479.2 ± 76.7
T4	B3	December	443.8 ± 50.4	465.4 ± 76.5	-	491.1 ± 65.3	481.0 ± 67.9
C2	B4	December	321.8 ± 46.8	352.8 ± 43.1	-	336.9 ± 43.9	310.1 ± 32.6
T4	B4	December	314.3 ± 35.1	333.8 ± 47.7	-	349.7 ± 59.3	341.3 ± 36.6
C2	B5	December	427.0 ± 61.9	462.2 ± 104.6	-	423.1 ± 54.7	411.6 ± 61.2
T4	B5	December	411.8 ± 54.1	439.9 ± 56.4	-	459.3 ± 68.0	445.3 ± 48.2

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 37b: Effect of the interaction (ANOVA results) between treatment, breed type and year in different months on cow weights (for Table 37a)

Month	p value	F value
January	0.7298	0.71
February	0.9162	0.43
March	0.1587	1.44
April	0.5706	0.86
May	0.6618	0.77
June	0.8159	0.60
July	0.4280	1.02
August	0.8674	0.53
September	0.8596	0.54
October	0.6765	0.75
November	0.2527	1.26
December	0.9192	0.37

Tables 37a and 37b show the interaction between three factors, namely control and phosphorus supplementation with breed of cow and the trial year. There was no significant interaction between these factors.

4.2.2 Heifers

In this section the effects of various factors on the growth of heifers were quantified in terms of weight of the heifers.

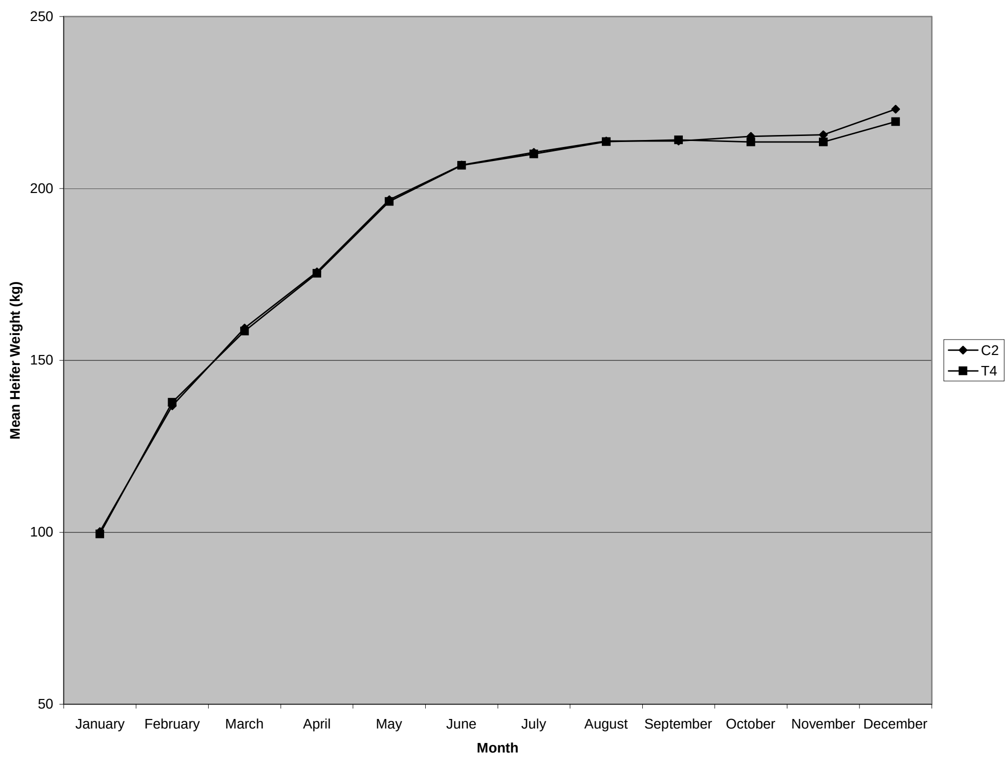
Table 38a: Trial 3- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on heifer weights (kg)

Month	**C2**	**T4**
n= 139	**Mean ± Std Dev**	**Mean ± Std Dev**
January	100.2 ± 25.9	99.5 ± 25.3
February	136.8 ± 36.6	137.8 ± 36.4
March	159.4 ± 34.7	158.5 ± 34.6
April	175.7 ± 37.3	175.3 ± 37.2
May	196.7 ± 39.2	196.2 ± 36.6
June	206.8 ± 41.3	206.7 ± 40.5
July	210.5 ± 40.6	210.0 ± 39.6
August	213.8 ± 40.5	213.6 ± 40.3
September	213.8 ± 41.5	214.1 ± 41.6
October	215.1 ± 40.8	213.5 ± 40.5
November	215.6 ± 41.2	213.5 ± 41.3
December	223.0 ± 40.4	219.4 ± 43.8
Average	**188.9 ± 38.3**	**188.2 ± 38.0**

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 38b: Effect of treatment (ANOVA results) in different months on heifer weights (For Table 38a)

Month	p value	F value
January	0.7979	0.07
February	0.8460	0.04
March	0.8872	0.02
April	0.9145	0.01
May	0.9521	0.00
June	0.9349	0.01
July	0.8827	0.02
August	0.8752	0.02
September	0.9056	0.01
October	0.6741	0.18
November	0.7908	0.07
December	0.6767	0.17



Graph 12: Trial 3- Effect of treatment and month on mean heifer weights (kg)

Tables 38a and 38b show that in the heifer group, there was no significant difference between the control group and the group receiving phosphorus supplementation with regard to weights over the months. On closer inspection of the table there is no real difference at all between the two groups. Both groups grew at the same rate and were consistently similar throughout. This can clearly be seen in Graph 12. This similarity between the two groups could be due to the fact that young animals seem to be able to adjust their rate of bone deposition in response to nutritional changes, with mature animals losing this ability (Braithwaite, 1975). This ability would result in the heifers being able to adjust to any phosphorus deficiencies and therefore there would be no effect from phosphorus supplementation. Another reason could be that the heifers were only in the system for one year before having their first calf. This short time span could to a degree explain the lack of differences between the two groups.

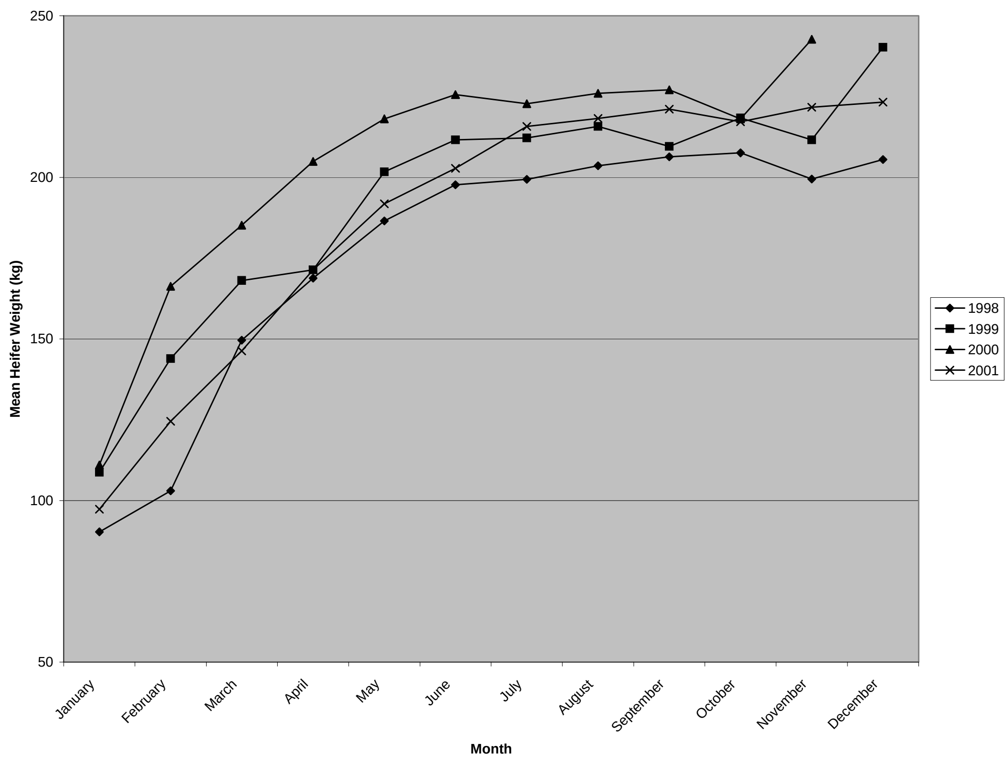
Table 39a: Trial 3- Summary statistics (mean ± std dev) for the effect of year of the trial on heifer weights (kg)

Month	**Year**			
n= 139	**1998**	**1999**	**2000**	**2001**
	Mean ± Std Dev	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**
January	90.3 ± 21.3 ^{B}	108.7 ± 24.6 ^{AC}	111.0 ± 26.9 ^{A}	97.3 ± 26.1 ^{BC}
February	103.0 ± 19.0 ^{A}	143.9 ± 31.4 ^{B}	166.3 ± 38.9 ^{C}	124.5 ± 28.6 ^{D}
March	149.6 ± 29.0 ^{C}	168.1 ± 33.2 ^{A}	185.2 ± 39.1 ^{B}	146.3 ± 29.5 ^{C}
April	168.8 ± 30.5 ^{B}	171.4 ± 36.9 ^{B}	204.9 ± 39.7 ^{A}	171.4 ± 37.3 ^{B}
May	186.5 ± 32.4 ^{A}	201.7 ± 34.4 ^{BC}	218.1 ± 40.0 ^{B}	191.8 ± 42.1 ^{AC}
June	197.7 ± 34.8 ^{B}	211.6 ± 39.9 ^{AB}	225.6 ± 41.8 ^{A}	202.8 ±45.8 ^{B}
July	199.4 ± 34.1 ^{A}	212.2 ± 39.5 ^{AB}	222.8 ± 39.8 ^{B}	215.8 ± 45.9 ^{B}
August	203.6 ± 34.4 ^{A}	215.8 ± 40.1 ^{AB}	226.0 ± 38.9 ^{B}	218.2 ± 46.9 ^{AB}
September	206.4 ± 35.2 ^{a}	209.6 ± 41.3 ^{ab}	227.1 ± 40.5 ^{b}	221.1 ± 48.3 ^{ab}
October	207.6 ± 35.8 ^{a}	218.4 ± 42.8 ^{a}	218.1 ± 37.7 ^{a}	217.2 ± 46.0 ^{a}
November	199.5 ± 33.7 ^{B}	211.6 ± 38.1 ^{BC}	242.7 ± 38.7 ^{A}	221.7 ± 46.0 ^{C}
December	205.5 ± 32.0 ^{A}	240.3 ± 45.5 ^{B}	-	223.3 ±42.8 ^{C}
Average	**176.5 ± 31.0**	**192.8 ± 37.3**	**187.3 ± 35.2**	**187.6 ± 40.4**

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
$^{A, B, C}$ Row means with different superscripts differ ($p < 0.001$)

Table 39b: Effect of year (ANOVA results) in different months on heifer weights (for Table 39a)

Month	p value	F value
January	<0.0001	16.06
February	<0.0001	21.65
March	<0.0001	24.07
April	<0.0001	13.34
May	<0.0001	14.29
June	<0.0001	9.73
July	0.0003	6.87
August	0.0006	6.24
September	0.0103	3.94
October	0.0029	4.96
November	<0.0001	15.50
December	<0.0001	37.99



Graph 13: Trial 3- Effect of year and month on mean heifer weights (kg)

In Tables 39a and 39b it can be seen that the year of the trial had a significant effect on the weights of heifers. This would be due to climate differences, which cause changes in pasture and therefore availability of grazing to the animals. In general it could be seen that mean weights were best in 1999. Grazing was obviously good that year which is reflected in higher mean weights of heifers in that particular year. Judkins *et al*. (1985) found that grazing cattle only responded to phosphorus supplementation during drought. The lowest weights occurred in 1998. Again a growth pattern can be seen with a substantial increase in weight for the first half of the year and then a levelling off towards the end of the year (Graph 13).

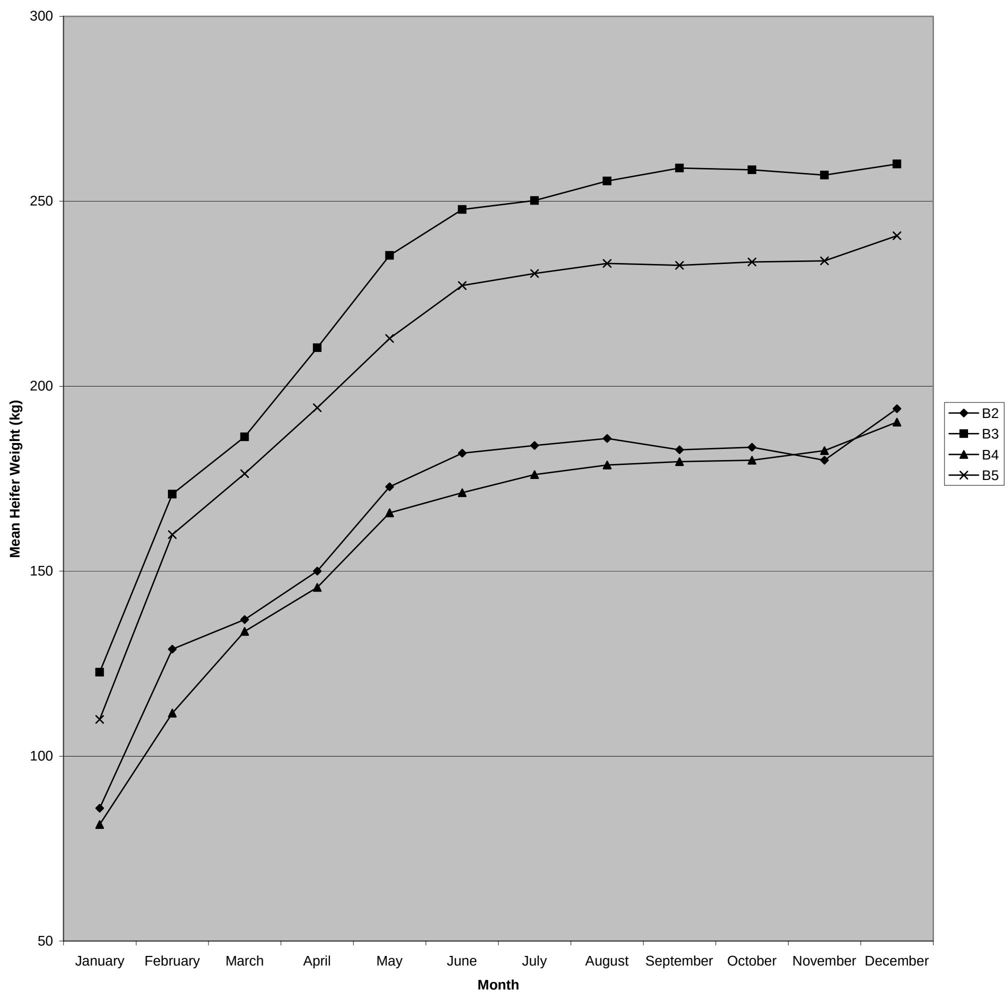
Table 40a: Trial 3- Summary statistics (mean ± std dev) for the effect of the different breed types on heifer weights (kg)

Month	**Breed type**			
n= 139	**B2**	**B3**	**B4**	**B5**
	Mean ± Std Dev	**Mean ± Std Dev**	**Mean ± Std Dev**	**Mean ± Std Dev**
January	85.9 ± 17.0 [c]	122.7 ± 22.5 [a]	81.5 ± 15.0 [c]	109.9 ± 21.6 [b]
February	128.9 ± 19.4 [a]	170.8 ± 32.2 [b]	111.6 ± 19.8 [a]	159.9 ±30.8 [b]
March	136.9 ± 21.4 [a]	186.3 ± 30.9 [b]	133.7 ± 21.2 [a]	176.4 ± 27.9 [b]
April	150.0 ± 20.7 [c]	210.4 ± 29.2 [a]	145.6 ± 21.2 [c]	194.2 ± 27.1 [b]
May	172.8 ± 24.1 [c]	235.4 ± 31.7 [a]	165.8 ± 20.1 [c]	212.9 ± 25.4 [b]
June	181.9 ± 22.7 [c]	247.8 ± 32.8 [a]	171.2 ± 19.5 [c]	227.2 ± 27.3 [b]
July	184.0 ± 22.5 [c]	250.2 ± 34.5 [a]	176.1 ± 18.3 [c]	230.5 ± 25.7 [b]
August	185.9 ± 21.6 [c]	255.5 ± 34.8 [a]	178.7 ± 17.4 [c]	233.2 ± 24.4 [b]
September	182.8 ± 19.4 [c]	259.0 ± 34.8 [a]	179.6 ± 19.3 [c]	232.7 ± 25.7 [b]
October	183.5 ± 19.7 [c]	258.5 ± 31.9 [a]	180.0 ± 17.8 [c]	233.6 ± 25.6 [b]
November	180.0 ± 22.6 [c]	257.1 ± 35.7 [a]	182.6 ± 20.1 [c]	233.9 ± 25.9 [b]
December	193.9 ± 28.4 [c]	260.1 ± 40.5 [a]	190.3 ± 20.2 [c]	240.7 ± 30.5 [b]
Average	**163.9 ± 21.6**	**226.2 ± 32.6**	**158.1 ± 19.2**	**207.1 ± 26.5**

[a, b, c] Row means with different superscripts differ ($p < 0.001$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 40b: Effect of breed (ANOVA results) in different months on heifer weights (for Table 40a)

Month	p value	F value
January	<0.0001	46.00
February	<0.0001	40.13
March	<0.0001	54.53
April	<0.0001	62.75
May	<0.0001	68.24
June	<0.0001	73.17
July	<0.0001	66.71
August	<0.0001	71.03
September	<0.0001	68.30
October	<0.0001	80.37
November	<0.0001	72.06
December	<0.0001	68.57



Graph 14: Trial 3- Effect of breed and month on mean heifer weights (kg)

In Tables 40a and 40b it can be seen that breed type had a significant effect on heifer weight. This is also clear in Graph 15. When the table is examined it can be seen that there was no significant difference between Afrikaner type and Nguni type heifers. This could be explained by the fact that both could be considered smaller breed types, with average breed weights at twelve and eighteen months being 211kg and 290kg for Afrikaner types and 178kg and 239kg for Nguni types respectively (Beef breeding in South Africa, ARC- Animal Improvement Institute). We can also see that Simmentaler heifers weighed more than the heifers of the other three breeds, which is in agreement with them being a large breed with breed averages for twelve and eighteen months being 299kg and 384kg respectively (Beef breeding in South Africa, ARC- Animal Improvement Institute). The Bonsmara type had an average weight between these two groups and could be regarded as leaning towards being a larger breed with breed averages at twelve and eighteen months being 248kg and 325kg respectively (Beef breeding in South Africa, ARC- Animal Improvement Institute).

Table 41a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and the year of the trial on heifer weights (kg)

Treatment	Month	Year			
n= 139		1998	1999	2000	2001
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	January	91.7 ± 21.4	107.6 ± 24.1	110.3 ± 29.5	96.6 ± 28.2
T4	January	88.8 ± 21.7	110.1 ± 26.0	112 ± 24.7	98.1 ± 24.6
C2	February	102.0 ± 14.8	142.9 ± 31.8	161.8 ± 42.4	124.2 ± 29.5
T4	February	104 ± 23.9	145.1 ± 31.8	172.2 ± 35.1	124.7 ±28.6
C2	March	151.4 ± 29.2	166.1 ± 34.3	182.7 ± 40.7	146.2 ± 30.4
T4	March	147.8 ± 29.3	170.6 ± 32.6	188.7 ± 38.9	146.4 ± 29.6
C2	April	169.5 ± 30.1	171.6 ± 39.6	200.7 ± 40.2	171.6 ± 37.7
T4	April	168.0 ± 31.6	171.1 ± 34.6	210.4 ± 40.5	171.1 ± 37.9
C2	May	187.3 ± 34.1	201.1 ± 38.4	214.0 ± 41.6	193.1 ± 43.7
T4	May	185.7 ± 31.3	202.6 ± 30.1	223.6 ± 39.5	190.6 ± 41.7
C2	June	198.8 ± 36.0	209.8 ± 40.9	220.7 ± 42.6	205.1 ± 48.1
T4	June	196.7 ± 34.3	213.9 ± 39.9	232.2 ± 42.1	200.6 ± 44.7
C2	July	200.2 ± 34.4	212.0 ± 40.6	218.3 ± 41.3	217.6 ± 48.1
T4	July	198.7 ± 34.5	212.5 ± 39.5	228.7 ± 39.2	213.9 ± 45.1
C2	August	205.3 ± 35.3	214.5 ± 39.8	222.3 ± 40.6	218.9 ± 48.8
T4	August	201.9 ± 34.2	217.5 ± 41.7	230.9 ± 38.4	217.4 ± 46.5
C2	September	208.3 ± 35.2	209.3 ± 41.2	219.5 ± 42.4	222.8 ± 50.3
T4	September	204.5 ± 35.9	209.9 ± 42.7	237.3 ± 37.7	219.3 ± 47.6
C2	October	208.2 ± 35.5	220.5 ± 43.7	215.7 ± 39.3	218.2 ± 47.0
T4	October	207.0 ± 36.9	215.9 ± 42.9	221.3 ± 37.4	216.2 ± 46.5
C2	November	200.5 ± 34.1	212.8 ± 37.2	241.7 ± 42.1	221.9 ± 46.8
T4	November	198.6 ± 33.9	210.0 ± 40.2	244.0 ± 36.1	221.5 ± 46.6
C2	December	207.3 ± 29.8	241.3 ± 42.7	-	223.9 ± 43.4
T4	December	203.8 ± 34.6	239.3 ± 50.0	-	222.8 ± 43.4

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 41b: Effect of the interaction (ANOVA results) between treatment and year in different months on heifer weights (for Table 41a)

Month	p value	F value
January	0.8140	0.32
February	0.9918	0.03
March	0.9242	0.16
April	0.9804	0.06
May	0.9376	0.14
June	0.8487	0.27
July	0.9663	0.09
August	0.9669	0.09
September	0.7538	0.40
October	0.9392	0.13
November	0.9826	0.06
December	0.9248	0.08

It can be seen from Tables 41a and 41b that the interaction between the year of the trial with control or phosphorus supplementation was not significant. This means that any effect treatment may have had on heifer weights has not been complicated by year effect.

Table 42a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and breed type on heifer weights (kg)

Treatment	Month	Breed type			
n= 139		B1	B2	B3	B4
		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	January	88.0 ± 19.4	123.9 ± 23.0	81.2 ± 13.8	110.8 ± 22.6
T4	January	82.9 ± 13.5	121.5 ± 22.7	81.7 ± 16.5	108.9 ± 21.0
C2	February	128.8 ± 23.7	169.8 ± 35.9	110.6 ± 17.4	161.1 ± 31.6
T4	February	129.0 ± 1.41	171.8 ± 29.9	112.6 ±22.5	157.7 ± 31.1
C2	March	139.0 ± 25.7	187.9 ± 30.5	132.6 ± 19.3	178.7 ± 27.1
T4	March	134.0 ± 14.9	184.8 ± 32.2	134.8 ± 23.6	173.9 ± 29.2
C2	April	151.4 ± 25.6	211.2 ± 27.7	145.0 ± 21.0	196.4 ± 25.9
T4	April	148.0 ± 12.2	209.6 ± 31.5	146.2 ± 21.9	191.9 ± 28.8
C2	May	174.0 ± 27.8	238.5 ± 30.1	164.5 ± 19.2	215.2 ± 27.4
T4	May	171.1 ± 19.7	232.3 ± 34.0	167.3 ± 21.3	210.4 ± 23.5
C2	June	183.0 ±26.0	252.0 ± 29.7	170.5 ± 19.0	227.3 ± 27.6
T4	June	180.3 ± 18.8	243.6 ± 36.2	172.0 ± 20.4	227.1 ± 27.8
C2	July	185.1 ± 26.2	254.7 ± 30.8	175.0 ± 17.6	231.2 ± 25.7
T4	July	182.4 ± 17.7	245.8 ± 38.4	177.2 ± 19.3	229.7 ± 26.3
C2	August	187.2 ± 25.7	259.2 ± 31.7	178.6 ± 16.7	233.9 ± 24.4
T4	August	184.0 ± 15.7	251.9 ± 38.4	178.8 ± 18.6	232.5 ± 25.0
C2	September	183.4 ± 23.0	261.5 ± 31.0	180.0 ± 18.6	232.6 ± 28.1
T4	September	182.0 ± 14.5	256.5 ± 39.2	179.1 ± 20.3	232.8 ± 23.5
C2	October	184.6 ± 22.7	260.1 ± 29.2	181.1 ± 17.8	236.0 ± 27.6
T4	October	182.0 ± 16.0	256.8 ± 35.3	178.9 ± 18.2	231.0 ± 23.6
C2	November	180.4 ± 24.6	259.5 ± 33.5	184.2 ± 19.9	236.5 ± 26.5
T4	November	179.4 ± 21.3	254.8 ± 38.8	180.9 ± 20.6	231.0 ± 25.5
C2	December	197.8 ± 27.8	260.9 ± 36.4	194.5 ± 22.3	240.7 ± 32.6
T4	December	188.3 ± 30.5	259.4 ± 45.7	186.3 ± 17.6	240.6 ± 29.3

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 42b: Effect of the interaction (ANOVA results) between treatment and breed in different months on heifer weights (for Table 42a)

Month	p value	F value
January	0.9531	0.11
February	0.9126	0.18
March	0.8915	0.21
April	0.8995	0.20
May	0.6433	0.56
June	0.9195	0.17
July	0.8389	0.28
August	0.9222	0.16
September	0.9605	0.10
October	0.9207	0.16
November	0.7990	0.34
December	0.8606	0.25

In Tables 42a and 42b, the interaction between breed and treatments, which were a control group and a group receiving phosphorus supplementation, is shown. This interaction proved not to be significant, showing that any effect on weight of heifers was due to treatment and not complicated by breed type.

Table 43a: Trial 3- Summary statistics (mean ± std dev) for the interaction between year of the trial and breed type on heifer weights (kg)

Breed	Month	Year			
type		1998	1999	2000	2001
n= 139		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B2	January	77.2 ± 10.3	98.3 ± 17.4	-	-
B3	January	105.2 ± 17.7	135.5 ± 13.2	147.0 ± 20.1	122.8 ± 19.3
B4	January	71.3 ± 16.0	88.9 ± 10.3	93.8 ± 16.0	75.7 ± 8.4
B5	January	103.3 ± 16.1	129.7 ± 17.9	110.3 ± 22.1	102.2 ± 23.3
B2	February	-	128.9 ± 19.4	-	-
B3	February	-	180.3 ± 13.5	212.0 ± 26.1	148.6 ± 22.2
B4	February	103.0 ± 19.0	118.4 ± 13.8	135.0 ± 20.5	98.71 ± 8.1
B5	February	-	170.9 ± 21.4	173.8 ± 32.6	136.4
B2	March	126.2 ± 14.5	152.3 ± 21.1	-	-
B3	March	169.6 ± 25.7	207.7 ± 15.8	230.5 ± 25.8	172.6 ± 19.0
B4	March	127.7 ± 22.1	142.0 ± 16.2	153.8 ± 22.3	119.0 ± 9.9
B5	March	168.1 ± 19.2	194.7 ± 23.0	193.1 ± 32.3	158.2 ± 24.8
B2	April	144.8 ± 18.8	157.4 ± 22.4	-	-
B3	April	193.4 ± 26.2	212.7 ± 15.2	251.0 ± 25.5	209.8 ± 25.6
B4	April	145.2 ± 22.2	138.6 ± 15.2	173.0 ± 23.1	137.3 ± 10.1
B5	April	186.0 ± 19.7	205.8 ± 20.0	212.7 ± 32.7	180.6 ± 27.3

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 43a (continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between year of the trial and breed type on heifer weights (kg)

Breed type n= 139	Month	Year 1998 Mean ± Std Dev	1999 Mean ± Std Dev	2000 Mean ± Std Dev	2001 Mean ± Std Dev
B2	May	161.0 ± 20.7	189.7 ± 18.6	-	-
B3	May	214.6 ± 26.6	246.7 ± 23.7	268.5 ± 24.8	236.2 ± 31.1
B4	May	159.5 ± 21.6	173.4 ± 15.6	184.3 ± 19.7	153.1 ± 11.4
B5	May	205.0 ± 18.7	228.1 ± 17.6	225.8 ± 30.8	201.6 ± 26.7
B2	June	172.8 ± 23.0	194.9 ± 15.4	-	-
B3	June	228.4 ± 27.2	262.7 ± 19.6	270.5 ± 25.9	249.2 ± 38.7
B4	June	166.7 ± 22.1	176.4 ± 16.5	187.0 ± 19.3	160.9 ± 13.1
B5	June	217.4 ± 21.3	245.3 ± 21.6	240.0 ± 32.4	215.2 ± 25.4
B2	July	174.8 ± 22.7	197.1 ± 15.3	-	-
B3	July	227.3 ± 30.7	260.3 ± 14.9	270.0 ± 23.3	259.2 ± 40.9
B4	July	170.8 ± 22.6	176.1 ± 16.2	186.5 ± 19.1	174.6 ± 14.8
B5	July	218.9 ± 20.0	248.0 ± 21.0	234.0 ± 29.3	230.0 ± 27.9
B2	August	177.2 ± 22.0	198.3 ± 14.6	-	-
B3	August	233.2 ± 30.3	268.3 ± 16.6	274.5 ± 24.9	262.6 ± 41.8
B4	August	174.2 ± 21.1	179.1 ± 15.7	191.3 ± 17.4	175.1 ± 13.4
B5	August	223.6 ± 19.3	247.3 ± 21.7	235.3 ± 28.5	234.0 ± 26.8
B2	September	177.8 ± 21.7	190.0 ± 14.2	-	-
B3	September	237.0 ± 31.6	266.0 ± 17.2	279.0 ± 24.2	268.8 ± 41.1
B4	September	177.5 ± 18.8	173.9 ± 16.7	197.8 ± 17.5	176.7 ± 14.9
B5	September	226.8 ± 18.8	242.7 ± 21.8	230.2 ± 37.3	235.4 ± 26.9
B2	October	176.4 ± 20.4	193.7 ± 14.2	-	-
B3	October	237.2 ± 31.7	277.3 ± 15.1	270.5 ± 22.5	263.6 ± 33.8
B4	October	180.2 ± 22.4	183.1 ± 17.5	185.3 ± 16.7	173.9 ± 14.1
B5	October	229.1 ± 21.8	253.3 ± 23.0	224.0 ± 24.9	231.6 ± 28.1
B2	November	167.8 ± 19.1	197.4 ± 14.5	-	-
B3	November	228.8 ± 29.1	266.7 ± 21.2	285.5 ± 28.2	268.4 ± 36.0
B4	November	174.5 ± 18.8	178.7 ± 17.1	207.8 ± 18.8	179.0 ± 14.1
B5	November	219.9 ± 19.5	236.9 ± 18.9	254.7 ± 28.9	234.8 ± 26.9
B2	December	-	218.6 ± 18.7	-	-
B3	December	-	303.3 ± 23.2	-	265.6 ± 34.5
B4	December	181.3 ± 21.5	203.9 ± 19.0	-	183.8 ± 13.0
B5	December	225.6 ± 20.0	276.0 ± 26.5	-	236.5 ± 25.9

[a, b, c] Row means with different superscripts differ ($p < 0.05$)

B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 43b: Effect of the interaction (ANOVA results) between year and breed in different months on heifer weights (for Table 43a)

Month	p value	F value
January	0.1220	1.68
February	0.2935	1.26
March	0.3665	1.10
April	0.1854	1.47
May	0.3538	1.12
June	0.5835	0.81
July	0.3803	1.08
August	0.3954	1.06
September	0.1688	1.52
October	0.1110	1.72
November	0.2311	1.36
December	0.0235	2.74

In Tables 43a and 43b it can be seen that the interaction between breed and year was not significant except for in the month of December. The weight of the animal is largely determined by its breed type. This may vary slightly due to year effect. By this it is meant that the animal's weight can be affected to a degree by the climate of a particular year, in that in a drought year the animal's weight will be lower due to poor availability of pasture, whereas in a good year, with lots of available grazing, it may be slightly higher than usual. Year effect may also be cancelled out due to the fact that all four breed types are adapted to the South African climate or that the climate of the different years was very similar.

Table 44a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on heifer weights (kg)

Treatment	Breed	Month	Year			
n= 139	type		1998	1999	2000	2001
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	January	77.8 ± 11.8	98.2 ± 21.2	-	-
T4	B2	January	76.6 ± 9.9	98.5 ± 4.9	-	-
C2	B3	January	111.2 ± 13.1	128.7 ± 12.7	156.0 ± 25.5	120.8 ± 26.2
T4	B3	January	99.2 ± 21.1	142.3 ± 11.6	138.0 ± 15.6	124.8 ± 11.8
C2	B4	January	70.8 ± 14.9	87.1 ± 10.5	93.0 ± 9.7	75.7 ± 10.1
T4	B4	January	71.8 ± 18.4	90.6 ± 10.7	95.0 ± 26.5	75.7 ± 7.3
C2	B5	January	103.8 ± 14.7	132.8 ± 9.3	109.2 ± 26.8	101.6 ± 28.6
T4	B5	January	102.8 ± 18.5	125.8 ± 26.5	111.8 ± 18.5	102.8 ± 20.0
C2	B2	February	-	128.8 ± 23.7	-	-
T4	B2	February	-	129.0 ± 1.4	-	-
C2	B3	February	-	174.7 ± 12.9	217.0 ± 32.5	148.0 ± 28.6
T4	B3	February	-	186.0 ± 14.0	207.0 ± 29.7	149.2 ± 17.0
C2	B4	February	102.0 ± 14.8	115.4 ± 15.2	130.0 ± 14.6	99.4 ± 10.1
T4	B4	February	104.0 ± 23.9	121.4 ± 12.7	143.3 ± 29.7	98.0 ± 6.2
C2	B5	February	-	176.4 ± 9.9	171.6 ± 39.5	135.2 ± 23.7
T4	B5	February	-	164.0 ± 31.3	176.5 ± 27.2	137.6 ± 26.7
C2	B2	March	125.6 ± 19.3	152.4 ± 25.7	-	-
T4	B2	March	126.8 ± 10.2	152.0 ± 2.8	-	-
C2	B3	March	178.4 ± 18.3	202.7 ± 19.7	236.0 ± 33.9	169.2 ± 23.9
T4	B3	March	160.8 ± 30.9	212.7 ± 12.7	225.0 ± 26.9	176.0 ± 14.4
C2	B4	March	126.3 ± 18.1	136.3 ± 16.1	153.6 ± 16.1	119.4 ± 12.4
T4	B4	March	129.0 ± 27.3	147.7 ± 15.3	154.0 ± 35.0	118.6 ± 7.6
C2	B5	March	169.5 ± 16.0	199.6 ± 12.7	190.4 ± 38.1	160.8 ± 26.6
T4	B5	March	166.8 ± 23.0	188.5 ± 33.2	196.5 ± 28.6	155.6 ± 25.7
C2	B2	April	144.4 ± 24.6	158.4 ± 27.4	-	-
T4	B2	April	145.2 ± 13.7	155.0 ± 1.4	-	-
C2	B3	April	200.4 ± 16.1	208.7 ± 17.2	253.0 ± 32.5	206.8 ± 31.1
T4	B3	April	186.4 ± 34.0	216.7 ± 15.3	249.0 ± 29.7	212.8 ± 22.0
C2	B4	April	144.0 ± 18.7	134.0 ± 16.7	172.0 ± 17.7	137.7 ± 13.3
T4	B4	April	146.3 ± 27.0	143.1 ± 13.1	174.7 ± 35.2	136.9 ± 6.5
C2	B5	April	185.0 ± 16.4	215.2 ± 5.0	208.4 ± 37.5	184.0 ± 26.6
T4	B5	April	187.0 ± 23.8	194.0 ± 26.4	218.0 ± 30.2	177.2 ± 30.5

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 44a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on heifer weights (kg)

Treatment	Breed	Month	Year			
n= 139	type		1998	1999	2000	2001
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	May	160.8 ± 28.6	187.2 ± 22.1	-	-
T4	B2	May	161.2 ± 12.0	196.0 ± 2.8	-	-
C2	B3	May	223.6 ± 21.3	245.3 ± 31.4	268.0 ± 31.1	237.6 ± 35.1
T4	B3	May	205.6 ± 30.6	248.0 ± 20.3	269.0 ± 29.7	234.8 ± 30.6
C2	B4	May	157.7 ± 18.3	168.9 ± 17.8	182.4 ± 15.6	153.1 ± 15.4
T4	B4	May	161.3 ± 26.2	178.0 ± 12.8	187.3 ± 29.1	153.1 ± 6.6
C2	B5	May	203.3 ± 19.0	241.5 ± 5.5	224.0 ± 38.0	204.4 ± 24.9
T4	B5	May	206.8 ± 19.5	214.8 ± 14.7	228.0 ± 24.4	198.8 ± 31.1
C2	B2	June	173.6 ± 31.7	192.4 ± 17.1	-	-
T4	B2	June	172.0 ± 13.7	201.0 ± 12.7	-	-
C2	B3	June	236.8 ± 19.9	262.0 ± 22.5	267.0 ± 38.2	255.2 ± 39.8
T4	B3	June	220.0 ± 33.0	263.3 ± 21.2	274.0 ± 22.6	243.2 ± 41.2
C2	B4	June	165.7 ± 17.1	172.0 ± 18.4	187.2 ± 17.3	161.1 ± 17.5
T4	B4	June	167.7 ± 27.9	180.9 ± 14.3	186.7 ± 26.6	160.6 ± 8.2
C2	B5	June	215.5 ± 22.4	248.8 ± 8.8	235.6 ± 39.7	216.4 ± 23.5
T4	B5	June	219.3 ± 21.5	241.0 ± 33.2	245.5 ± 24.9	214.0 ± 30.0
C2	B2	July	173.8 ± 30.6	196.4 ± 16.9	-	-
T4	B2	July	175.8 ± 14.7	199.0 ± 15.6	-	-
C2	B3	July	232.8 ± 22.2	262.7 ± 19.2	272.0 ± 31.1	264.8 ± 38.5
T4	B3	July	221.8 ± 39.4	258.0 ± 13.1	268.0 ± 25.5	253.6 ± 46.9
C2	B4	July	169.7 ± 16.0	173.7 ± 18.1	185.2 ± 15.5	173.7 ± 20.5
T4	B4	July	171.8 ± 29.3	178.6 ± 15.0	188.7 ± 28.0	175.4 ± 7.4
C2	B5	July	219.1 ± 20.3	250.8 ± 13.6	230.0 ± 35.2	232.0 ± 26.6
T4	B5	July	218.8 ± 21.1	244.5 ± 29.9	239.0 ± 24.0	228.0 ± 32.1
C2	B2	August	176.8 ± 30.8	197.6 ± 16.4	-	-
T4	B2	August	177.6 ± 11.9	200.0 ±14.1	-	-
C2	B3	August	240.0 ± 22.3	270.7 ± 20.0	275.0 ± 32.5	265.2 ± 42.8
T4	B3	August	226.4 ± 38.0	266.0 ± 16.4	274.0 ± 28.3	260.0 ± 45.6
C2	B4	August	174.3 ± 13.5	178.3 ± 18.9	190.4 ± 14.3	174.3 ± 17.7
T4	B4	August	174.0 ± 28.2	180.0 ± 12.6	192.7 ± 25.3	176.0 ± 8.6
C2	B5	August	224.5 ± 21.1	248.4 ± 8.5	233.2 ± 35.5	235.2 ± 26.7
T4	B5	August	222.8 ± 18.8	246.0 ± 34.0	238.0 ± 21.6	232.8 ± 29.9

[a, b, c] Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 44a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and the year of the trial on heifer weights (kg)

Treatment	Breed	Month	Year			
n= 139	type		1998	1999	2000	2001
			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B2	September	178.0 ± 29.8	188.8 ± 15.3	-	-
T4	B2	September	177.6 ± 13.0	193.0 ± 15.6	-	-
C2	B3	September	242.0 ± 21.6	265.3 ± 17.5	279.0 ± 29.7	271.6 ± 41.8
T4	B3	September	232.0 ± 41.4	266.7 ± 20.8	279.0 ± 29.7	266.0 ± 45.1
C2	B4	September	178.7 ± 15.2	173.1 ± 20.4	196.4 ± 12.4	176.3 ± 19.6
T4	B4	September	176.3 ± 29.5	174.6 ± 13.7	200.0 ± 27.5	177.1 ± 9.8
C2	B5	September	228.3 ± 21.2	246.8 ± 10.9	218.8 ± 46.3	239.2 ± 26.6
T4	B5	September	225.3 ± 17.5	237.5 ± 32.3	244.5 ± 19.3	231.6 ± 29.7
C2	B2	October	177.2 ± 27.7	192.0 ± 16.1	-	-
T4	B2	October	175.6 ± 13.1	198.0 ± 11.3	-	-
C2	B3	October	238.0 ± 26.6	283.3 ± 11.5	271.0 ± 26.9	264.0 ± 30.7
T4	B3	October	236.4 ± 39.4	271.3 ± 18.0	270.0 ± 28.3	263.2 ± 40.3
C2	B4	October	181.3 ± 14.5	186.6 ± 21.7	184.0 ± 14.7	173.4 ± 19.0
T4	B4	October	179.0 ± 29.8	179.7 ± 12.9	187.3 ± 23.2	174.3 ± 8.4
C2	B5	October	229.0 ± 26.9	258.8 ± 14.7	225.2 ± 31.0	235.2 ± 29.2
T4	B5	October	229.3 ± 17.1	246.5 ± 31.8	222.5 ± 19.2	228.0 ± 30.0
C2	B2	November	167.2 ± 26.5	193.6 ± 15.1	-	-
T4	B2	November	168.4 ± 11.1	207.0 ± 9.9	-	-
C2	B3	November	231.6 ± 24.2	268.0 ± 28.2	292.0 ± 33.9	269.2 ± 31.1
T4	B3	November	226.0 ± 36.1	265.3 ± 18.0	279.0 ± 32.5	267.6 ± 43.9
C2	B4	November	175.0 ± 9.9	183.1 ± 19.4	205.6 ± 18.4	177.7 ± 19.5
T4	B4	November	174.0 ± 26.0	174.3 ± 14.5	211.3 ± 23.0	180.3 ± 6.7
C2	B5	November	221.0 ± 22.3	240.4 ± 12.8	257.6 ± 32.1	236.4 ± 27.3
T4	B5	November	218.8 ± 17.8	232.5 ± 26.3	251.0 ± 28.5	233.2 ± 29.5
C2	B2	December	181.2 ± 25.8	214.4 ± 19.7	-	-
T4	B2	December	172.0 ± 13.0	229.0 ± 15.6	-	-
C2	B3	December	231.6 ± 18.5	301.3 ± 19.4	-	266.0 ± 33.2
T4	B3	December	226.0 ± 34.8	305.3 ± 31.0	-	265.2 ± 39.6
C2	B4	December	185.2 ± 15.3	212.0 ± 21.8	-	183.7 ± 17.4
T4	B4	December	178.0 ± 26.7	195.7 ± 12.3	-	183.9 ± 7.9
C2	B5	December	222.3 ± 23.8	281.0 ± 17.7	-	238.0 ± 26.5
T4	B5	December	229.0 ± 16.3	271.0 ± 35.5	-	234.9 ± 28.2

$^{a, b, c}$ Row means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 44b: Effect of the interaction (ANOVA results) between treatment, breed and year in different months on heifer weights (for Table 44a)

Month	p value	F value
January	0.8490	0.48
February	0.7508	0.48
March	0.8575	0.47
April	0.7984	0.55
May	0.7919	0.55
June	0.9817	0.21
July	0.9998	0.05
August	1.0000	0.03
September	0.9816	0.21
October	0.9991	0.08
November	0.9956	0.13
December	0.7755	0.50

The interaction between year of the trial, breed type and treatment group was shown not to be significant in Table 87. This again shows that any effect that treatment has on heifer weight is not complicated by the various other factors.

4.2.3 Calves

In this section the effects of various factors on the reproductive characteristics of cows were quantified in terms of calf birth weight, calf weaning weight and weight gain of calves.

Table 45a: Trial 3- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Birth Weight	Weaning Weight	Weight Gain
n= 443	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	31.8 ± 7.7	196.7 ± 39.9	164.9 ± 35.6 [a]
T4	33.2 ± 7.6	205.6 ± 50.3	172.2 ± 44.1 [b]

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 45b: Effect of treatment (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 45a)

	p value	F value
Birth Weight	0.1904	1.72
Weaning Weight	0.0587	3.61
Weight Gain	0.0464	4.01

Tables 45a and 45b look at whether treatment had a significant effect on birth weight, weaning weight and weight gain of calves. Treatment was not significant as far as birth weight was concerned, with both the control and supplemented groups having similar weights at birth. This was expected as the cow usually buffers factors such as poor nutrition and therefore external factors seldom have an effect on the calf's birth weight.

Weaning weight was however different with treatment not being significant but tending towards significance, with the phosphorus supplemented group having calves with a higher weaning weight. Karn (1997) and De Brouwer *et al*. (2000) also found an increase in calf weaning weights where phosphorus supplementation was given. This is attributed to the fact that phosphorus supplementation has been known to improve milk yield. This is in agreement with both Fishwick *et al*. (1977) and Read *et al*. (1986a). This could be due to one of two reasons, the first being that phosphorus supplementation has been known to reduce weight loss in the lactating cow. Karn (1997) and De Brouwer *et al*. (2000) found that phosphorus supplemented cows gained more weight during their calving and lactating period than did unsupplemented cows. The cow is therefore in a better condition and can produce more milk.

Phosphorus supplementation has also been known to increase feed intake, which can lead to an increased milk yield. Davison *et al*. (1997) found that feed intake was improved by phosphorus supplementation. Treatment was also significant with regards to weight gain. With all other factors being similar, the results suggest that the phosphorus supplemented cows tended to have a higher milk yield; therefore having more milk available to the calf, leading to an increased weight gain.

Table 46a: Trial 3- Summary statistics (mean ± std dev) for the effect of sex on birth weight, weaning weight and weight gain of calves (kg)

Sex	Birth Weight	Weaning Weight	Weight Gain
n= 443	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B	34.1 ± 8.1 [a]	208.6 ± 48.9 [a]	174.7 ± 43.1 [a]
H	31.0 ± 6.9 [b]	195.2 ± 42.0 [b]	163.5 ± 37.3 [b]

[a, b, c] Column means with different superscripts differ ($p < 0.001$)
B= bull calf, H= heifer calf

Table 46b: Effect of sex (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 46a)

	p value	F value
Birth Weight	<0.0001	17.84
Weaning Weight	0.0002	14.09
Weight Gain	0.0005	12.49

Tables 46a and 46b show that there was a significant difference between bulls and heifers for birth weight, weaning weight and weight gain. This was expected because on average bull calves are born heavier than heifers, have a faster growth rate than heifers and therefore reach higher weaning weights. This is due to bulls having a higher metabolic rate than heifers.

Table 47a: Trial 3- Summary statistics (mean ± std dev) for the effect of breed type on birth weight, weaning weight and weight gain of calves (kg)

Breed type	Birth Weight	Weaning Weight	Weight Gain
n= 443	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B2	31.7 ± 4.0 [a]	195.0 ± 24.1 [a]	163.2 ± 23.2 [a]
B3	40.5 ± 6.3 [b]	250.5 ± 38.9 [b]	210.6 ± 37.3 [b]
B4	25.7 ± 4.0 [c]	166.2 ± 22.1 [c]	139.9 ± 20.7 [c]
B5	35.1 ± 5.8 [d]	217.9 ± 41.5 [d]	182.4 ± 37.9 [d]

[a, b, c] Column means with different superscripts differ ($p < 0.001$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 47b: Effect of breed (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 47a)

	p value	F value
Birth Weight	<0.0001	189.04
Weaning Weight	<0.0001	106.33
Weight Gain	<0.0001	76.60

Tables 47a and 47b show that breed type had a significant effect on birth weight, weaning weight and weight gain of calves. This was expected because of the different sizes of the different breed types. The smaller sized cows will produce smaller calves at birth. These calves will also have a lower mature weight, so it is to be expected that their weaning weights and weight gains will be lower than that of larger breed calves. This is reflected in the table by Nguni calves having the lowest births weights and therefore the lowest weight gain and weaning weight. Next are the Afrikaner calves and Bonsmara calves respectively, with Simmentaler (the largest breed) having the heaviest birth and weaning weights and therefore the highest weight gains. This is in agreement with Du Plessis *et al*. (2006), who studied the reproductive traits of various breed types. In that particular experiment it was found that the larger Simmentaler calves gained a 100g/day more than the Bonsmara, with the Bonsmara gaining 150g/day more than the Afrikaner type. The Afrikaner type cows gained a similar amount of weight per day as the Nguni type did, but reached a higher weaning weight due to a higher birth weight. These findings also agree with the breed averages for birth weights and weaning weights of these breeds for the years 1993 to 1998 according to the ARC. Birth weights were 26kg, 33kg, 36kg and 39kg respectively for Nguni, Afrikaner, Bonsmara and Simmentaler calves, with weaning weights of 155kg, 185kg, 214kg and 240kg respectively (Beef breeding in South Africa, ARC- Animal Improvement Institute).

Table 48a: Trial 3- Summary statistics (mean ± std dev) for the effect of birth year of a calf on its birth weight, weaning weight and weight gain (kg)

Year	Birth Weight	Weaning Weight	Weight Gain
n= 443	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
1998	32.8 ± 7.2 [b]	211.7 ± 44.7 [b]	178.7 ± 39.5 [b]
1999	32.4 ± 6.6 [ab]	205.5 ± 41.4 [b]	172.6 ± 35.8 [b]
2000	33.9 ± 7.6 [b]	207.5 ± 51.2 [b]	173.8 ± 46.0 [b]
2001	30.7 ± 7.6 [a]	180.2 ± 39.5 [a]	149.6 ± 34.3 [a]
2002	32.6 ± 9.2 [ab]	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.001$)

Table 48b: Effect of birth year (ANOVA results) on birth weight, weaning weight and weight gain of calves (for Table 48a)

	p value	F value
Birth Weight	<0.0001	7.08
Weaning Weight	<0.0001	15.82
Weight Gain	<0.0001	16.13

In Tables 48a and 48b it can be seen that the birth year of the calf was significant for birth weight, weaning weight and weight gain. On close inspection, it can however be seen that the difference in birth weights over the years was very small. This was expected because as previously mentioned, the cow tends to buffer any effects and therefore year should not really have much of an effect on birth weight. As far as weight gain and weaning weight are concerned, year would have an effect. Differences in the climate over the years, especially with regard to rainfall, will result in differences in pasture composition and quality as well as availability of grazing. In years of bad grazing, fewer nutrients will be available to the cow and her milk yield will be lower. Milk yield will also be lower due to the cow being in a poorer condition. This will in turn lead to less milk for the calf, which means a reduced growth rate and therefore a lower weaning weight. The opposite will result from a good year, with good grazing, leading to increased milk yield and higher growth rates and weaning weights of calves.

Table 49a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and sex on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Birth Weight	Weaning Weight	Weight Gain
n= 443		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B	32.7 ± 8.3	201.1 ± 38.0	169.1 ± 33.5
C2	H	30.9 ± 6.9	192.7 ± 41.3	160.8 ± 37.2
T4	B	35.4 ± 7.8	215.7 ± 56.7	180.1 ± 50.3
T4	H	31.0 ± 6.8	197.3 ± 42.7	165.7 ± 37.4

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B= bull calf, H= heifer calf

Table 49b: Effect of interaction (ANOVA results) between treatment and sex on birth weight, weaning weight and weight gain of calves (For Table 49a)

	p value	F value
Birth Weight	0.9053	0.01
Weaning Weight	0.4243	0.64
Weight Gain	0.4799	0.50

Tables 49a and 49b show that the interaction between treatment and sex was not significant for birth weight, weaning weight or weight gain of calves. This was especially true where birth weight was concerned, with external factors having little to no effect on birth weight of the calf. This lack of significance shows that where treatment had an effect on birth weight, weaning weight and weight gain it was not complicated by sex of the calf.

Table 50a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and breed type on birth weight, weaning weight and weight gain of calves (kg)

Treatment n= 443	Breed type	Birth Weight Mean ± Std Dev	Weaning Weight Mean ± Std Dev	Weight Gain Mean ± Std Dev
C2	B2	31.7 ± 3.9	198.1 ± 18.1	165.9 ± 14.9
C2	B3	40.4 ± 6.8	235.9 ± 33.0	197.7 ± 34.5
C2	B4	25.3 ± 4.6	167.8 ± 24.1	141.6 ± 22.3
C2	B5	34.1 ± 5.4	212.0 ± 39.4	178.0 ± 36.8
T4	B2	31.8 ± 4.2	191.7 ± 29.6	160.2 ± 30.0
T4	B3	40.6 ± 5.9	260.5 ± 39.9	218.7 ± 37.1
T4	B4	26.0 ± 3.3	164.6 ± 20.1	138.3 ± 19.2
T4	B5	36.1 ± 6.0	223.4 ± 43.0	186.6 ± 38.8

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 50b: Effect of interaction (ANOVA results) between treatment and breed on birth weight, weaning weight and weight gain of calves (for Table 50a)

	p value	F value
Birth Weight	0.7695	0.38
Weaning Weight	0.3738	1.04
Weight Gain	0.3704	1.05

In Tables 50a and 50b it can be seen that the interaction between treatment and breed was not significant for birth weight, weaning weight or weight gain. This again shows that any effect that treatment had on these three parameters was not affected by breed type. Again it can be seen that the larger the breed size the heavier the birth weight, the higher the weight gain and the heavier the weaning weight of a calf. These breeds are also well adapted to South African conditions and are therefore able to adjust to various changes in climate. This will result in treatment having less of an effect.

Table 51a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and the birth year of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Year	Birth Weight	Weaning Weight	Weight Gain
n= 443		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	1998	32.3 ± 7.3	206.6 ± 40.7	174.2 ± 36.6
C2	1999	32.8 ± 6.7	207.3 ± 34.8	175.5 ± 30.6
C2	2000	32.4 ± 6.9	199.2 ± 37.7	166.4 ± 34.8
C2	2001	29.9 ± 7.8	171.3 ± 36.5	141.2 ± 30.5
C2	2002	31.2 ± 9.6	-	-
T4	1998	33.3 ± 7.1	216.8 ± 48.3	183.1 ± 42.2
T4	1999	32.0 ± 6.6	204.0 ± 46.6	170.1 ± 40.0
T4	2000	35.4 ± 8.0	215.0 ± 60.3	180.0 ± 53.3
T4	2001	31.3 ± 7.4	187.7 ± 40.8	156.6 ± 36.2
T4	2002	33.9 ± 8.6	-	-

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 51b: Effect of interaction (ANOVA results) between treatment and birth year on birth weight, weaning weight and weight gain of calves (for Table 51a)

	p value	F value
Birth Weight	0.1739	1.60
Weaning Weight	0.2246	1.47
Weight Gain	0.1377	1.86

In Tables 51a and 51b it is shown that the interaction between treatment and birth year was not significant for birth weight, weaning weight or weight gain. Any effect treatment may have on these three parameters is therefore not complicated by the birth year of the calf.

Table 52a: Trial 3- Summary statistics (mean ± std dev) for the interaction between the different breed types and sex on birth weight, weaning weight and weight gain of calves (kg)

Sex	Breed	Birth Weight	Weaning Weight	Weight Gain
n=443	type	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B	B2	33.2 ± 4.3	205.8 ± 19.5	172.4 ± 17.9
B	B3	42.4 ± 5.9	255.0 ± 44.5	212.0 ± 41.5
B	B4	26.5 ± 3.9	171.5 ± 23.3	144.3 ± 22.4
B	B5	35.7 ± 6.6	226.8 ± 48.1	190.5 ± 44.2
H	B2	30.3 ± 3.2	186.1 ± 24.4	155.5 ± 24.7
H	B3	37.8 ± 5.8	246.3 ± 33.1	209.3 ± 33.2
H	B4	24.9 ± 4.0	161.6 ± 20.0	136.1 ± 18.4
H	B5	34.6 ± 4.9	210.3 ± 33.5	175.6 ± 30.5

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type
B= bull calf, H= heifer calf

Table 52b: Effect of interaction (ANOVA results) between breed type and sex on birth weight, weaning weight and weight gain of calves (for Table 52a)

	p value	F value
Birth Weight	0.2900	1.25
Weaning Weight	0.1764	1.66
Weight Gain	0.1123	2.02

The interaction between sex and breed was shown not to be significant for birth weight, weaning weight and weight gain of calves.

Table 53a: Trial 3- Summary statistics (mean ± std dev) for the interaction between the birth year of the calf and sex on birth weight, weaning weight and weight gain of calves (kg)

Sex	Year	Birth Weight	Weaning Weight	Weight Gain
n=443		Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
B	1998	35.1 ± 7.0	224.1 ± 45.5	188.5 ± 40.6
B	1999	32.9 ± 6.8	210.9 ± 44.7	177.0 ± 38.5
B	2000	35.4 ± 8.8	218.0 ± 57.0	183.7 ± 49.6
B	2001	31.9 ± 8.0	184.7 ± 42.7	152.9 ± 38.1
B	2002	35.2 ± 9.3	-	-
H	1998	31.2 ± 6.9	203.4 ± 42.6	172.0 ± 37.7
H	1999	31.7 ± 6.4	198.5 ± 36.0	167.0 ± 31.8
H	2000	32.6 ± 6.1	200.5 ± 46.4	166.8 ± 42.6
H	2001	29.5 ± 7.0	176.0 ± 36.3	146.4 ± 30.5
H	2002	29.0 ± 7.8	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B= bull calf, H= heifer calf

Table 53b: Effect of interaction (ANOVA results) of birth year and sex on birth weight, weaning weight and weight gain of calves (for Table 53a)

	p value	F value
Birth Weight	0.6337	0.64
Weaning Weight	0.8907	0.21
Weight Gain	0.7114	0.46

Tables 53a and 53b show that the interaction between sex and birth year was of the calf not significant for birth weight, weaning weight or weight gain of the calf.

Table 54a: Trial 3- Summary statistics (mean ± std dev) for the interaction between birth year and breed type on birth weight, weaning weight and weight gain of calves (kg)

Year	Breed	Birth Weight	Weaning Weight	Weight Gain
n=443	type	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
1998	B2	31.2 ± 3.7 [cdfg]	196.0 ± 23.1	164.1 ± 23.1
1998	B3	39.5 ± 5.4 [be]	257.2 ± 35.2	216.5 ± 36.2
1998	B4	25.7 ± 3.9 [acd]	172.7 ± 24.3	147.2 ± 21.8
1998	B5	37.4 ± 4.7 [befg]	236.7 ± 34.1	199.2 ± 31.8
1999	B2	30.8 ± 4.4 [cdg]	193.9 ± 26.4	162.5 ± 24.8
1999	B3	40.6 ± 5.3 [be]	255.7 ± 37.3	215.1 ± 34.3
1999	B4	26.8 ± 3.1 [acd]	173.2 ± 18.8	146.4 ± 18.2
1999	B5	34.2 ± 5.0 [efg]	224.3 ± 31.9	187.8 ± 26.6
2000	B2	32.9 ± 3.9 [befg]	198.0	161.0
2000	B3	41.2 ± 8.4 [be]	262.6 ± 44.8	229.2 ± 38.7
2000	B4	27.4 ± 4.1 [acd]	163.2 ± 21.5	136.0 ± 21.0
2000	B5	38.0 ± 6.2 [bef]	231.5 ± 34.6	194.3 ± 32.5
2001	B2	-	-	-
2001	B3	39.7 ± 7.1 [be]	222.8 ± 27.8	180.9 ± 25.2
2001	B4	25.5 ± 4.2 [ac]	157.9 ± 20.9	132.3 ± 18.7
2001	B5	31.0 ± 5.1 [dg]	187.0 ± 42.7	155.4 ± 40.1
2002	B2	-	-	-
2002	B3	41.5 ± 5.5 [b]	-	-
2002	B4	22.8 ± 3.1 [a]	-	-
2002	B5	35.9 ± 4.9 [befg]	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 54b: Effect of interaction (ANOVA results) between birth year and breed on birth weight, weaning weight and weight gain of calves (for Table 54a)

	p value	F value
Birth Weight	0.0013	2.98
Weaning Weight	0.0502	2.05
Weight Gain	0.1169	1.67

Tables 54a and 54b look at the interaction between breed and the birth year of the calf. This interaction was significant for birth weight. Birth weight is almost entirely determined by breed of the calf. This once again comes down to breed size with smaller breeds of cows producing calves with lower birth weights than larger breeds of cows. Year of birth should not have that much of an effect on birth weight as the cow usually buffers any detrimental factors and produces a calf of on average the same weight no matter what the conditions are. As far as weaning weight is concerned there was a tendency towards significance. This is due to the fact that weaning weight will be affected by both the year, which will have an effect on milk production of the cow, and by frame size and breed type, of the calf. There was no significant effect where weight gain was concerned, with weight gains of a specific breed being fairly similar over the years.

Table 55a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, sex and breed type on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Breed	Birth Weight	Weaning Weight	Weight Gain
n= 443		type	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B	B2	32.7 ± 4.4	204.0 ± 21.5	169.4 ± 18.1
C2	B	B3	42.3 ± 6.4	235.2 ± 27.6	194.3 ± 27.2
C2	B	B4	25.7 ± 4.4	173.9 ± 23.6	147.4 ± 22.2
C2	B	B5	34.4 ± 5.7	221.9 ± 38.4	187.8 ± 36.2
C2	H	B2	30.7 ± 3.3	192.1 ± 12.6	162.5 ± 11.1
C2	H	B3	37.3 ± 6.4	236.4 ± 38.2	201.0 ± 41.8
C2	H	B4	24.9 ± 4.9	161.3 ± 23.3	135.5 ± 21.1
C2	H	B5	34.0 ± 5.2	204.5 ± 39.2	170.6 ± 36.2
T4	B	B2	33.8 ± 4.4	208.2 ± 18.2	176.5 ± 18.5
T4	B	B3	42.4 ± 5.7	267.4 ± 49.2	223.0 ± 45.8
T4	B	B4	27.6 ± 2.8	168.7 ± 23.0	140.8 ± 22.7
T4	B	B5	36.6 ± 7.1	230.7 ± 55.4	192.8 ± 50.8
T4	H	B2	30.0 ± 3.3	180.7 ± 31.4	149.3 ± 32.0
T4	H	B3	38.1 ± 5.5	253.7 ± 27.8	214.4 ± 26.7
T4	H	B4	25.0 ± 3.2	161.7 ± 17.5	136.5 ± 16.5
T4	H	B5	35.4 ± 4.5	216.3 ± 25.6	180.8 ± 22.8

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type
B= bull calf, H= heifer calf

Table 55b: Effect of interaction (ANOVA results) between treatment, sex and breed on birth weight, weaning weight and weight gain of calves (for Table 55a)

	p value	F value
Birth Weight	0.6318	0.57
Weaning Weight	0.6082	0.61
Weight Gain	0.5426	0.72

Tables 55a and 55b show the interaction between treatment (control vs. phosphorus supplementation), sex and breed type of the calf on birth weight, weaning weight and weight gain of the calf. This interaction was shown not to be significant for birth weight, weaning weight or weight gain.

Table 56a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, sex and birth year of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Year	Birth Weight	Weaning Weight	Weight Gain
n= 443			Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	B	1998	33.9 ± 7.2	204.1 ± 35.0	170.0 ± 31.0
C2	B	1999	32.9 ± 6.2	210.0 ± 36.3	177.9 ± 32.4
C2	B	2000	32.2 ± 8.4	203.1 ± 42.6	173.4 ± 37.5
C2	B	2001	30.7 ± 8.9	181.7 ± 36.9	150.6 ± 30.4
C2	B	2002	33.3 ± 10.6	-	-
C2	H	1998	31.2 ± 7.3	208.2 ± 44.8	176.9 ± 40.2
C2	H	1999	32.7 ± 8.0	200.5 ± 31.6	169.4 ± 25.9
C2	H	2000	32.6 ± 5.8	197.2 ± 36.0	162.5 ± 33.5
C2	H	2001	29.3 ± 6.8	162.1 ± 34.6	132.9 ± 28.8
C2	H	2002	27.6 ± 6.5	-	-
T4	B	1998	36.4 ± 6.8	242.7 ± 47.3	205.7 ± 41.8
T4	B	1999	32.9 ± 7.7	212.2 ± 55.4	175.6 ± 47.0
T4	B	2000	37.9 ± 8.4	227.6 ± 63.9	190.4 ± 56.1
T4	B	2001	32.8 ± 7.4	187.1 ± 47.6	154.6 ± 44.0
T4	B	2002	37.3 ± 7.2	-	-
T4	H	1998	31.2 ± 6.6	198.4 ± 40.8	166.9 ± 35.2
T4	H	1999	31.2 ± 5.5	197.6 ± 38.4	166.0 ± 34.6
T4	H	2000	32.6 ± 6.6	204.2 ± 56.5	171.1 ± 50.6
T4	H	2001	29.6 ± 7.3	188.4 ± 34.0	158.5 ± 27.2
T4	H	2002	30.1 ± 8.7	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B= bull calf, H= heifer calf

Table 56b: Effect of interaction (ANOVA results) between treatment, sex and birth year on birth weight, weaning weight and weight gain of calves (for Table 56a)

	p value	F value
Birth Weight	0.1496	1.70
Weaning Weight	0.1112	2.02
Weight Gain	0.699	2.39

Tables 56a and 56b show the interaction between control and phosphorus supplementation with sex and year of birth. This interaction was not significant for birth weight, weaning weight or weight gain.

Table 57a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, birth year and breed type of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Year	Breed	Birth Weight	Weaning Weight	Weight Gain
n= 443		type	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	1998	B2	31.9 ± 4.6	196.9 ± 16.0	164.0 ± 13.6
C2	1998	B3	38.4 ± 5.9	247.4 ± 34.6	208.0 ± 39.8
C2	1998	B4	25.4 ± 4.4	172.6 ± 24.2	147.3 ± 21.4
C2	1998	B5	36.8 ± 4.7	231.6 ± 34.3	194.8 ± 33.1
C2	1999	B2	31.6 ± 5.0	199.0 ± 20.4	167.4 ± 16.5
C2	1999	B3	40.9 ± 5.2	241.2 ± 38.2	201.2 ± 35.8
C2	1999	B4	26.8 ± 3.2	183.4 ± 20.8	156.6 ± 19.7
C2	1999	B5	35.1 ± 5.5	227.1 ± 34.4	193.6 ± 32.7
C2	2000	B2	31.7 ± 2.5	-	-
C2	2000	B3	40.5 ± 10.1	219.5 ± 24.5	182.0 ± 41.0
C2	2000	B4	27.0 ± 5.3	166.2 ± 22.7	139.9 ± 22.5
C2	2000	B5	35.5 ± 4.3	224.5 ± 27.5	189.0 ± 26.7
C2	2001	B2		-	-
C2	2001	B3	41.1 ± 7.0	226.4 ± 31.6	185.2 ± 27.0
C2	2001	B4	25.6 ± 5.2	152.7 ± 20.0	126.5 ± 15.5
C2	2001	B5	29.6 ± 5.0	171.7 ± 32.1	141.3 ± 29.4
C2	2002	B2	-	-	-
C2	2002	B3	41.5 ± 7.0	-	-
C2	2002	B4	22.3 ± 3.1	-	-
C2	2002	B5	34.8 ± 5.1	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 57a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, birth year and breed type of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment n= 443	Year	Breed type	Birth Weight Mean ± Std Dev	Weaning Weight Mean ± Std Dev	Weight Gain Mean ± Std Dev
T4	1998	B2	30.6 ± 2.7	195.1 ± 30.0	164.1 ± 31.1
T4	1998	B3	40.7 ± 4.7	265.8 ± 35.6	224.0 ± 33.6
T4	1998	B4	26.2 ± 3.3	172.7 ± 25.6	147.1 ± 23.4
T4	1998	B5	37.9 ± 4.9	241.4 ± 35.0	203.2 ± 31.7
T4	1999	B2	30.0 ± 3.8	187.3 ± 33.2	156.1 ± 33.0
T4	1999	B3	40.4 ± 5.6	266.6 ± 35.0	225.6 ± 31.3
T4	1999	B4	26.8 ± 3.2	165.1 ± 12.4	138.3 ± 12.4
T4	1999	B5	33.3 ± 4.4	222.2 ± 31.4	183.2 ± 21.3
T4	2000	B2	34.0 ± 4.8	198.0	161.0
T4	2000	B3	41.6 ± 7.7	281.8 ± 38.1	239.7 ± 31.3
T4	2000	B4	27.8 ± 2.4	160.5 ± 20.7	132.7 ± 19.8
T4	2000	B5	40.6 ± 6.9	241.1 ± 41.9	201.6 ± 39.2
T4	2001	B2	-	-	-
T4	2001	B3	38.8 ± 7.4	220.3 ± 27.1	177.9 ± 25.5
T4	2001	B4	25.3 ± 3.2	162.8 ± 21.3	137.8 ± 20.3
T4	2001	B5	32.3 ± 5.0	199.2 ± 47.1	166.7 ± 44.7
T4	2002	B2	-	-	-
T4	2002	B3	41.5 ± 4.2	-	-
T4	2002	B4	23.5 ± 3.0	-	-
T4	2002	B5	36.8 ± 4.6	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 57b: Effect of interaction (ANOVA results) between treatment, birth year and breed on birth weight, weaning weight and weight gain of calves (for Table 57a)

	p value	F value
Birth Weight	0.7087	0.72
Weaning Weight	0.3426	1.13
Weight Gain	0.1602	1.52

The interaction between treatment (control vs. phosphorus supplementation), breed type and birth year was shown not to be significant for birth weight, weaning weight and weight gain in Tables 57a and 57b.

Table 58a: Trial 3- Summary statistics (mean ± std dev) for the interaction between year of birth, sex and breed type on birth weight, weaning weight and weight gain of calves (kg)

Sex n=443	Year	Breed type	Birth Weight Mean ± Std Dev	Weaning Weight Mean ± Std Dev	Weight Gain Mean ± Std Dev
B	1998	B2	31.5 ± 4.8	204.7 ± 24.9	172.2 ± 23.7
B	1998	B3	41.1 ± 5.0	263.7 ± 41.4	220.1 ± 41.1
B	1998	B4	27.4 ± 2.2	181.5 ± 27.2	154.1 ± 26.6
B	1998	B5	39.1 ± 4.1	246.5 ± 32.9	207.4 ± 32.4
B	1999	B2	33.6 ± 4.1	207.9 ± 17.0	174.3 ± 14.3
B	1999	B3	41.0 ± 5.4	258.7 ± 43.4	217.6 ± 40.2
B	1999	B4	27.1 ± 2.9	175.3 ± 19.7	148.2 ± 19.3
B	1999	B5	33.7 ± 4.5	236.9 ± 37.0	198.6 ± 30.9
B	2000	B2	34.2 ± 4.2	198.0	161
B	2000	B3	46.8 ± 10.4	294.7 ± 60.2	246.0 ± 49.0
B	2000	B4	28.1 ± 4.7	170.3 ± 25.9	142.8 ± 25.5
B	2000	B5	39.6 ± 7.2	255.3 ± 30.7	217.2 ± 27.3
B	2001	B2	-	-	-
B	2001	B3	42.8 ± 4.8	224.6 ± 29.0	182.0 ± 28.3
B	2001	B4	26.6 ± 3.9	161.2 ± 21.1	134.5 ± 19.0
B	2001	B5	30.3 ± 5.8	186.6 ± 49.1	155.3 ± 46.8
B	2002	B2	-	-	-
B	2002	B3	42.2 ± 5.3	-	-
B	2002	B4	23.2 ± 3.4	-	-
B	2002	B5	37.5 ± 4.8	-	-
H	1998	B2	30.9 ± 2.5	189.5 ± 20.8	158.0 ± 22.1
H	1998	B3	37.7 ± 5.4	251.5 ± 30.4	213.4 ± 34.0
H	1998	B4	25.1 ± 4.2	168.3 ± 22.3	143.8 ± 19.1
H	1998	B5	36.3 ± 4.9	229.6 ± 34.6	193.3 ± 31.4
H	1999	B2	28.9 ± 3.7	183.0 ± 28.1	153.3 ± 28.0
H	1999	B3	39.6 ± 5.5	250.4 ± 26.5	210.8 ± 23.6
H	1999	B4	26.2 ± 3.7	169.1 ± 17.0	142.9 ± 16.5
H	1999	B5	34.5 ± 5.4	212.9 ± 22.7	179.2 ± 20.3
H	2000	B2	31.3 ± 3.1	-	-
H	2000	B3	37.8 ± 4.8	253.0 ± 37.8	22.9 ± 35.8
H	2000	B4	26.8 ± 3.5	157.7 ± 16.1	130.9 ± 15.8
H	2000	B5	36.5 ± 4.8	214.1 ± 26.4	177.6 ± 25.3
H	2001	B2	-	-	-
H	2001	B3	36.2 ± 7.9	220.4 ± 29.1	179.4 ± 23.3
H	2001	B4	24.5 ± 4.3	155.4 ± 21.1	130.7 ± 19.0
H	2001	B5	31.9 ± 4.1	187.4 ± 36.7	155.5 ± 33.3
H	2002	B2	-	-	-
H	2002	B3	38.8 ± 5.8	-	-
H	2002	B4	22.5 ± 2.9	-	-
H	2002	B5	34.0 ± 4.4	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type
B= bull calf, H= heifer calf

Table 58b: Effect of interaction (ANOVA results) between birth year, sex and breed on birth weight, weaning weight and weight gain of calves (for Table 58a)

	p value	F value
Birth Weight	0.5493	0.88
Weaning Weight	0.7385	0.62
Weight Gain	0.7432	0.62

Tables 58a and 58b show that the interaction between sex of the calf, birth year of the calf and breed type of the calf was not significant for birth weight, weaning weight or weight gain of the calf.

Table 59a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, sex, birth year and breed type of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment n= 443	Sex	Year	Breed type	Birth Weight Mean ± Std Dev	Weaning Weight Mean ± Std Dev	Weight Gain Mean ± Std Dev
C2	B	1998	B2	31.8 ± 7.0	195.3 ± 27.2	161.3 ± 22.1
C2	B	1998	B3	40.8 ± 6.0	231.0 ± 18.4	186.5 ± 19.1
C2	B	1998	B4	27.2 ± 1.8	176.8 ± 25.3	149.6 ± 25.3
C2	B	1998	B5	37.8 ± 5.0	231.5 ± 32.2	193.8 ± 34.0
C2	B	1999	B2	35.0 ± 3.7	209.2 ± 18.6	174.2 ± 15.8
C2	B	1999	B3	39.8 ± 4.9	235.2 ± 39.5	196.6 ± 38.0
C2	B	1999	B4	26.8 ± 2.9	181.6 ± 22.3	154.8 ± 21.2
C2	B	1999	B5	34.3 ± 3.3	242.6 ± 26.9	209.2 ± 24.3
C2	B	2000	B2	31.2 ± 1.1	-	-
C2	B	2000	B3	49.0 ± 12.7	-	-
C2	B	2000	B4	27.3 ± 6.0	176.3 ± 24.1	150.1 ± 22.9
C2	B	2000	B5	36.0 ± 4.5	250.0 ± 16.8	214.0 ± 13.3
C2	B	2001	B2	-	-	-
C2	B	2001	B3	43.0 ± 7.0	238.0 ± 11.1	195.7 ± 13.3
C2	B	2001	B4	25.1 ± 5.3	155.7 ± 19.5	130.0 ± 14.7
C2	B	2001	B5	29.3 ± 5.6	179.7 ± 25.8	148.7 ± 24.0
C2	B	2002	B2	-	-	-
C2	B	2002	B3	42.8 ± 6.1	-	-
C2	B	2002	B4	22.9 ± 3.4	-	-
C2	B	2002	B5	38.3 ± 5.9	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type
B= bull calf, H= heifer calf

Table 59a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, sex, birth year and breed type of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Year	Breed	Birth Weight	Weaning Weight	Weight Gain
n= 443			type	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
C2	H	1998	B2	32.0 ± 1.2	198.0 ± 4.3	166.0 ± 5.3
C2	H	1998	B3	36.8 ± 5.8	254.0 ± 39.1	216.6 ± 44.3
C2	H	1998	B4	24.3 ± 5.2	170.0 ± 24.8	145.9 ± 20.3
C2	H	1998	B5	36.0 ± 4.8	231.6 ± 39.7	195.6 ± 36.5
C2	H	1999	B2	27.3 ± 1.9	186.3 ± 16.1	159.0 ± 15.0
C2	H	1999	B3	47.0	271.0	224.0
C2	H	1999	B4	27.0 ± 5.7	192.5 ± 9.2	165.5 ± 3.5
C2	H	1999	B5	35.8 ± 7.4	201.3 ± 33.3	167.7 ± 30.7
C2	H	2000	B2	32.2 ± 3.4	-	-
C2	H	2000	B3	36.3 ± 6.5	219.5 ± 24.5	182.0 ± 41.0
C2	H	2000	B4	26.6 ± 4.9	156.1 ± 17.3	129.6 ± 18.0
C2	H	2000	B5	35.4 ± 4.4	215.3 ± 24.9	179.9 ± 24.6
C2	H	2001	B2	-	-	-
C2	H	2001	B3	38.7 ± 7.6	209.0 ± 52.3	169.5 ± 41.7
C2	H	2001	B4	25.9 ± 5.4	150.7 ± 21.2	124.1 ± 16.5
C2	H	2001	B5	30.0 ± 4.7	163.7 ± 38.1	134.0 ± 34.6
C2	H	2002	B2	-	-	-
C2	H	2002	B3	30.0	-	-
C2	H	2002	B4	21.2 ± 2.5	-	-
C2	H	2002	B5	32.9 ± 3.6	-	-
T4	B	1998	B2	31.3 ± 2.2	214.0 ± 23.6	183.0 ± 23.6
T4	B	1998	B3	41.3 ± 4.9	276.8 ± 41.7	233.6 ± 40.6
T4	B	1998	B4	27.7 ± 3.2	189.3 ± 34.0	161.7 ± 32.5
T4	B	1998	B5	40.5 ± 3.0	261.5 ± 29.8	221.0 ± 28.4
T4	B	1999	B2	30.0 ± 2.8	204.5 ± 17.7	174.5 ± 14.8
T4	B	1999	B3	42.2 ± 6.0	288.0 ± 29.6	243.8 ± 27.1
T4	B	1999	B4	27.3 ± 3.0	167.4 ± 13.2	139.9 ± 13.4
T4	B	1999	B5	32.8 ± 6.4	229.8 ± 50.6	181.0 ± 37.5
T4	B	2000	B2	36.3 ± 4.3	198.0	161.0
T4	B	2000	B3	45.8 ± 11.0	294.7 ±60.2	246.0 ± 49.0
T4	B	2000	B4	29.2 ± 1.7	163.3 ± 28.4	134.2 ± 27.7
T4	B	2000	B5	41.0 ± 7.7	258.3 ± 37.4	219.0 ± 33.8
T4	B	2001	B2	-	-	-
T4	B	2001	B3	42.7 ± 3.6	214.5 ± 35.9	171.8 ± 34.0
T4	B	2001	B4	27.8 ± 2.2	166.0 ± 22.8	138.4 ± 22.4
T4	B	2001	B5	31.1 ± 6.2	191.8 ± 62.7	160.3 ± 60.0
T4	B	2002	B2	-	-	-
T4	B	2002	B3	41.7 ± 4.7	-	-
T4	B	2002	B4	24.3 ± 3.8	-	-
T4	B	2002	B5	37.2 ± 4.6	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type
B= bull calf, H= heifer calf

Table 59a(continued): Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, sex, birth year and breed type of the calf on birth weight, weaning weight and weight gain of calves (kg)

Treatment	Sex	Year	Breed	Birth Weight	Weaning Weight	Weight Gain
n= 443			type	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
T4	H	1998	B2	30.0 ± 3.1	181.0 ± 28.3	150.0 ± 30.7
T4	H	1998	B3	39.3 ± 5.0	247.3 ± 12.1	208.0 ± 7.2
T4	H	1998	B4	25.7 ± 3.3	166.5 ± 21.1	141.6 ± 18.7
T4	H	1998	B5	36.4 ± 5.3	228.0 ± 33.7	191.3 ± 30.0
T4	H	1999	B2	30.0 ± 4.3	180.4 ± 37.0	148.8 ± 36.6
T4	H	1999	B3	37.8 ± 4.3	245.3 ± 27.5	207.5 ± 25.9
T4	H	1999	B4	26.0 ±3.6	162.4 ± 11.8	136.4 ± 11.9
T4	H	1999	B5	35.5 ± 3.5	217.9 ± 17.5	184.1 ± 14.4
T4	H	2000	B2	30.0 ± 2.4	-	-
T4	H	2000	B3	38.8 ± 3.5	275.3 ± 26.8	236.5 ± 23.8
T4	H	2000	B4	27.0 ± 2.5	158.8 ± 16.1	131.8 ± 15.0
T4	H	2000	B5	39.8 ± 5.1	211.0 ± 34.1	171.3 ± 29.9
T4	H	2001	B2	-	-	-
T4	H	2001	B3	35.0 ± 8.5	228.0 ± 10.6	186.0 ± 7.0
T4	H	2001	B4	22.9 ± 1.9	160.2 ± 21.0	137.3 ± 19.8
T4	H	2001	B5	33.7 ± 2.7	207.7 ± 20.9	174.0 ± 18.8
T4	H	2002	B2	-	-	-
T4	H	2002	B3	41.0 ± 3.6	-	-
T4	H	2002	B4	23.3 ± 2.9	-	-
T4	H	2002	B5	36.0 ± 5.4	-	-

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type
B= bull calf, H= heifer calf

Table 59b: Effect of interaction (ANOVA results) between treatment, sex, birth year and breed on birth weight, weaning weight and weight gain of calves (for Table 59a)

	p value	F value
Birth Weight	0.1536	1.46
Weaning Weight	0.2665	1.28
Weight Gain	0.1306	1.67

Table 59a and 59b shows the interaction between treatment (control vs. phosphorus supplementation), sex, breed type and year of birth. This interaction was not significant for birth weight, weaning weight or weight gain of calves.

Table 60a: Trial 3- Summary statistics (mean ± std dev) for the effect of birth month on birth weight, weaning weight and weight gain of calves (kg)

Month	Birth Weight	Weaning Weight	Weight Gain
n= 443	Mean ± Std Dev	Mean ± Std Dev	Mean ± Std Dev
January	37.0	198.0	161.0
October	34.5 ± 8.2	215.0 ± 48.3	181.4 ± 42.8
November	31.2 ± 7.0	196.1 ± 42.6	164.0 ± 37.3
December	32.0 ± 8.2	180.3 ± 40.1	147.9 ± 33.8

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.001$)

Table 60b: Effect of birth month (ANOVA results) on birth weight, weaning weight and weight gain (for Table 60a)

	p value	F value
Birth Weight	0.0823	1.97
Weaning Weight	<0.0001	13.64
Weight Gain	<0.0001	15.85

In Tables 60a and 60b the effect of birth month on birth weight, weaning weight and weight gain is shown. Month of birth was not significant but showed a tendency towards significance with regard to birth weight. Birth weights were however very similar to one another over the various months as usually the cow buffers any external factors, and birth weight is determined by breed type, sex and age of the cow, with young cows, which may not yet be fully grown, producing smaller calves than older cows.

Birth month was however highly significant for weaning weight and weight gain, with calves born in the beginning of the calving season (October rather than November or December), generally having better weight gain and therefore heavier weaning weights than those calves born later in the calving season. This is due to the fact that cows that calve earlier have access to better quality pasture/grazing for longer, which results in better maintenance of body condition during lactation leading to a better milk yield. Cows who calve at the end of the calving season are still lactating in the winter months when there is poorer quality grazing. This results in a poorer body condition and milk yield.

Calves therefore tend to have lower growth rates and therefore lower weaning weights. Calving down in the month of October is also optimum as it means the cows were in good condition at conception. Conception would have happened in January or February when there was still good grazing allowing the cow to maintain condition (Taylor, 2006).

4.2.4 Reproduction

In this section we consider the effects of various factors on reproductive characteristics of cows quantified in terms of the total amount of calves produced per cow, the average calving intervals of cows and the reproduction rate of cows.

Table 61a: Trial 3- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on the average calving interval of cows (with total amount of years that the cows were in the system)

Treatment	Average CI	Years in system
n= 226	Mean ± Std Dev	Mean ± Std Dev
C2	413.2 ± 210.4	3.4 ± 1.0
T4	371.9 ± 30.8	3.8 ± 1.0

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 61b: Effect of treatment (ANOVA results) on the average calving interval of the cow (for Table 61a)

	p value	F value
Treatment	0.1833	1.79
Years in system	0.0870	2.98

Tables 61a and 61b show the effect of control and phosphorus supplementation on the average calving interval of cows. Calving interval is defined as the number of days between the births of two consecutive calves produced by a particular cow. This table shows that treatment had no significant effect on average calving interval. This is in agreement with Fishwick *et al*. (1977), who found that phosphorus supplemented cows did not return to oestrus sooner than unsupplemented cows and therefore did not calve earlier than unsupplemented cows.

The number of years the cow was in the system for did however show a tendency towards significance. This is due to the fact that cows that were in the system for longer produced more calves and therefore, on average, the calculation for calving interval would be more accurate than that of a cow who was in the system for one or two breeding seasons only. Also cows that were in the system for longer would have been older and average calving interval tends to improve with the age of the cow, especially from the first and second calf onwards. This can be seen in the table, as cows in the treatment group T4 were on average in the system for longer and had a lower and therefore better average calving interval than did the cows in the control group.

Table 62a: Trial 3- Summary statistics (mean ± std dev) for the effect of breed type on the average calving interval of the cow (with total amount of years the cow was in the system)

Breed type	Average CI	Years in system
n= 226	Mean ± Std Dev	Mean ± Std Dev
B2	364.5 ± 9.2	3.0 ± 0.0
B3	382.5 ± 41.0	3.7 ± 1.1
B4	419.0 ± 249.3	3.8 ± 1.1
B5	384.7 ± 74.9	3.6 ± 1.1

$^{a, b, c}$ Column means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 62b: Effect of breed type (ANOVA results) on the average calving interval of the cow (for Table 62a)

	p value	F value
Breed type	0.8060	0.33
Years in system	0.0870	2.98

Tables 62a and 62b show that breed had no significant effect on the average calving interval of a cow. The number of years the cow was in the system for once again showed a tendency towards significance.

Table 63a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and breed type on the average calving interval of the cow (with total amount of years the cow was in the system)

Treatment	Breed	Average CI	Years in system
n= 226		Mean ± Std Dev	Mean ± Std Dev
C2	B2	361.9 ± 12.1	3.0 ± 0.0
C2	B3	388.6 ± 27.4	3.4 ± 1.0
C2	B4	462.1 ± 336.7	3.6 ± 1.1
C2	B5	393.8 ± 102.2	3.3 ± 1.0
T4	B2	366.7 ± 5.4	3.0 ± 0.0
T4	B3	376.4 ± 51.6	4.0 ± 1.1
T4	B4	369.2 ± 29.7	4.0 ± 1.0
T4	B5	374.5 ± 17.2	4.0 ± 1.0

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 63b: Effect of interaction (ANOVA results) between treatment and breed type on the average calving interval of the cow (for Table 63a)

	p value	F value
Treatment*breed	0.5782	0.66
Years in system	0.0870	2.98

Tables 63a and 63b show the interaction of control and phosphorus supplementation with breed type. The interaction was not significant for average calving interval.

Table 64a: Trial 3- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on the total amount of calves produced per cow (with total amount of years the cow was in the system for)

Treatment	Total Calves	Years in system
n= 226	Mean ± Std Dev	Mean ± Std Dev
C2	1.8 ± 1.5	2.4 ± 1.3^{a}
T4	2.1 ± 1.8	2.7 ± 1.5^{b}

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 64b: Effect of treatment (ANOVA results) on the total amount of calves produced per cow (for Table 64a)

	p value	F value
Treatment	0.9809	0.00
Years in system	<0.0001	1318.80

In Tables 64a and 64b it can be seen that control and phosphorus supplementation treatment had no significant influence on the total amount of calves a cow produced while in the system. What did have a significant effect was the total amount of years the cow was in the system for. The longer the cow was in the system for, the more calves she was given the chance to produce. Also the longer the cow was in the system for, the older she would have been. Cows tend to manage to produce one calf a year after their first or second calf. Therefore a heifer may struggle to recover after her first calf and would then often not conceive in her second breeding season. If she were then removed from the system it would not be an accurate summary of her breeding capabilities.

It can be seen in the table that the phosphorus supplemented group had a slightly higher mean than the control group for total calves produced, but in agreement with what has just been said, the total amount of years in the system was also slightly higher for this group. It should also be mentioned here that management would have a greater effect on the total amount of calves produced by a cow then treatment would. This again comes down to how long the cow is allowed to remain in the system for. Management would decide if a cow should be removed from the system as soon as she skips a breeding season or if she should be allowed to stay in for another year.

Table 65a: Trial 3- Summary statistics (mean ± std dev) for the effect of breed type on the total amount of calves produced per cow (with total amount of years the cow was in the system for)

Breed n= 226	Total Calves Mean ± Std Dev	Years in system Mean ± Std Dev
B2	1.5 ± 1.2	2.2 ± 0.9
B3	2.1 ± 1.6	2.6 ± 1.5
B4	2.1 ± 1.7	2.6 ± 1.6
B5	2.0 ± 1.7	2.6 ± 1.4

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 65b: Effect of breed type (ANOVA results) on the total amount of calves produced per cow (for Table 65a)

	p value	F value
Breed type	0.6773	0.51
Years in system	<0.0001	1318.80

In tables 65a and 65b it can again be seen that the total amount of calves produced per cow was dependent more on the total amount of years she was in the system for, with breed type having had no significant effect. This is again down to management of the herd rather than other factors. It can therefore be said that total amount of calves produced is not an accurate indication of the effect of breed or treatment on reproduction in cows.

Table 66a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment and breed type on the total amount of calves produced per cow (with total amount of years the cow was in the system for)

Treatment	Breed	Total Calves	Years in system
n= 226		Mean ± Std Dev	Mean ± Std Dev
C2	B2	1.4 ± 1.3	2.1 ± 0.9
C2	B3	1.9 ± 1.4	2.5 ± 1.3
C2	B4	2.0 ± 1.6	2.5 ± 1.5
C2	B5	1.9 ± 1.5	2.5 ± 1.3
T4	B2	1.6 ± 1.2	2.3 ± 0.8
T4	B3	2.3 ± 1.9	2.8 ± 1.6
T4	B4	2.1 ± 1.9	2.7 ± 1.6
T4	B5	2.1 ± 1.9	2.8 ± 1.5

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 66b: Effect of interaction (ANOVA results) between treatment and breed type on the total amount of calves produced per cow (for Table 66a)

	p value	F value
Treatment*breed	0.9989	0.01
Years in system	<0.0001	1318.80

Tables 66a and 66b show that the interaction between treatment and breed had no significant influence on the total amount of calves produced per cow. It can again be seen that the main determining factor of total amount of calves produced per cow was the number of years the cow was in the system for, and therefore comes down to management. It can again be stated that the total amount of calves produced per cow is a poor indication of the cow's reproductive capabilities.

Table 67a: Trial 3- Summary statistics (mean ± std dev) for the effect of control diet and a dietary phosphorus supplementation treatment on the reproductive rate of cows (with age of the cow as a variable)

Treatment	Reproductive rate	Age of cow
n= 226	Mean ± Std Dev	Mean ± Std Dev
C2	0.6 ± 0.4	4.4 ± 2.7[a]
T4	0.6 ± 0.4	4.8 ± 3.1[b]

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year

Table 67b: **Effect of interaction (ANOVA results) between treatment and age of cow on the reproductive rate of cows (for Table 67a)**

	p value	F value
Treatment	0.6114	0.26
Age of cow	<0.0001	78.27

Tables 67a and 67b show the reproductive rate of the cow. This was calculated by taking the total amount of calves produced by the cow while she was in the system, and dividing it by the total amount of years the cow was in the system for. Here treatment was not significant. What did prove to be significant was the age of the cow. This can be explained by the fact that a heifer has her first calf when she is not yet fully grown. She often experiences difficulties such as distocia. This often causes a longer recovery period after parturition. Also if she is not yet fully grown, the heifer will often lose body condition during lactation, also leading to a longer recovery period. In this case, a heifer will often not conceive during her second breeding season. This becomes less of a problem once she is older and fully-grown. Therefore, the older the cow (to a degree) the better her reproductive rate should be.

Table 68a: Trial 3- Summary statistics (mean ± std dev) for the interaction between breed type and cow age on the reproductive rate of cows (with age of the cow as a variable)

Breed type	Reproductive rate	Age of cow
n= 226	Mean ± Std Dev	Mean ± Std Dev
B2	0.6 ± 0.4	5.0 ± 2.9
B3	0.7 ± 0.4	5.2 ± 3.6
B4	0.6 ± 0.4	3.7 ± 2.0
B5	0.6 ± 0.4	4.9 ± 3.0

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 68b: Effect of interaction (ANOVA results) between breed type and cow age on the reproductive rate of cows (for Table 68a)

	p value	F value
Breed type	0.2892	1.26
Age of cow	<0.0001	78.27

Tables 68a and 68b show that breed type did not significantly influence the reproductive rate of cows. As explained previously, age of the cow was significant and greatly determines the reproductive rate of the cow. Another factor here is the fact that all four of these breeds are well adapted to the climate and conditions and should therefore show the same level of reproductive capabilities.

Table 69a: Trial 3- Summary statistics (mean ± std dev) for the interaction between control diet, a dietary phosphorus supplementation treatment, breed type and cow age on the reproductive rate of cows (with age of the cow as a variable)

Treatment n= 226	Breed type	Reproductive rate Mean ± Std Dev	Age of cow Mean ± Std Dev
C2	B2	0.5 ± 0.4	4.7 ± 2.9
C2	B3	0.7 ± 0.3	5.1 ± 3.2
C2	B4	0.6 ± 0.4	3.4 ± 1.8
C2	B5	0.6 ± 0.4	4.8 ± 2.9
T4	B2	0.6 ± 0.4	5.4 ± 2.9
T4	B3	0.7 ± 0.4	5.2 ± 4.0
T4	B4	0.6 ± 0.4	4.0 ± 2.1
T4	B5	0.6 ± 0.4	5.0 ± 3.2

[a, b, c] Column means with different superscripts differ ($p < 0.05$)
C= control, T4= Kimtrafos 12 P all year
B2= Afrikaner type, B3= Simmentaler type, B4= Nguni type, B5= Bonsmara cross type

Table 69b: Effect of interaction (ANOVA results) between treatment, breed type and cow age on the reproductive rate of cows (for Table 69a)

	p value	F value
Treatment*Breed	0.8479	0.27
Age of cow	<0.0001	78.27

Tables 69a and 69b show that that the interaction between treatment (control vs. phosphorus supplementation) and breed type had no significant effect on the reproductive rate of the cow. Again age of the cow is the significant factor. Reproductive rate within the system however is perhaps not the best way to look at the effects of treatment and breed on reproductive capabilities of the cows.

CHAPTER 5: CONCLUSION

The effects of phosphorus supplementation on growth and reproduction of beef cows in semi-arid areas is affected by season, year and reproductive status of the animal. In Trial 1, phosphorus supplementation had no significant effect on cow or heifer weight. Treatment significantly influenced cow weights in Trial 2. Trial 3 showed a varying effect of treatment on cow weight, with phosphorus supplementation having a significant effect in the months of June through to November. In both instances, the phosphorus supplemented groups showed heavier weights than the control groups.

Phosphorus supplementation did not have a significant effect on birth weight, weaning weight or weight gain of calves in Trial 1. In Trial 2 and 3, phosphorus supplementation again had no significant effect on birth weight of calves, but was either significant (Trial 2) or tending towards significance (Trial 3) for weaning weight. Weight gain was significantly influenced by phosphorus supplementation in both Trial 2 and Trial 3, with the treated groups gaining more weight than the control groups. This could be due to the cow maintaining a better body condition during lactation and therefore being able to produce more milk. It could also be due to the possible increased milk yield often caused by the secondary effects of increased feed intake, which results from phosphorus supplementation.

With regard to the reproductive status of the cows, phosphorus supplementation had no significant effect on the average calving interval of the cows. Phosphorus supplemented cows did not return to oestrus sooner, and did not calve earlier than cows not receiving phosphorus supplementation.

Whether phosphorus supplementation should be given to grazing beef cattle is still unclear, with supplementation yielding varied results. There do however seem to be significant improvements in weight and body condition of cows, as well as calf weaning weights in animals that have received phosphorus supplementation in some cases. It has also been shown that phosphorus supplementation is highly beneficial in areas where there are severe deficiencies of phosphorus. It is therefore up to management to weigh up the costs of phosphorus supplementation and the related benefits.

CHAPTER 6: REFERENCES

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