FORAGE SYSTEMS FOR GOAT PRODUCTION IN SOUTH AFRICA

by

SHEILA DRUMMOND HOUSEHAM
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ABSTRACT

Goats are found in almost every country and are an important source of protein and produce lactose-free milk. In South Africa, survival rates of goat kids are low, mainly due to malnutrition. Intensive goat production systems based on cultivated pastures were evaluated, at various stocking rates to evaluate the effects of improved nutrition on goat production. The pastures chosen to be evaluated for goat production were *Pennisetum clandestinum* (Kikuyu) and *Secale cereale* (Stooling rye).

Kikuyu is one of the more important dryland summer pasture species in KwaZulu-Natal. Three stocking rates of goats on kikuyu were evaluated using ewes with kids. When analysing the period to weaning, the ewes lost weight in all stocking rate treatments and for both years. The years had a significant effect on weight loss (P<0.001; R^2=95.7%) with a mean ADG of -0.0267 $kg.animal^{-1}.day^{-1}$. There was a significant difference between ADGs between stocking rates, with ADGs of -0.0157, -0.026 and -0.0384 $kg.animal^{-1}.day^{-1}$ at stocking rates of 30, 45 and 60 $goats.ha^{-1}$ respectively (P<0.001; R^2=95.7%). The analyses of the entire grazing period showed no significant difference in ewe ADGs between treatments, but a significant difference between the two years (P=0.03), with a mean ADG of -0.0205 $kg.animal^{-1}.day^{-1}$. There was no significant difference between kid masses between treatments. There was a significant difference between kid performance between years (P<0.001; R^2=21.8%). However, factors such as ewe start mass (P<0.001) and whether the kid was a singleton or a multiple (P=0.015) had an influence on kid ADG, while gender had no significant effect (P=0.446). Interpretation of the combined ewe plus kid weight revealed that the high stocking rate produced the highest total mass per hectare (P<0.001) with an overall mean of 2377 $kg.ha^{-1}$. Kid ADG was positively correlated to ewe ADG (P=0.013; R^2=5.8%) although this was not a strong relationship. Protein was negatively correlated to pasture height (P=0.036; R^2=30.8%) and had a quadratic relationship with ADG (P<0.001; R^2=48.4%) with maximum ADG occurring at protein levels of 26.17%. Rainfall was different between the two seasons, which affected pasture growth, with the stocking rates in the second year being too low, so the maximum stocking rate per hectare was not reached.

Stooling rye is a pasture used predominantly in South Africa and is a good source of high quality winter feed. Four stocking rates were evaluated over winter, using pregnant ewes. Rainfall was not an important variable since supplementary irrigation was given and the difference in temperatures between the years was negligible. The rate of weight gain showed a similar response for both years with the level of weight gain varying significantly between years (P=0.001; R^2=90.2%). The regressions for ADG on stocking rate were determined and were y=0.2340-0.00293x for 2001 (P=0.151; R^2=58.0%) and y=0.1292-0.002198x for 2002 (P=0.137; R^2=61.6%). Gain per hectare was determined, as were the stocking rates at which maximum gain per hectare were achieved and this was determined to be 40 $goats.ha^{-1}$ during 2001 and 29 goats.ha^{-1} for 2002. The respective ADGs at these stocking rates were 0.1168 and 0.0633 kg.day^{-1} and daily gains.ha^{-1} were 4.672 and 1.898 kg.ha^{-1}.day^{-1} respectively. Herbage analyses revealed that there were extremely high levels of protein in the pasture (33.87%) even though the pasture was not excessively fertilised. Average daily gain was negatively related to NDF levels (P=0.006; R^2=38.4%). ADF levels (P<0.001; R^2=48.4%) and NDF levels (P<0.001; R2=60.4%) showed a quadratic relationship with pasture age. Blood serum revealed that selenium levels in all treatments were lower than the normal range, while all other minerals were within the normal range.

To maximise animal performance, the highest quality pasture should be offered to producing animals, namely growing animals. The seasonal variation between years has a large effect on the performance of goats on pastures.

PREFACE

This thesis documents research conducted in the University of Natal from May 2001 to April 2003 on Cedara Research Station, under the supervision of Professor Kevin P. Kirkman.

I declare that the results contained in this thesis are from my own original work, except where acknowledged. I also declare that these results have not been submitted in any form for any degree or diploma to any university.

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SD Househam

November 2011

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1 OVERVIEW

Goats are found in almost every country and in many countries they are considered to be the most important source of animal protein, with whole communities depending on their goat flocks (Mowlem, 1992). Goats convert natural vegetation into valuable products such as meat, milk, wool (cashmere), mohair, skins, pelts and manure (Gürsoy, 2006) and turn low quality forage into products of a high feeding value (Ruiz *et al.*, 2009). In KwaZulu-Natal, South Africa, there were 831,857 goats in the province and their primary use was for meat, fibre and milk (Min *et al.,* 1999). Historically, goats have not been incorporated into mainstream research and development projects (Steele, 1996) in South Africa, probably because their economic value has not been recognised.

One negative aspect related to goat development programmes is the association of goat production with poverty. Gandhi was reputed to have called the goat "the poor woman's cow" (Ramsay & Donkin, 2000). Goat production has probably the biggest potential for improvement out of all South African livestock and has huge potential for value-added products, meat and milk products and cultural purposes (Ramsay & Donkin, 2000). Goats are important for meat, milk and hides and have the ability to adapt to all climatic conditions (Nyamukanza & Scogings, 2008). South Africa has numerous breeds of goats, including Angoras, Boergoats and about three million goats of other breeds (South African Indigenous) (Donkin & Boyazoglu, undated). "Nguni goats" is a term used to describe the South African indigenous goats (Akingbade *et al.*, 2001). The Nguni goats are one of the South African un-improved indigenous goat breeds. They are smaller than the Boer goat and have a short-haired coat. Colours vary from black to white and combinations of colours. Nguni goats are kept primarily for meat and cultural practices (Akingbade *et al.*, 2001). The Nguni goat is well adapted to South Africa, showing resistance to heartwater, a major tick-borne disease (Donkin & Boyazoglu, undated). Adult females are still prone to mastitis and kids prone to coccidiosis (Donkin & Boyazoglu, undated).

Milk is in high demand as a quality protein source to fend off malnutrition, especially in children, and is especially of benefit to children who are allergic to cow's milk (Donkin & Boyazoglu, undated). Milk is needed in high volumes in rural areas of South Africa, and this need is mainly filled by cattle. Since not all people own cattle (Donkin & Boyazoglu, undated) and milk goats are scarce in South Africa and indigenous goats are plentiful, the ability of the indigenous goat to supply milk to rural households in South Africa needs to be explored. The milk goat was bred to produce milk in large quantities first and foremost, and to provide meat as a secondary purpose. They therefore provide milk in much larger quantities than the indigenous goats can, but are less resistant to some of the tick-borne diseases evident in South Africa and are less hardy than the South African indigenous goats.

Some of the common problems experienced in goat enterprises in the sub-humid zones are high pre-weaning mortality rates and low milk production, which are exacerbated by seasonal fluctuation in feed supply (which restricts milk production and increases kid mortality), low intake of poor-quality feed and internal parasites (Peacock, 1996). Genetic potential is often not realised due to insufficient and seasonal changes in nutrient supply (Animut *et al.,* 2006). Low productivity of livestock in developing nations is mainly a result of gastrointestinal parasites (Ketzis *et al.*, 2002).

Information on goat performance, reproductive performance and survival rates is scarce. Some information from international and local literature highlights this issue. Singh *et al*. (1991) reported that the influence of season of birth on survival rates from three to six months of age was found to be significant ($P<0.01$). Kids born during summer had a significantly lower survival rate (67.24% ± 4.54) than those born during winter (86.85% ± 4.33). Birth weight of kids had a significant influence on their survival ($P<0.05$). During the six to 12 months of age period, kids weighing 2.0 to 2.5 kg at birth had significantly higher survival rates (90.84% ± 6.67) than those weighing less than 1.5 kg.

Low productivity (of meat, milk and fibre) of most indigenous breeds can result in a decline in the goat industry (Gürsoy, 2006) due to economic factors. Small, sickly goat kids with numerous deaths at birth are common in undernourished flocks (Church, 1991). The degree of development of a livestock industry is affected to a large degree by livestock feed supply (Raun, 1982). Forage crops can make a major contribution to the improvement of goat enterprises (Peacock, 1996). Payne *et al.* (2006) stated that non-supplemented rangeland and hay-based finishing systems do not support rapid weight gains. With the help of fodder and forage species, most of these limitations can be overcome, simply by improving the nutritional plane of these animals (and thereby improving the economic value of the goat).

Nutrition plays an essential role in goat farming systems for the following reasons:

- it is a production factor that can be altered easily and rapidly (feed quantity and quality);
- it has a large effect on production costs; and
- feeding directly impacts on other components, such as reproductive performance of flocks (Morand-Fehr, 2005).

In seasonally breeding species such as sheep and goats, pregnancy and fetal development frequently take place against a background of seasonal cycles in body weight and limited nutrient availability, which has an enormous influence on the successful outcome of the pregnancy and subsequent perinatal survival (Bassett, 1992).

A potential solution to the immediate problem that is commonly experienced by goat farmers is to utilize cultivated pastures to increase the nutritional plane of the animals and thereby reduce the impact of a poor feeding regime on the economic status of the indigenous goat in South Africa. Due to the high cost of producing a pasture, it is recommended that the pasture forage be given to the highest producing animals, which are those animals that maintain the cash flow. Therefore, the high quality forage should be utilized by the high producers (pregnant, lactating and growing animals). Church (1991) stated that protein is usually the first limiting nutrient for animals (nonpregnant, nonlactating) producing at a low level. Energy intake affects milk production, with a rapid response rate to changes in energy intake levels (Hadjipanayiotou & Morand-Fehr, 1991).

Moderate to good quality forages are digested with similar efficiency by sheep and goats, while poor quality forages are digested more efficiently by goats (Tisserand *et al*., 1991). Goats have a higher tolerance level to unpalatable forages than most other livestock species (Devendra, 1978) due to their high digestive efficiency for cellulose (Devendra, 1974). Forage crops play a role in increasing feed supply, improving feed quality and reducing seasonal fluctuations in herbage availability (Peacock, 1996). The decision to use perennial or annual pastures, summer or winter pastures, is based on how long specific areas will be available for forage, with annuals being used when the areas are available for a short period (Peacock, 1996).

The objective of this study was to evaluate goat production on both a winter annual pasture and a summer perennial pasture in KwaZulu-Natal. The indigenous goats' potential for intensive production systems was also evaluated. This experiment was designed to compare production between pasture species and was not an evaluation of a production system.

The two species selected for evaluating of goat production were *Secale cereale* (stooling rye) and *Pennisetum clandestinum* (kikuyu). The two species are very different, with kikuyu being a tropical, summer producing perennial pasture and stooling rye being an annual forage cereal that grows during autumn and spring. Grasses are classified as C_3 and C_4 grasses based on their photosynthetic pathways. Stooling rye is of a higher quality than kikuyu and is a C_3 temperate species, while kikuyu is a C_4 tropical species. The C_4 grasses have enhanced photosynthetic capacity and have higher nitrogen and water use efficiencies. The higher crop growth rates of tropical C_4 grasses compared with C_3 pasture plants, whether they are of temperate or tropical origin, seem to be due mainly to higher leaf photosynthetic rates and to the absence of photorespiration associated with the C_4 pathway. However, light utilization efficiencies are probably also higher in C_4 grasses. In addition to these two characteristics, the longer growing season of C_4 grasses in the warm conditions of the tropics contributes to their higher net annual production of dry matter (Ludlow, 1985). The quantitative anatomical differences between C_3 and C_4 grasses can account for a significant part of the generally higher dry matter digestibility of C_3 grasses (Wilson & Hattersley, 1989).

2 FORAGE SYSTEMS FOR GOAT PRODUCTION IN SOUTH AFRICA

Wild goats (*Capra aegagrus)* belong to the genus *Capra* and the tribe Caprini, which belong to the family Bovidae, in the sub-order Ruminantia, and in the order Artiodactyla (Nozawa, 1991). Quartermain (1991) stated that the goat is probably the most versatile of the domestic animal species, both in terms of adaptation to environment and in produce obtained from the goat. Devendra (1974) cites small body size, inquisitive feeding habits, high digestive efficiency for cellulose and efficiency of feed utilization as inherent advantageous nutritional qualities of goats.

Rangelands support grazing and browsing animals in communal and commercial systems. In many countries, livestock are kept for a range of purposes that extend beyond commercial gain, and livestock owners' objectives therefore vary (Kirkman & Carvalho, 2003).

2.1 GOAT PRODUCTION

Goats are regarded as an important livestock species in developing countries in Asia and Africa (Nozawa, 1991). Small-scale farming in African countries plays a major role in the livelihood of rural people and contributes approximately 30% to the national economy but would appear to not be sustainable due to low productivity (Lehloenya *et al.*, 2007).

Goats excel because they are adapted to a wide range of environmental conditions (Gall, 1991) which is assisted by their highly selective behaviour because it enables goats to stay in difficult areas and cope with toxic plants (Morand-Fehr, 2005). Goats are an important but under-utilized indigenous resource and provide an alternative income due to their versatility (Smuts, 1997). They are used as a means of investment or may be sold for cash flow. They provide employment opportunities, especially the effective utilization of unpaid family labour (Devendra, 1992; Morand-Fehr *et al*., 1993). Goats in the tropics are primarily used for meat production (Devendra, 1991). Goats are kept traditionally by a large part of the population in the rural areas of South Africa (Braker *et al.*, 2002) and are important to subsistence farmers and are used to maintain social bonds with the community, e.g. as lobola (dowry) (Braker *et al.,* 2002). Goats are also used for ceremonial and religious purposes and provide an income as well as meat and milk for the household (Braker *et al.,* 2002; Lehloenya *et al.*, 2007). Goat production is considered an alternative to improve the income and nutrition of rural communities and to incorporate these communities into commercial markets (Braker *et al*., 2002). In South Africa there were approximately 6,328,768 goats (in 2010)(DAEA, 2010) and their primary use was for meat, fibre and milk (Ramsay & Donkin, 2010). The ancient people in Korea used goat meat as a health promoting food. Compared to pigs, sheep and cattle, goats have lower amount of fat deposits (Devendra, 1991). The Korean Native goat meat is more expensive than other animal meat in Korea and is consumed more in processed form (Min *et al.*, 1999). In the period from 1990 to

1994, the total importation of goat meat into Korea was 5,500 tons of which imports from Australia accounted for more than 90% (Min *et al.*, 1999).

Landau *et al.* (2000) conducted research trials in the Mediterranean Basin and found that when considering the local breeds, sheep are better producers of meat in respect of growth rate, feed conversion efficiency and dressing percentage, in comparison to goats. They also found that the importance of goats increases whenever milk production becomes the most important element in productivity and when environmental conditions become harsher.

2.1.1 Diet versatility of goats

Goats are versatile forage harvesters and can survive under a range of conditions that many other species will battle to thrive in (Lu, 1988). Goats have proven their flexibility to cold and hot climates, to grazing sparse pastures and to using high quality rations (Gall, 1991). Lu (1989) stated that goats have heat resistant characteristics and are less susceptible to heat stress than their livestock counterparts. Raats (unpublished) classified goats as intermediate selector feeders and Kababya *et al*. (1998) stated that goats are opportunistic feeders. Paggot (1992) reported that the feeding behaviour of animals varies according to species. Ruminants, like the goat, chew the forage into coarse pieces and then regurgitate later and grind the food into a fine mix (Odo *et al.*, 2001). Odo *et al*. (2001) found that goats secrete more saliva and with a higher level of nitrogen than sheep, and prefer to select combinations of grasses and shrub plants or tree leaves, but grasses were the most preferred. In contrast, Nozawa (1991) stated that goats prefer to browse than to graze. Goats consume a much wider variation of plant types and select the material with highest nutrient concentration (Quick & Dehority, 1986; Narjisse, 1991; Odo *et al*., 2001) but best digest forage rich in cell wall and poor in nitrogen (Morand-Fehr, 2005). Goats are able to achieve a bipedal stance due to their agility, which enables them to reach higher into the tree canopy for food and the mobile upper lip and prehensile tongue assists with forage harvesting (Odo *et al*., 2001).

The progress and efficiency of a livestock industry is influenced by livestock feed supply (Raun, 1982). Forage crops can play a major role in the improvement of goat enterprises (Peacock, 1996). Intensification can improve production dramatically, even to the extent of 50% in total animal liveweight per hectare (Maree & Casey, 1993).

2.1.2 Limitations of goat production

Age at first kidding has been reported by Lehloenya *et al.* (2007) to be between 16 and 18 months of age in indigenous South African goats, with the kidding interval being 12 months. There is therefore potential to reduce the age at first kidding. Pre-weaning kid mortality is a major factor limiting goat production in the tropics and subtropics (Akingbade *et al*., 2003). Poor maternal milk supply due to poor nutrition during lactation has been recognised as the cause. By providing adequate nutrition, one can improve milk yield of dams and can thereby alleviate pre-weaning kid mortality and improve growth of offspring (Akingbade *et al.*, 2003), since survivability and growth of the young are closely related to the milk output of the mother (Cissé *et al*., 2002). Church (1991) stated that protein is usually the first limiting nutrient for animals (nonpregnant, nonlactating) producing at a low level.

Seasonal cycles in body weight and nutrient availability play a large role in the outcome of pregnancy and foetal survival (Bassett, 1992). Oestrus is dependent primarily on latitude and therefore photoperiodic stimulus (Rhind, 1992). Animal age, genotype, lactation and nutritional state can also affect oestrus (Rhind, 1992). It has been shown that, under conditions of severe under-nutrition, oestrus can be inhibited in the ewe, or the breeding season can be prematurely terminated (Knight *et al.*, 1983; Rhind, 1992). Gastrointestinal parasites result in low productivity of livestock, particularly in developing nations (Ketzis *et al*., 2002).

In both intensive and extensive grazing systems, it is desirable to maximise the proportion of forage in the diet in order to minimise feed costs (Baumont *et al.,* 2000). Intake is influenced mainly by hunger, which is distressing, and by satiety, which is pleasing (Baumont *et al.,* 2000). Feed intake and dietary choices are regulated by short-term body homeostatic regulation and long-term nutritional requirements and body reserves, therefore ruminants develop preferences for feeds that are richer in energy (Baumont *et al*., 2000). However, in a free-choice situation, diet selection does not always maximise energy density in the diet. Illius *et al*. (1999) found that when given a choice between grass species, goats selected diets that maximized intake rate.

The main factor influencing the performance of animals in an *ad libitum* situation is the level of dry matter intake (Masson *et al*., 1991). Stocking rate has a large effect on liveweight production when grazing animals are used to evaluate treatments (Kirkman & Carvalho, 2003). The efficiency of conversion of pasture to animal products is affected by grazing method, stock type and stocking rate, of which stocking rate is the most influential (Kirkman & Carvalho, 2003). Pasture management strategies should maximise pasture quality and utilisation while maintaining the regrowth potential of the plant (Reeves & Fulkerson, 1996). Stocking rate should depend on what the pasture can produce, while herd size should be determined by grass supply (Yuanquing *et al*., undated).

Huston (1994) stated that there are three conditions that limit productivity in goats:

1. kids that do not develop adequate body size have decreased lifetime productivity (Shelton, 1961);
2. ewes that are underfed at breeding fail to ovulate and conceive at high levels (Taylor *et al.,* 1988); and

3. pregnant ewes that are underfed tend either to abort or to give birth to small, weak offspring that often die within the first week (Wentzel *et al.,* 1976).

2.1.3 Variables in goat production

Animal movement, animal numbers, animal type and breeding can be manipulated in order to manage animals and forage supply. Irrigation can increase productivity, reliability of production and can extend the growing season (Kirkman & Carvalho, 2003). The economic viability of livestock systems on pastures is questionable, unless the added value to the product is greater than the cost of production (Kirkman & Carvalho, 2003). In the USA, goat prices have risen to such a degree that producers are investing in winter pastures for meat goat production as an alternative to grasslands (Animut, 2006).

Complex interactions between the vegetation and the animal exist, which affect intake and diet composition. Selective grazing allows the animal to consume a diet of a higher nutrient quality than that on offer (Baumont *et al.*, 2000), which then has an effect on the vegetation by either over-utilising or under-utilising selected species. Cissé *et al.,* (2002) stated that animals generally consume plants with a higher level of crude protein than the average of that on offer.

One management strategy that influences forage selectivity is stocking rate (Animut *et al.*, 2005). Stocking rate affects forage availability, animal performance and intake, and in addition, affects the vegetation, which then affects the economic viability of the system. Repeated overgrazing decreases plant vigour, which reduces both the production potential of the plant and the longevity of the pasture, which has a large effect on the economics of the system (Morris *et al.,* 1999). O'Reagain & Turner (1992) reported that stocking rate affects both animal production and range condition and unless the range is stocked at a sustainable level, degradation is likely, and a threshold stocking rate exists, above which range degradation occurs.

2.1.3.1 Theoretical model of animal production

Several relationships between animal production and stocking rate exist, with that most widely accepted being the Jones Sandland model of 1974 (Jones & Sandland, 1974). This model has both a linear and quadratic component to describe the ADG and gain per hectare functions respectively.

Generally, as stocking rate increases, individual animal performance declines but production per unit area increases (up to a certain level) (O'Reagain & Turner, 1992) suggesting that total animal production is optimized at moderate stocking rates. Lighter stocking rates are better for reproductive animals due to the improved survival and growth rates of offspring. Heavy stocking rate systems are under greater pressure in drought years and generally have a shorter grazing season (O'Reagain & Turner, 1992).

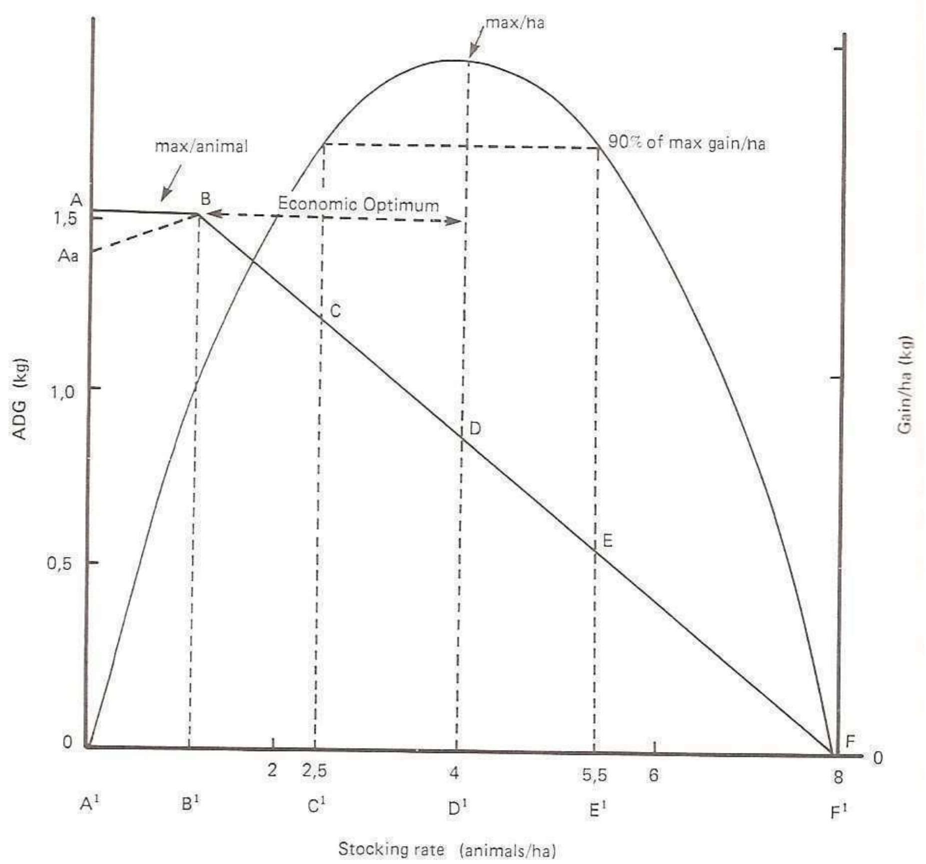


Figure 1: The theoretical relationship between stocking rate and average daily gain and between stocking rate and livemass gain per hectare (Edwards, 1981).

The critical stocking rate is point D^1 (Figure 1). At stocking rates above this point, animal performance declines due to an increase in grazing pressure that decreases the quantity of forage available. At point F^1 (Figure 1), animal gains are zero and animals are at maintenance. The gain per hectare model (Figure 1) is normally quadratic in shape, with a sharp increase in production per ha with each unit increase in stocking rate. The rate of increase slows and then decreases rapidly (Morris *et al.,* 1999).

The peak gain per animal (i.e. ADG) occurs at stocking rate point B^1 (Figure 1), which is a lower stocking rate than that at which maximum gain per hectare occurs (point D^1) (Figure 1). This implies that in order to maximise gain per hectare the stocking rate should be higher than that at which maximum gain per animal is achieved. If stocked to maximise gain per animal, there would be an economic loss since maximum gain per hectare would occur at a higher stocking rate (between points B^1 and D^1 in Figure 1).

Jones and Sandland (1974) indicate that there is a linear relationship between liveweight gain per head and stocking rate (line AB in Figure 1) to a critical point. Gain per unit area increases linearly (line AaB in Figure 1) as stocking rate is increased to the critical point (point B), then decreases linearly with further increases (line BF in Figure 1) (Jones & Sandland, 1974; Kirkman & Carvalho, 2003). In pastures with large amounts of accumulated herbage, line AaB (Figure 1) is a more realistic performance model.

Selection of forage by the animal is possible with grazing at light stocking rates, while overgrazing reduces the possibility of selection. In most rotational grazing systems, more animals per hectare can be carried in comparison to continuous grazing systems at lower stocking rates, but this does not necessarily increase production per animal except at low stocking rates. The longer the rotation, the greater the total yield, but the lower the quality of the forage (Kirkman & Carvalho, 2003). This is due to the fact that the pasture grass matures, increases in bulk (therefore a higher total yield) but decreases in quality as the proportion of fibre in the plant increases.

Stocking rate affects production in four ways:

1. the lighter the stocking rate the better each grazing animal will perform (within the limits of the potential of the pasture and the animal);
2. the production per hectare from the pasture will increase with increased stocking rate up to a certain point after which production declines;
3. the optimum economic return will vary depending on the stocking rate, the cost of livestock, fixed and variable costs and the price of the product; when costs are fixed, the optimum economic return will be obtained at a stocking rate somewhere between the maximum production per animal and the maximum gain per hectare; and
4. the condition of the pasture and consequently its ability to produce and to continue producing herbage, as well as the botanical composition of mixed pastures are determined by the stocking rate applied over the whole or portions of the season (Edwards, 1980).

2.1.3.2 Plant factors

For a given plant, ingestibility (the ability to take in food), like digestibility, is dependent on the vegetation stage and number of times the plant has been grazed during the season. During the first grazing cycle, ingestibility decreases as the plant matures (Demarquilly *et al.,* 1981) due to the increase in its fill effect. As the plant ages, the amount of cell content (which is rapidly degraded and has a low fill effect) decreases, and the volume of cell wall increases, so forage retention time in the rumen and fill effect increase (Grenet & Demarquilly, 1987). Digestion time is also increased (Baumont *et al.*, 1997). The length of time dry matter spends in the rumen is closely related to forage ingestibility (Baumont *et al.,* 1996).

When producing supplementary feed on small areas of land, species that give a high yield per hectare are tolerant to frequent defoliation and that are adapted to local conditions need to be chosen. Animal production systems in South Africa rely on intensive pastures to a large extent. With pasture costs escalating, the objective should be to maximum forage yields through high fertiliser application rates (Miles *et al.*, 1995). Management (e.g. stocking rates and fertilization) directly affect the nutritional value of pastures and it is important that input levels are high enough to improve livestock production (Minson 1980; Rohweder & Albrecht, 1995).

Pastures as a fodder source provide good quality feed in large volumes, if managed correctly. There is a wide range of plant species that produce herbage at differing times of the year, which can be selected from to provide fodder in times of shortages. Selecting the correct species (and cultivar) is therefore important in order to match forage production to demand. By increasing the amount and quality of feed on offer, goat production systems can increase animal performance levels and can thereby address some of the current limiting factors.

Due to their cold tolerance, small grain crops such as stooling rye can play an important role in meat production by extending the grazing season through late autumn and early winter and are productive, high quality forages (Lema *et al.* 2007). Stooling rye is the most cold-tolerant and least demanding in soil and moisture requirements of the small grain cereals and has rapid growth rates in autumn and spring (Lema *et al.,* 2007).

The two species selected for evaluating of goat production were stooling rye and *Pennisetum clandestinum* (kikuyu). The two species are very different, with kikuyu being a tropical, summer producer and stooling rye being a forage cereal that produces during autumn and spring. The C_4 grasses like kikuyu, have enhanced photosynthetic capacity and have higher nitrogen and water use efficiencies. A major advantage of C_4 plants over C_3 plants (such as stooling rye) is their better drought resistance, water-use efficiency and better heat tolerance, probably due to reduced photorespiration (Marais, 2001). These two species complement each other well, with kikuyu providing high yields of good quality fodder over the summer period, and stooling rye providing excellent quality feed in potentially high quantities (if management levels are good) over the cooler period of the year. These species can be integrated into current production systems either individually or together and will combine well with the utilisation of indigenous vegetation.

2.2 THE ORIGIN OF *SECALE CEREALE*

Cultivated rye originated from either *S. montanum*, a wild species found in southern Europe and nearby parts of Asia, or from *S. anatolicum*, a wild rye found in Syria, Armenia, Iran, Turkestan, and the Kirghis Steppe. Rye was initially found as a weed in wheat and barley fields in southern

Asia and had co-evolved with wheat and barley for over 2,000 years until its value as a crop was recognized (Oelke *et al*., 2000).

2.3 TAXONOMY AND GENERAL BOTANICAL DESCRIPTION OF *SECALE CEREALE*

Stooling rye is a member of the grass family *Poaceae*, the sub-family *Pooideae,* the tribe *Triticeae,* the genus *Secale* and the species *cereale* (Evans & Scoles, 1976; Anonymous, 2011). Only one species of stooling rye, *Secale* (S.) *cereale* L., is extensively cultivated (Bushuk, 1976). Stooling rye is a tall, hardy, tufted annual grass that grows between 1m and 1.5m tall and has a blue-green colour. It has many smooth, long-pointed, soft leaves 1.2 cm in width (Reed, 1976). It thrives on infertile, submarginal areas and is renowned for its ability to grow on sandy soils (Duke, 1983). Leaf proteins have anti-freeze properties, which enable the stooling rye to be a winter-grower (Hon *et al.,* 1994).

Kassier & Goodenough (2002) described forage cereals as a collective term given to some of the rye, stooling rye, oats, triticale and a few wheats that are suitable for herbage production as opposed to grain production. Rye and stooling rye are both of the species *Secale cereale* and within these species are types with different flowering behaviours. Longevity of the pasture and also the time of peak herbage production is affected by flowering behaviour. The three forage cereal types are short-, medium- and long-duration types. The long-duration types (for example, the stooling rye Mac Blue cultivar) have the longest time from establishment to flowering and require a specific combination of daylength and low temperature to flower. The long-duration types therefore remain vegetative (good quality herbage) the longest and provide grazing up to late winter/early spring. The long-duration types, like the medium-duration types, have a prostrate growth form and are densely tillered, and are well suited to sheep grazing. They are slow to start growing after establishment but have the advantage of lasting the longest and providing herbage in late winter when the other two types are already either dead or in the reproductive stage (Kassier & Goodenough, 2002).

Populations of cultivated rye consist of winter, spring and intermediate phenotypes. The winter stooling rye types are medium and long duration varieties, while the spring types are short duration varieties. The short duration varieties become reproductive as soon as growth conditions allow and they behave like true annuals. The medium and long duration varieties require a period of vernalization. The term vernalization is applied to the treatment of young plants by low temperature to induce a shorter vegetative period and hasten flowering and fruiting. Vernalization treatment can be reversed by high temperatures. Time of flowering is determined by the degree of vernalization required (i.e. the number of cold days required). The period of vernalization of short duration stooling rye is relatively short (10-12 days) while that of medium and long duration stooling is longer (40-60 days). All stooling rye planted in spring will go to seed rapidly and will not behave like Italian ryegrasses which grow for 18 months before becoming reproductive. Winter stooling rye generally overwinters in the tillering state (Oelke *et al.,* 2000). The lowest temperature at which stooling rye will germinate is 3^{o}-5^{o}, with the optimum temperatures being between 25^{o} and 31 ^{o}C**.**

2.4 REQUIREMENTS OF *SECALE CEREALE*

2.4.1 Agro-ecological diversity

Agro-ecological diversity refers to the range of environmental conditions in which the crop is produced and relates particularly to rainfall, altitude and edaphic conditions (Kassier, 2002). Stooling rye can be grown in a wider range of environmental conditions than any other small grain (Oelke *et al*., 2000) since it is an extremely hardy plant and is often grown where other grains will not grow (Bushuk, 1976). Stooling rye is very winter hardy and drought resistant and reasonably tolerant of acidity (Anon, 1983).

2.5 AGRONOMIC REQUIREMENTS OF *SECALE CEREALE*

2.5.1 Establishment

A fine, firm seedbed is required for even establishment (du Plooy, 1957; Skerman & Riveros, 1990) and the seed can either be drilled or broadcast (du Plooy, 1957; Skerman & Riveros, 1990). Most stooling rye is grown as an autumn-sown annual, which is generally called winter rye (Bushuk, 1976). The seed is planted in the autumn, it germinates and grows into a plant of about 15cm, remains dormant during the winter and then continues to grow to maturity in the spring and early summer. The recommended seeding rate for row planting is 40 to 60 $kg.ha^{-1}$.

2.5.2 Fertilisation

Stooling rye fertility levels are a target soil phosphorus (P) of 11 $mg.L^{-1}$ (for sample density 1.0 $g.mL^{-1}$) and target soil potassium (K) of 120 $mg.L^{-1}$ with an annual N application of 200 kg $N.ha^{-1}$. The target soil magnesium (Mg) level is 100 $mg.L^{-1}$ with a permissible acid saturation (PAS) of 25% (Manson *et al.*, 2000). The desired pH of stooling rye lands is 6.5 although it does tolerate some acidity (Anon, 1983). Nitrogen and phosphorus applications in autumn result in increased autumn growth and therefore better winter ground cover (Briggle, 1959). Nitrogen should be applied in spring to replenish nutrients lost through winter leaching (Briggle, 1959).

2.5.3 Diseases

Fewer diseases and insects attack stooling rye than attack other cereals (Briggle, 1959). Disease is not a major problem in stooling rye, with the possible exception of ergot caused by the organism *Claviceps purpurea*. No source of resistance has yet been identified within the genus, so breeding for ergot resistance is not possible (Evans & Scoles, 1976). Other diseases that are known to attack Stooling Rye include Anthracnose (*Colletotrichum graminicola*), Brown wheat rust/ Leaf rust (*Puccinia recondita f.sp tritici*), Spot blotch (*Cochliobolus sativa*), Stem rust of cereals (*Puccinia graminis*) and Take-all (*Gaeumannomyces graminis var tritici*). Stooling rye may be attacked by mildew (*Erysiphe graminis),* leaf blotch (*Rhynchosporium secalis)* and septoria leaf spot (*Septoria secalis)* (Anon, 1983). These diseases may be present on overwintering crops and though the plants may grow away from them initially further build up may occur later in the season (Anon, 1983). These diseases can all be controlled using either chemicals or selecting varieties resistant to these diseases.

2.5.4 Weeds

Winter annuals and/or perennial weeds are usually the major weed problem in autumn sown cereal grains. Perennial weeds should be controlled by tillage or herbicides before or during seedbed preparation. Dense stands of stooling rye that are established in autumn will enable the stooling rye to compete well with weeds in spring (Oelke *et al*., 2000).

2.6 PRESENT UTILISATION OF *SECALE CEREALE*

The stooling rye crop has many uses. It is used as flour for bread, as grain for livestock feed, and as a forage for livestock (Bushuk, 1976) and has been grown for many years for early spring grazing (Anon, 1983). Its ability to control weeds makes it useful in a crop rotation and in some countries it is used as a pioneer species to improve wasteland and sterile soils (Bushuk, 1976). Stooling rye generally does better than other cereals on poorly prepared land (Briggle, 1959). In late autumn and early spring, stooling rye usually provides more forage than other small grains or permanent pastures and during the period of rapid early growth, stooling rye has a higher carrying capacity than wheat or oats (Briggle, 1959). The winter hardiness of stooling rye and its ability to grow in low-fertility soils makes it an attractive crop for high altitudes and marginal soil types (Evans & Scoles, 1976).

Stooling rye is a high potential winter feed. Autumn-sown stooling rye is widely used as forage for livestock (Bushuk, 1976; Hopkins *et al.,* 1997) in cool temperate regions of central Europe and North America (Hopkins *et al*., 1997). Occasionally it is grazed in the autumn and used as spring cover crop or ploughed in as a green manure for a crop of higher economic value (Bushuk, 1976).

More than 50% of the rye grown in the U. S. is used as pasture, hay, or as a cover crop (Oelke *et al*., 2000). Stooling rye adds organic matter to the soil, reduces soil erosion and enhances water penetration and retention (Oelke *et al*., 2000). Stooling rye combines with red or crimson clover and ryegrass and is a good source of forage (Oelke *et al*., 2000). Stooling rye generally provides more forage than other small grains in late autumn and early spring because of its rapid growth and its adaptation to low temperatures (Oelke *et al*., 2000).

Early autumn sowing of stooling rye will produce a higher yield (Anon, 1983) than if planted in late autumn. Grazing should occur when the crop is about 10cm high and a carrying capacity of 50 or more lactating ewes per hectare is feasible (Anon, 1983). Stooling rye is generally less palatable than wheat, oats and most grasses and is therefore less preferred than these other species. For this reason, it is usually grazed more successfully in pure stands than in mixes (Briggle, 1959). Maximum growth rates of stooling rye are achieved quickly after emergence and spring growth rate starts earlier in the season than for many other grasses (Hopkins *et al.,* 1997).

2.7 ORIGIN OF *PENNISETUM CLANDESTINUM* HOCHST. EX. CHIOV.

Kikuyu grass was named after the Kikuyu people who live in Kenya (east of the Aberdare Mountains) where the grass thrives (Mears, 1970; Skerman & Riveros, 1990). Kikuyu originated on deep red, well-drained latosolic soils at forest margins and in grassy glades at an elevation of between 1950 and 2700m in east and central Africa (Ethiopia, Kenya, Tanzania, Uganda and Zaire) (Tainton, 1998) at a mean annual rainfall of 1000 - 1600 mm (Marais, 2001). From the Democratic Republic of Congo and Kenya, kikuyu has been introduced widely in tropical areas such as southern Africa, Colombia, Hawaii, Australia, Brazil and the northern areas of New Zealand (Skerman & Riveros, 1990).

Its natural habitat consists of elevated, high-moisture and low-temperature areas. Varying climatic conditions within its habitat, and in the marginal regions around it, are conducive to ecotype development. Edwards (1937) recognised three distinct landraces from Kenya, but many more races, differing in morphology and chemical composition, are likely to exist within its distribution range (Marais, 2001).

In the natural habitat of kikuyu at elevations above 2250m, mean minimum and maximum temperatures range from 2-8 ^{o}C and 16-22 ^{o}C respectively. Frosts occur sporadically at night. In the subtropics where frosts are light, exposed herbage is dessicated (Mears, 1970).

2.8 TAXONOMY AND GENERAL BOTANICAL DESCRIPTION OF *PENNISETUM CLANDESTINUM* HOCHST. EX. CHIOV.

Kikuyu is described by Gibbs Russell *et al.* (1990) as a perennial, rhizomatous and stoloniferous plant that was naturalised from the east African highlands. It creeps vigorously by rhizomes and stolons and has an abundance of bright green leaves. Kikuyu grows between 30-1200mm tall and leaf blades are 50-300mm long and 3-7mm wide (Gibbs Russell *et al*., 1976). Flowering is controlled by apical dominance, but ecotypes appear to vary in sensitivity to auxin. South African kikuyu appears to be highly apical-dominant and does not flower under grazing conditions (Marais, 2001). Flowering in kikuyu does not appear to be sensitive to changes in daylength (Mears, 1970).

2.9 DIVERSITY OF *PENNISETUM CLANDESTINUM*

Kikuyu grows from sea level to 3500m (Tainton, 1998). In Africa, kikuyu is found in areas of high altitude with annual rainfall between 1000 and 1500 mm (Quinlan *et al.*, 1975). The region experiences tropical conditions of cool nights, warm days and frequent mists (Quinlan *et al.*, 1975).

Optimal growth temperatures are between 16 ^{o}C and 21 ^{o}C while the minimum temperatures for growth varies between 2 ^{o}C and 8 ^{o}C (Tainton, 1998). Kikuyu does not thrive in areas with high temperatures (Tainton, 1998) mainly, perhaps, because of disease problems under these conditions. Reports on the frost hardiness of kikuyu vary widely, with the interpretation of frost tolerance of kikuyu varying between authors. Crowder & Chheda (1982) (cited by Tainton, 1998) report its frost tolerance as good. The latter mention that while its leaves wither and die in frosty environments, its stolons are unaffected, which is substantiated by Skerman & Riveros (1990). Tainton (1998) reports that kikuyu tolerates only moderate levels of frost.

The rainfall of kikuyu's natural habitat ranges between 1000 and 1600mm (Tainton, 1998). Tainton (1998) estimates its rainfall requirement to be 1269 ± 632mm (Russell & Webb, 1976). Although kikuyu has a high rainfall requirement, it does grow in areas in South Africa with rainfall lower than 1000 mm. Kikuyu's drought tolerance in its natural habitat is said to be good because of the deep root system it develops in the deep well drained soils (Tainton, 1998). Whiteman (1980) regards its drought tolerance as fair. Kikuyu is said to tolerate waterlogging well and to survive periods of submergence of up to ten days (Tainton, 1998). Kikuyu is able to utilize moisture at depth during dry periods (Mears, 1970) due to its deep root system.

Kikuyu thrives on well-drained, fertile soils with a high nitrogen level, but can tolerate moderate waterlogging and high salinity. It does not do well on shallow, infertile soils. Kikuyu is highly efficient in using soil phosphorus, but on virgin soils requires high input levels of phosphorus for establishment (Marais, 2001).

2.10 AGRONOMIC REQUIREMENTS OF *PENNISETUM CLANDESTINUM* HOCHST. EX. CHIOV.

Kikuyu's high yield potential, resilience under poor management, and favourable response to nitrogen fertilisers are some of the factors that make this grass widely utilised (Miles *et al*., 1995).

Kikuyu thrives on alluvial soils and in moist sandy soils, provided reasonable levels of soil fertility are maintained (Tainton, 1998). It does not grow well on shallow, droughty, infertile heavy clays (Tainton, 1998). Tainton (1998) states that kikuyu does not grow well in shade and is reported to be tolerant of fire. In the higher rainfall eastern parts of South Africa, soil acidity frequently restricts the growth of a crop and pasture species. Kikuyu, however, is highly tolerant of soil acidity, with soil acid saturations of up to 60% having little or no effect on the productivity of the grass. Since kikuyu generally contains inadequate calcium (Ca) for the nutrition of ruminants, liming is recommended when soil acid saturations exceed 40% (Miles, 1998). Kikuyu's resilient growth habit and persistence enable low management input levels to maintain its' productivity (Reynolds, 2004).

In order to maximise production per hectare, frequent hard grazings can be used but the definition of this varies from area to area and with time of year. The recommendation is a grazing cycle of 3-4 weeks in the main growing period (summer) and this is increased to up to 6 weeks as growth slows down in the cooler months (Quinlan *et al.*, 1975). Rotational grazing is strongly recommended in all situations, with a period of absence of three weeks during peak growth rates, with the interval between grazings increasing as growth rates slow down (Quinlan *et al.*, 1975).

2.10.1 Establishment

Kikuyu can be established using either seed or vegetative material. Establishing a kikuyu pasture from seed is slower than establishing with vegetative material (Cunningham, 1998). Time of planting should coincide with the growing period of the grass, which is from spring to autumn. In climates that experience frosts and cold weather, planting should not occur after April (Quinlan *et al.*, 1975) in the Southern hemisphere.

2.10.2 Fertilization

Kikuyu is said to tolerate high salinity levels (Russel, 1976) and to tolerate irrigation with saline water even on saline soils, provided sufficient water is applied to keep high levels of soil salts at depth (Tainton, 1998). Kikuyu production peaks in the midsummer months (Miles *et al*., 1995). The dry matter yield of kikuyu can range from 5 – 8 t DM.ha $^{-1}$ at low levels of Nitrogen (N) fertilization (60 – 150 kg N.ha^{-1}), to an average production of 12 t DM.ha^{-1} and to beyond 16 t DM.ha^{-1} with heavy N fertilization (267 – 375 kg N.ha^{-1}). Yields are dependent on fertilizer application rates. The fertilization requirements of kikuyu pastures are related to environmental conditions and the level of production required. Generally, kikuyu requirements are 250 – 500 kg N.ha^{-1}, maintained at a minimum soil test level of 140 mg.L^{-1} potassium (K) and 10 – 18 mg.L^{-1} phosphorus (P) (Reynolds, 2004). Reasonable levels of soil fertility need to be maintained for kikuyu to persist productively. Kikuyu responds well to nitrogen rates of up to 45 kg of N per hectare per month and is useful in mixes with tropical and temperate legumes (Quinlan *et al.*, 1975). Large single applications of nitrogen fertiliser should be avoided and applications above 50 $kg.ha^{-1}.month^{-1}$ are undesirable (Marais, 2001).

2.10.3 Diseases

Kikuyu is sensitive to a number of diseases that tend to become a problem under hot humid tropical lowland conditions (Tainton, 1998). Kikuyu yellows and rust are two commonly experienced problems on kikuyu pastures. Little is known about kikuyu yellows but it does not appear to have a detrimental effect on production. Rust can be grazed off to reduce its prevalence and is not detrimental to yield. A disease known in New South Wales, Australia, as "Kikuyu yellows" is the major disease of kikuyu. Symptoms are patches of yellow, chlorotic leaves that develop and spread in the pasture. The pathogen causing the disease has not been identified with certainty. "Kikuyu yellows" and "kikuyu dieback" are the two most serious diseases recorded (Quinlan *et al.*, 1975).

2.10.4 Pests

If soil fertility is maintained, kikuyu is not troubled by pests and diseases. Attack by non-specific insects such as armyworms (*Spodoptera* spp.), webworms (*Oncopera* spp.) and grass caterpillar (*Herpetogramma licarsisalis)* are common but do not kill the plant (Quinlan *et al.*, 1975). The African armyworm caterpillar (*Spodoptera exempta* or *Mythimna convecta*) is indigenous to east and central Africa and has been blamed for kikuyu poisoning. Regular seasonal outbreaks occur usually every 6-8 months, between November-December and May-June. The young larvae prefer indigenous grasses, and they have co-evolved with kikuyu for many years (Marais, 2001). Bell (1998) stated that Armyworm (*Spodoptera exempta*) outbreaks occur sporadically in the higher rainfall areas of South Africa. Insecticides registered for use against armyworms are carbary, endosulfan, mercaptothion, tetrachlorvinphos, trichlorfon, chlorpyriphos and methomyl (Bell, 1998).

2.10.5 Weeds

Kikuyu's vigorous nature ensures that weeds are seldom a problem in well-fertilised pastures. Regular slashing to control weed competition and encourage runner formation is recommended (Quinlan *et al.*, 1975). Should weeds become an issue, fertiliser applications (with nitrogen, phosphorus and potassium) will increase the vigour of the kikuyu and it should then out-compete the weeds. In newly established kikuyu pastures, weeds can be controlled with the application of chemicals registered for use in perennial pastures.

Kikuyu often becomes a weed in cultivated areas due to its aggressive creeping habit and ability to regrow from cuttings. Repeated herbicide applications will control kikuyu (Quinlan *et al.*, 1975).

2.11 NUTRITIVE QUALITY OF *PENNISETUM CLANDESTINUM*

The nutrient content of kikuyu has been reviewed extensively, with nutritional levels in excess of those required for cattle maintenance and growth (Taylor, 1949; Lesch *et al*., 1974; Bredon & Stewart, 1978; Jones *et al*., 1980; Baker, 1982; Minson, 1982; Bransby, 1983; Bartholomew, 1985; Bredon *et al*., 1987; Fushai, 1997).

Kikuyu compares favourably with other tropical grass species in digestibility and protein levels. Digestibility of dry matter is in the range of 60% to 70% and decreases at a slower rate through the season than the taller tropical grasses. A strong negative correlation often exists between neutral detergent fibre (NDF), or cell wall concentration, and digestibility of grasses (Marais, 2001).

Crude protein levels are high (15%-18%) while the grass is being supplied with adequate nitrogen. Protein content of kikuyu is fairly stable and a level of over 12% has been measured in 4-month old regrowth (Quinlan *et al.*, 1975). Many authors have found crude protein levels of between 16% and 20% (Allwood, 1994; van Soest, 1994; Reeves & Fulkerson, 1996; van der Merwe, 1998).

Energy is kikuyu's major limiting factor for milk production, due to a lack of readily digestible non-structural carbohydrates and a low digestibility of structural components (Marais, 2001).

Kikuyu, a natrophobe, does not provide sufficient sodium for grazing animals, even when the soil contains sufficient sodium (Marais, 2001). Sodium levels may be insufficient for normal levels of animal production and consequently a salt supplement is recommended where kikuyu forms a significant part of the diet and stock water is also low in sodium.

Kikuyu grass belongs to one of the genera of tropical panicoid grasses accumulating oxalic acid (Marais, 1997). Oxalic acid causes acute toxicity in cattle consuming pastures with an oxalate concentration of more than 69 $g.kg^{-1}$ DM, due to its interference with energy metabolism and the precipitation of oxalate crystals in renal tubes (Marais, 2001). Marais (1998) reported an average soluble oxalate value in kikuyu of 30 $g.kg^{-1}$ DM. Animals used to grazing kikuyu should be able to metabolise these levels without any harmful effect (Marais, 1998). Fulkerson & Slack (1999) reported Ca: P ratios in kikuyu of 0.9:1 in summer-autumn and 2.5:1 in early spring, excluding the binding of calcium by oxalate. Seasonal mean herbage calcium (Ca) and phosphorus (P) concentrations range between 0.22% to 0.33% and 0.27% to 0.39% respectively, while seasonal mean Ca:P ratio's range from 1.1:1 to 0.63:1 (Miles *et al*., 1995). Calcium concentrations and the Ca:P ratios are lowest in midsummer, while P concentrations increase in midsummer (Miles *et al*., 1995). These figures show a tendency for kikuyu to be deficient in Calcium (due to the low Ca:P ratio and the tendency for calcium to be bound by oxalate) and can therefore cause hypocalcaemia in livestock. Levels of phosphorus in adequately fertilized stands may reach 0.4% to 0.5% on a dry matter basis (Quinlan *et al.*, 1975). Oxalate-producing tropical grasses like kikuyu have been responsible for many of the incidences of hypocalcaemia in herbivores (Marais, 2001).

Herbage magnesium (Mg) concentrations, as indicated by Miles *et al*. (1995) range from 0.25% to 0.35% while potassium (K) concentrations range from 2.64% to 4.46%. Potassium concentrations in kikuyu are in excess of animal requirements and range from 9.3 - 42.4 $g.kg^{-1}$ DM and could seriously inhibit calcium and magnesium uptake by the plant. This results in potassium: calcium plus magnesium ratios ranging from 2.19 - 3.15. The safety threshold of 2.2 is often exceeded, making animals on kikuyu vulnerable to milk fever or hypomagnesaemic tetany (Kemp & t'Hart, 1957; Miles *et al.,* 1995). Since the potassium: calcium plus magnesium ratio of kikuyu tends to decreases as growth rate slows, it is recommended that kikuyu be grazed at the four to five-leaf growth stage (Marais, 2001).

2.12 PRESENT UTILISATION OF *PENNISETUM CLANDESTINUM* HOCHST

Kikuyu is the predominant dryland summer pasture grown in the Midlands of KwaZulu-Natal (de Villiers, 1998) and is one of the most important summer pasture species in South Africa (Miles *et al.,* 1995). The stoloniferous and rhizomatous nature of kikuyu lends itself for use in erosion control. It is widely used as a summer pasture in both irrigated and dryland situations and often used as winter foggage (deferred grazing or standing hay) during its dormant phase.

To obtain reasonable production from kikuyu, quality on offer is important (Murphy, 1990; Reynolds, 2004). As long as irrigation and fertilization rates are adequate, the most important production variable is stocking rate (Reynolds, 2004). Recent studies have shown that organic matter, digestibility, protein levels and some minerals are maximized when kikuyu is utilized at a level of four leaves per tiller, with a pasture height after grazing of roughly 60 mm (Reynolds, 2004).

2.13 LIMITATIONS OF *PENNISETUM CLANDESTINUM* HOCHST AS A HERBAGE

Marais (1998) stated that the most important chemical factors reducing the nutritive value of kikuyu are the low level of readily available energy in the grass, the low digestibility of structural components, the presence of oxalic acid in the plant, the low sodium content, and the high nitrate content of kikuyu when heavily fertilized with nitrogen.

Nitrate is relatively non-toxic, but is readily reduced to ammonia by microbial action in the rumen, with toxic nitrite as an intermediate. Nitrite reacts with haemoglobin to form methaemoglobin, which is unable to bind oxygen, resulting in oxygen starvation (cyanosis) of the tissue and, in severe cases, death. Excess nitrate in kikuyu pastures can be prevented by applying more moderate levels of nitrogen fertilizer and avoiding large single applications, especially to grazed pastures where urine and faeces recycle nutrients (Marais, 2001).

With the exception of high nitrate levels, none of the known anti-quality factors in kikuyu can be eliminated by good farm management practices (Marais, 1998). Calcium supplementation is essential (Marais, 2001), as is energy and sodium supplementation.

3 INDIGENOUS GOAT PRODUCTION ON KIKUYU (*PENNISETUM CLANDESTINUM* HOCHST*)*

Introduction

Kikuyu, *Pennisetum clandestinum* Hochst. ex. Chiov. (Mears, 1970; Skerman & Riveros, 1990) is the predominant dryland summer pasture grown in the Midlands of KwaZulu-Natal (de Villiers, 1998) and is one of the most important summer pasture species in South Africa (Miles *et al*., 1995). Kikuyu is widely used as a pasture due to its high yield potential, resilience under poor management and good response to nitrogen fertiliser (Miles *et al.*, 1995).

Kikuyu is described by Gibbs Russell *et al.* (1990) as a perennial, rhizomatous and stoloniferous plant that was naturalised from the east African highlands. It creeps vigorously by rhizomes and stolons and has an abundance of bright green leaves. Kikuyu grows between 30-1200mm tall and leaf blades are 50-300mm long and 3-7mm wide (Gibbs Russell *et al*., 1976). Flowering is controlled by apical dominance, but ecotypes appear to vary in sensitivity to auxin. South African kikuyu appears to be highly apical-dominant and does not flower under grazing conditions (Marais, 2001). Flowering in kikuyu does not appear to be sensitive to changes in daylength (Mears, 1970). In its natural habitat of elevations above 2250m, mean minimum and maximum temperatures range from 2 - 8^{o}C and 16 - 22^{o}C respectively with sporadic frosts at night that desiccates the herbage (Mears, 1970).

Kikuyu has an aggressive rooting system and is able to utilise moisture at depth. It is able to grow from sea level to altitudes of 3500m and can survive intermittent waterlogging (Tainton, 1998). Kikuyu can tolerate some soil acidity (up to 60%) with no detrimental effects on production but liming is advocated for soil acid saturations exceeding 40% (Miles, 1998) to alleviate the low calcium levels of the grass. Kikuyu responds well to nitrogen fertiliser, which increases its competitive ability (Mears, 1970). As the plant matures, the leaf to stem ratio decreases, which results in a rapid decrease in quality through the growing season (Marais, 2001).

Kikuyu has low levels of available energy, poorly digestible structural components, low sodium and calcium content and contains oxalic acid (Marais, 2001). Most of these nutritional deficiencies can be corrected through supplementation. The crude protein content of kikuyu is higher than most other tropical grasses (Mears, 1970) although not as high as most temperate grasses (Joyce, 1973). Fertilised kikuyu can satisfy the mineral requirements of most classes of animals (Mears, 1970). There is, however, a high hypomagnesaemic tetany potential for animals on kikuyu (Miles *et al.*, 1995).

The taxonomic description of wild goats (*Capra aegagrus)* is in the genus *Capra*, in the tribe of Caprini (goats and sheep), in the family Bovidae, in the sub-order Ruminantia, in the order Artiodactyla (Nozawa, 1991). Devendra (1974) cites small body size, inquisitive feeding habits, high digestive efficiency for cellulose and efficiency of feed utilization as inherent advantageous nutritional qualities of goats. Goats possess characteristics including versatility in harvesting forage and ability to survive under adverse foraging conditions that set them apart from other livestock species (Lu, 1988). In general, goats have heat resistant characteristics and are less susceptible to heat stress than their livestock counterparts (Lu, 1989).

The goat is regarded as an important livestock species in developing countries in Asia and Africa (Nozawa, 1991). In South Africa there were approximately 6.3 million goats (in November 2010) (DAFF, 2010). Their primary use was for meat, fibre and milk (Ramsay & Donkin, 2000). Goats are an important but under-utilized indigenous resource. Their small size, specialized feeding behaviour and low management (supervisory and time) requirements make them a versatile option to improve the household cash flow and nutritional constraints experienced by many of the rural inhabitants (Smuts, 1997). The importance of goats increases whenever milk production becomes the most important element in productivity and when environmental conditions become harsher (Landau *et* al., 2000). Goats serve as a means of capital storage and investment or may be sold to improve cash flow. Through their management and their products, they provide employment opportunities, especially the effective utilization of unpaid family labour (Smuts, 1997; Morand-Fehr *et al.,* 1993). Goats are kept traditionally by a large part of the population in the rural areas of South Africa (Els, 1996). These goats fulfil important roles within the households of subsistence farming systems in these rural areas. They are used to maintain social bonds with the community, e.g. as lobola (dowry) (Tapson, 1993) and as exchange with relatives. Goats are also used for ceremonial and religious purposes and they provide an income as well as meat and milk for the household (Braker *et al.,* 2002).

Nozawa (1991) stated that goats prefer to browse than to graze, while Odo *et al*. (2001) stated that goats generally show highest preference for grasses. Van Soest (1981) classified goats as intermediate selector feeders, which is helped by the goats' ability to stand on two legs to feed on a large variety of forage (Odo *et al*., 2001). Owen-Smith & Cooper (1988) observed feeding behaviour of animals in the Northern Transvaal, South Africa, and found that consumption of species varied with growth stage, season, soil type and availability of other species. They also found that goats were less selective than their native ungulates and that species neglected at one time of year may become favoured at another time.

Goats under rotational or restricted grazing systems (semi-intensive) have been observed to have fewer worm-egg counts than those kept under the free-range grazing or extensive system. With regards to season, the level of risk of nematode infections and the worm-egg output of goats are higher in the wet season than the dry season because the wet season supports larval development (Magona & Musisi, 2002).

Stocking rate has considerable effect on liveweight production when grazing animals are used to evaluate pasture treatments (Kirkman & Carvalho, 2003). Grazing method, stock type and stocking rate can be manipulated to maximise animal production, however, stocking rate has the largest impact on production per hectare (Kirkman & Carvalho, 2003).

Pasture nutritional value is affected by management input levels (e.g. stocking rates and fertilization) and it is important to ensure that management inputs are adequate to ensure improved livestock production (Minson, 1980; Rohweder & Albrecht, 1995). Grazing allows selection, but overgrazing reduces the ability of the animal to select, while rotational grazing allows the stocking rate to be increased but may not increase production per animal. A longer rotation increases the volume of forage on offer but decreases the quality of forage on offer (de Alba, 1959) due to the increase in fibre levels. The large difference in nutritive value of leaf and stem tissue means that management practices should be aimed at optimising the leaf: stem ratio of the grass on offer and preventing the accumulation of stem material. The nutritive value of kikuyu regrowth appears to be optimised at the 4.5 leaves per tiller growth stage (Marais, 2001).

Small ruminants are highly dependent on natural pastures as a food source, therefore animal productivity is dependent upon annual rainfall patterns (Cissé *et al.*, 2002) and seasonal variations in pasture nutritive value. Deficiencies in nitrogen and in mineral content limit the acceptability of grasses by ruminants, leading to reduced productivity (Cissé *et al.*, 2002). Weight loss varies widely and is affected by many factors, particularly the level of energy intake both preceding and following parturition (Agricultural & Food Research Council, Undated). The main sources of energy are starch, cellulose and hemicellulose, and are obtained principally through grazing (NRC, 1989). Energy provides the body with the ability to do work (NRC, 1989) and is the dietary component required by cattle in the greatest amount, usually accounting for the largest proportion of feed costs (Hamilton, 1997). Energy requirements are separated into maintenance and production, where maintenance is the energy intake that results in neither the nett gain nor loss of energy from the tissues of an animal (NRC, 1989). Production occurs at any level of energy above that required for maintenance (Reynolds, 2004). As the volume of herbage offered increases, so milk production increases (Foot *et al.*, 1987; Rattray *et al*., 1987; Cavallero *et al*., 1988). In contrast to energy, protein cannot be stored over a long period in goats (Landau *et al*., 1993; Kababya *et al*., 1998).

The nutritive value of forage is affected by intake levels and digestibility of the forage (Marais, 2001). Leng (1991) stated that in order to optimize ruminant production from forages, pasture quality and intake levels should be optimised, microbial growth maximised and the nutrients adjusted to correspond to the quantities and balances required for production. This is achieved through correct pasture and animal management (for example, not letting the pasture mature excessively before grazing) and providing supplements to correct mineral imbalances. In goats given forages *ad libitum* the main factor influencing performance is the level of dry matter intake (Morand-Fehr & Sauvant, 1978).

There has been minimal research of intensive goat production systems on pastures. The objective of the investigation was to determine the optimal stocking rate for goat production on kikuyu and to determine the production levels that can be achieved in the KwaZulu-Natal Midlands of South Africa. For the purpose of this investigation, a rotational grazing system was selected at three stocking rates.

Objectives

There has been minimal research of intensive goat production systems on pastures. For this investigation, a summer growing pasture was evaluated to test the potential for intensively farming the South African indigenous goat. This investigation was designed to determine what species are suitable for goat production in South Africa.

Kikuyu was selected as the summer pasture due to its prevalence in the country and its versatility and erosion-reducing potential. It is a hardy species that does not need supplementary irrigation to produce in KwaZulu-Natal. Once established, it is a relatively low-cost pasture and does tolerate some mismanagement.

The objectives of the investigation were to:

1. investigate the relation between stocking rate and animal production;
2. investigate the relationship between stocking rate and herbage availability; and
3. evaluate the potential for utilization of a perennial summer pasture for goat production in the KwaZulu-Natal Midlands of South Africa.

Procedure

Study area

The trial was conducted on the same site for two consecutive years (the summers of 2001 and 2002). The site for the trials was located on the Cedara Research Station (29^{o}32'S, 30^{o}17'E) of the KwaZulu-Natal Department of Agriculture and Environmental Affairs in the midlands of KwaZulu-Natal province in South Africa. The research station lies at an altitude of 1076 m above sea level, with long-term annual means of 885 mm, 1577 mm, 22.3^{o}C, 9.4^{o}C and 16.2^{o}C for rainfall, mean annual evaporation and maximum, minimum and average daily temperatures respectively (Agromet)[1]. Severe frosts occur during June and July. Seasonal long-term means are listed in Table 1.

Table 1. Long term average means of maximum temperature, minimum temperature, monthly rainfall and hours of sunshine experienced at Cedara Research Station [1].

	Average maximum temperature (^oC)	Average minimum temperature (^oC)	Average rainfall ($mm.month^{-1}$)	Average sunshine hours ($hours.day^{-1}$)
Summer (December to February	25.2	14.5	128.4	6.3
Autumn (March to May)	22.8	10.3	62.5	7.3
Winter (June to August)	19.9	4.4	18.8	8.0
Spring (September to November)	22.9	10.6	81.1	6.5

Established dryland kikuyu pastures were utilized for the kikuyu trial and the site was burnt (after more than 15 mm rain in 24 hours) before the experiment commenced for the first year only. The dominant soil type was a Hutton soil form, which is an orthic A horizon over a red apedal B horizon (Soil Classification Working Group, 1991). This is a well drained soil.

Fertilization

The soil P and K levels were raised to the recommended levels in accordance with soil analyses[2], which are 120 $mg.L^{-1}$ for K and 8 $mg.L^{-1}$ for P (AMBIC). The P (single superphosphate (10.5%P)) and K (KCl (48%K)) fertilizers were spread evenly on the site to correct mineral imbalances. The acid saturation was 21% and the pH (KCl) was 4.12. Nitrogen was applied in the form of Limestone Ammonium Nitrate (LAN (28%N)) at a rate of 50 kg $N.ha^{-1}$ after each grazing cycle, in accordance with recommendations (Miles, 1998). A total of 300 kg $N.ha^{-1}$ were applied to the treatment area over the trial duration.

Treatments and measurements

The experiment evaluated three stocking rates in a randomized block design with two replications (Table 2). Stocking rates were 30, 45 and 60 $goats.ha^{-1}$. Animal numbers per treatment were kept constant, with areas varying in size to simulate the various stocking rates.

[1] Agromet, ARC – Institute of Soil, Climate and Water, Private Bag X79, Pretoria, 0001, South Africa.
[2] Fertrec Laboratory, KwaZulu-Natal Department of Agriculture and Environmental Affairs, Private Bag X9059, Pietermaritzburg, 3200.

Table 2. Layout of trial for goats on kikuyu pastures.

Replication 1	Low stocking rate (30 goats.ha^{-1})	High stocking rate (60 goats.ha^{-1})	Medium stocking rate (45 goats.ha^{-1})
Replication 2	Medium stocking rate (45 goats.ha^{-1})	High stocking rate (60 goats.ha^{-1})	Low stocking rate (30 goats.ha^{-1})

There were ten ewes per treatment, with camp sizes being 0.33ha, 0.22ha and 0.17ha for the stocking rates 30, 45 and 60 goats.ha^{-1} respectively. Ewes with kids at foot were evenly allocated to each stocking rate and treatment. Each treatment was divided into four equally sized camps that were grazed on a rotational basis. The grazing period per camp was seven days and the period of absence was 21 days per camp. Samples of grazed herbage were collected once a month (before grazing) using the hand-plucking method (Cissé *et al.*, 2002) to determine forage quality. Herbage samples from each camp were oven-dried (at 60^{o}C) for 48 hours, milled (to pass a 1mm screen), analysed for N, dry ashed and analysed for K, Ca and Mg by atomic absorption, and P by colorimetric methods. The Kjeldahl method and Dumas method were used for the determination of N (prior to ashing)(Kjeldahl procedure: AOAC, 1980). All goats were weighed at two weekly intervals.

Animal management

All goats were initially vaccinated with Multivax-P© vaccine (which includes the Tetanus and Pulpy-Kidney vaccine) in accordance with veterinarian recommendations. Goats were dewormed three times during the trial period (alternating the active ingredient at each deworming) and footbathing (for footrot) was done when deemed necessary. All goats were given two Vitamin B-Co© injections during the trial period since vitamin B_1 was identified during the early stages of the trial (by autopsy) as being deficient in goats. All kids born during the trial were treated with Multivax-P© in accordance with recommendations and all male goats were castrated. Weaning occurred at an average age of 150 days. The goats were given a sodium (salt), calcium (bonemeal) and phosphorus supplement *ad libitum*.

Statistical analyses

Analysis of variance (ANOVA) and regression analyses, using the statistical package, Genstat 6.1 (Copyright 2002, Lawes Agricultural Trust, Rothamsted Experimental Station) were used to determine the effects of stocking rate on animal weight. Due to the logistics of grazing research, there were limited degrees of freedom for treatment differences. The experimental unit was the smallest unit to which a treatment was imposed (Fisher, 2000; Rayner, 1969), namely the group of animals, and the three stocking rates provided the source of variation. Fisher (2000) stated that in grazing experiments, the group of animals on the pasture is the single experimental unit and each animal on the pasture is a subsample, which should be representative of random samples of the population to which assumptions will be made. Fisher (2000) stated that variation within years comes from two sources, namely the pasture and the animal. Animal-to-animal variation is two to six times as large as paddock-to-paddock variation (Fisher, 2000). The assumptions that were made were that the animals would display correlated responses to treatment variables and that the pastures were uniform. The mean weight of the group was used in an analysis of variance so only the variation between the replications was considered in the analyses, not the variation between animals. Differences between treatments were determined for both ADGs to weaning and for the whole grazing period for both ewes and kids. Linear regressions were used to show the nature of any change over time and gain per hectare was determined for the years combined.

Rainfall and temperature data

Rainfall and temperature data were obtained from the Cedara AgroMet Station[1].

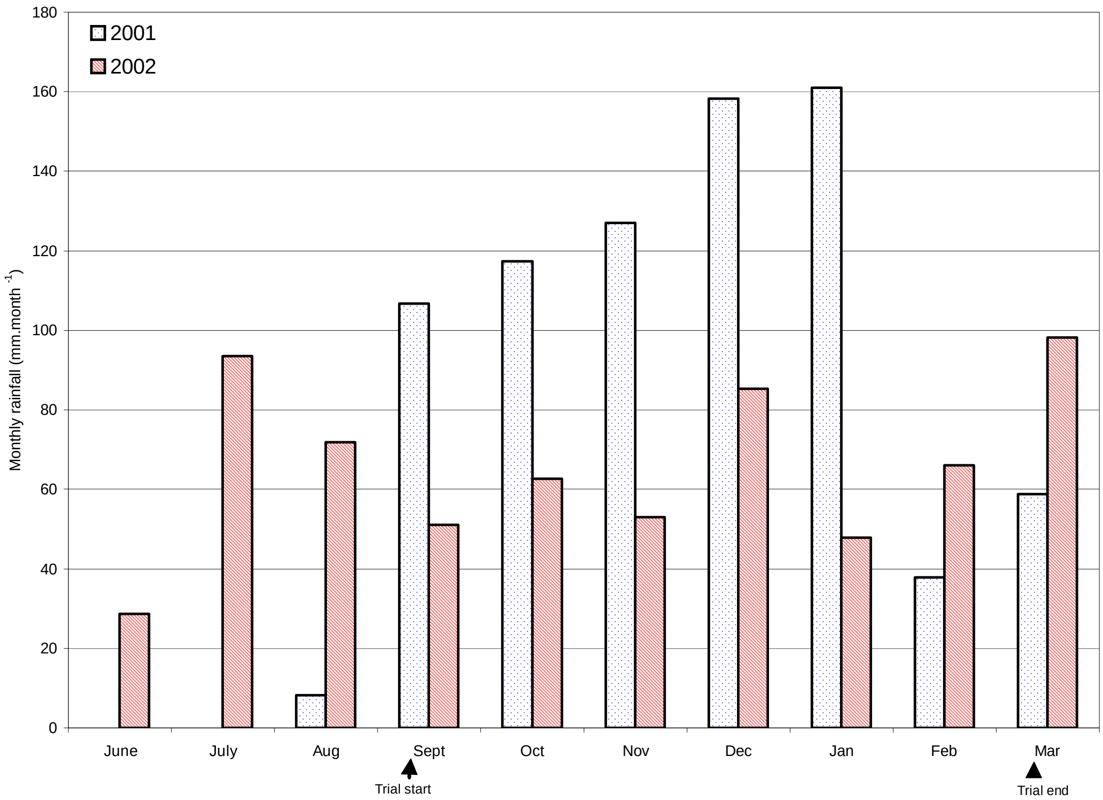


Figure 1: Rainfall experienced preceding and during the trial periods during 2001 and 2002.

[1] Agromet, ARC – Institute of Soil, Climate and Water, Private Bag X79, Pretoria, 0001, South Africa

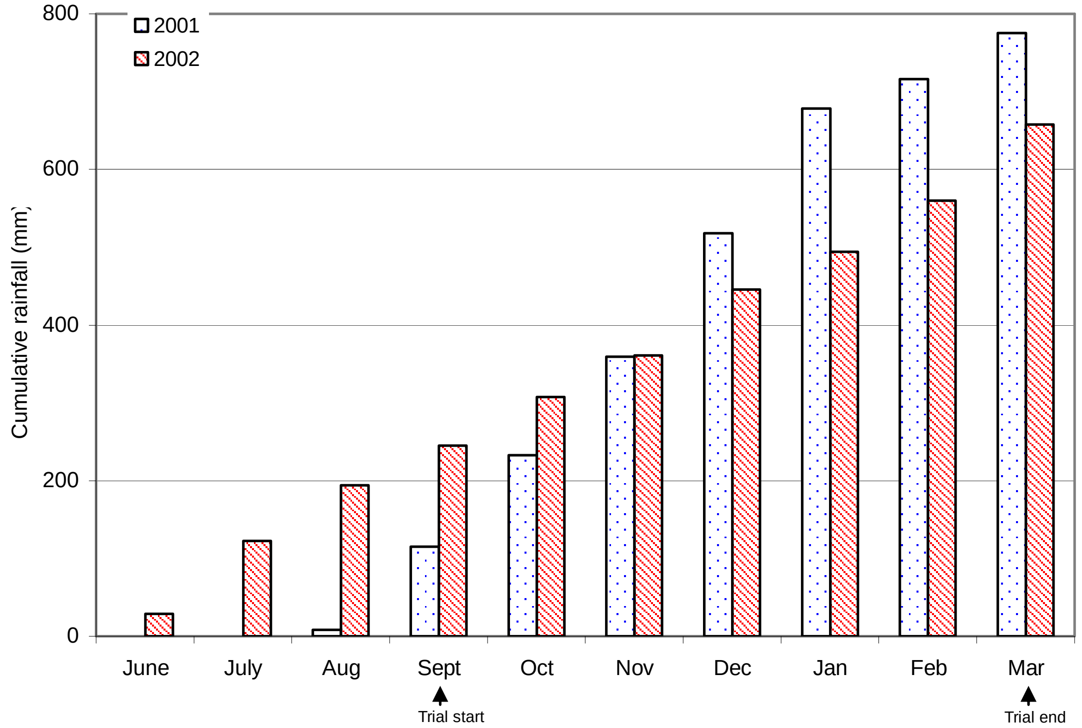


Figure 2: Cumulative rainfall experienced during 2001 and 2002 preceding and during the trial period.

In the months preceding the trial, 2002 had higher precipitation in June and July (Figures 1 and 2) than 2001 experienced. Soil moisture would have been limiting plant growth during this period in 2001. The precipitation experienced in September 2001 would have stimulated plant growth. The high rainfall in December 2001 and January 2002 would have resulted in high herbage production during this period for 2001, while 2002 experienced lower rainfall in December 2002 and January 2003 in comparison to 2001 (Figure 1). The rainfall experienced prior to the trial in 2002 would have stimulated herbage production earlier than would have occurred in 2001. The rainfall experienced during 2001 was higher than 2002, particularly in mid-summer (Figure 1) and would have therefore resulted in higher herbage production during the 2001 trial period. Herbage production was measured using a falling plate discmeter (Figure 4).

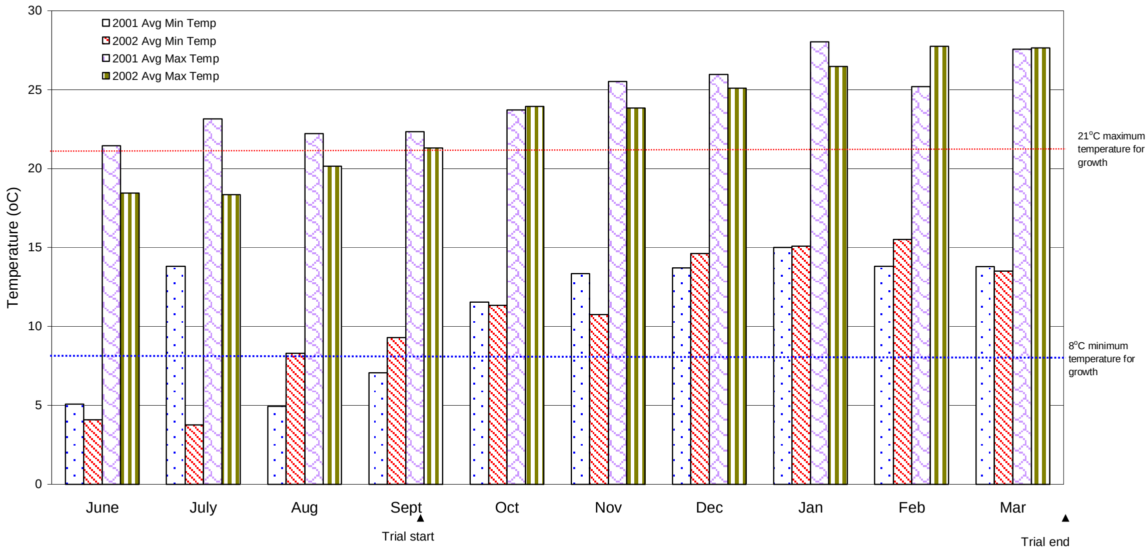


Figure 3: Average maximum and minimum temperatures experienced preceding and during the trial periods during 2001 and 2002.

In the months preceding the trial, 2002 had higher average maximum temperatures (Figure 3). The average minimum temperatures were higher in July 2001 than July 2002, and lower in August 2001 than August 2002 (Figure 3). The higher minimum temperatures experienced in August 2002 would have stimulated growth earlier than in 2001.

To summarise, 2001 experienced late spring rain, cooler spring minimum temperatures and high midseason rainfall. The 2002 year experienced early spring rain, warmer spring minimum temperatures and low midseason rainfall. The rainfall during the trial period was considerably higher in 2001 than 2002 with the 2002 year experienced more late-season rainfall than the 2001 year, with negligible differences in temperature. Temperature in June and July 2001 would have limited plant growth, which would have commenced in August when atmospheric and therefore soil temperatures increased. Since optimal growth temperatures are between 16°C and 21°C and minimum temperatures for growth vary between 2°C and 8°C (Tainton, 1998) negligible growth would have occurred prior to August in the 2001 year, or July in the 2002 year (Figure 3).

Results and discussion

The mean dry matter intake value calculated for goats are 76.7, 76.3 and 119.6 g DM/kg $W^{0.75}$ daily for growth, late pregnancy and lactation respectively (Kearl, 1982). Ewe mean mass at the end of the trial was used to determine apparent consumption for lactating goats and residual cover was added to the apparent consumption to determine grass production throughout the season (Figure 4). Residual cover was determined using a falling plate disc meter. The prediction of pasture yield (y) (kg $DM.ha^{-1}$) from disc meter height (d) (cm) as determined by Bartholomew (1985) was used, where y = 749.5 + 242.79d. Apparent intake was added to residual dry matter and an average of the two treatments was calculated to obtain total yield per treatment per year (Figure 4).

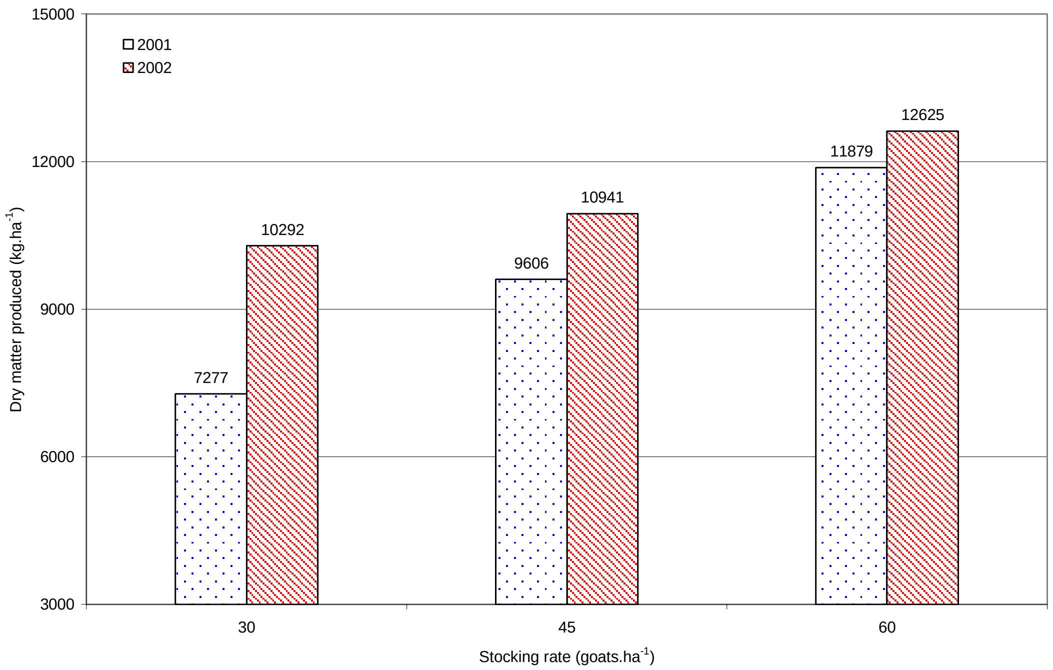


Figure 4: Apparent herbage production (kg $DM.ha^{-1}$) of kikuyu for 2001 and 2002.

The assumption that 2002 was a better year would appear correct since dry matter production was higher in 2002 than 2001 (Figure 4) therefore animal performance was better. As a result, the heavy stocking rate used during 2002 was not heavy enough for the good year experienced.

Animal performance

Since the animal weights had been evenly distributed between the treatments and the replications, there were no significant differences in ewe start masses. Average daily gains were calculated from the ewe start weights to weaning and also to the end of the trial period. The data for both years were combined and analysed using ANOVA, which showed a significant effect on ADG to weaning for both year and stocking rate but no interaction, so the stocking rate/year stratum was dropped from the ANOVA to increase the degrees of freedom (Ndiwa *et al*., 2003).

Table 3: An analysis of variance of goat ewe mean ADGs* to weaning using 2001 and 2002 data combined.

Year 2001/2002 ($kg.animal^{-1}.day^{-1}$)	-0.0061 [a]
Year 2002/2003 ($kg.animal^{-1}.day^{-1}$)	-0.0472 [b]
P	<0.001
LSD (5%)	0.00698
Ewe ADG ($kg.animal^{-1}.day^{-1}$) at 30 $goats.ha^{-1}$	-0.0157 [c]
Ewe ADG ($kg.animal^{-1}.day^{-1}$) at 45 $goats.ha^{-1}$	-0.0260 [d]
Ewe ADG ($kg.animal^{-1}.day^{-1}$) at 60 $goats.ha^{-1}$	-0.0384 [e]
Grand mean ($kg.animal^{-1}.day^{-1}$)	-0.0267
P	<0.001
LSD (5%)	0.00855
d.f	8
S. E.	0.00524
CV%	19.6

* Ewe ADGs excluding kid ADGs

[a] and [b] are significantly different from each other when using the LSD method (5%)

[c], [d] and [e] are significantly different from each other when using the LSD method (5%)

The investigation showed that the ewes lost weight until weaning in both years and in all treatments. The mean loss was 0.0061 and 0.0472 $kg.animal^{-1}.day^{-1}$ for the 2001/2002 and 2002/2003 years respectively (Table 3). Using the LSD method, there was a statistical difference between the two years (P<0.001)(Table 3 and Figure 5). When comparing ewe ADGs (the means of both years) there was also a significant difference between stocking rates at a 5% confidence level, with the mean ADGs being -0.0157, -0.026 and -0.0384 $kg.animal^{-1}.day^{-1}$ for 30, 45 and 60 $goats.ha^{-1}$ respectively (Table 3). The CV% obtained indicates some variation in the data. The loss in weight showed that the intake of the ewes was not sufficient to supply the requirements for maintenance plus milk production.

Regression analyses were conducted to determine the relationship between stocking rate and ewe ADG to weaning (Figure 5).

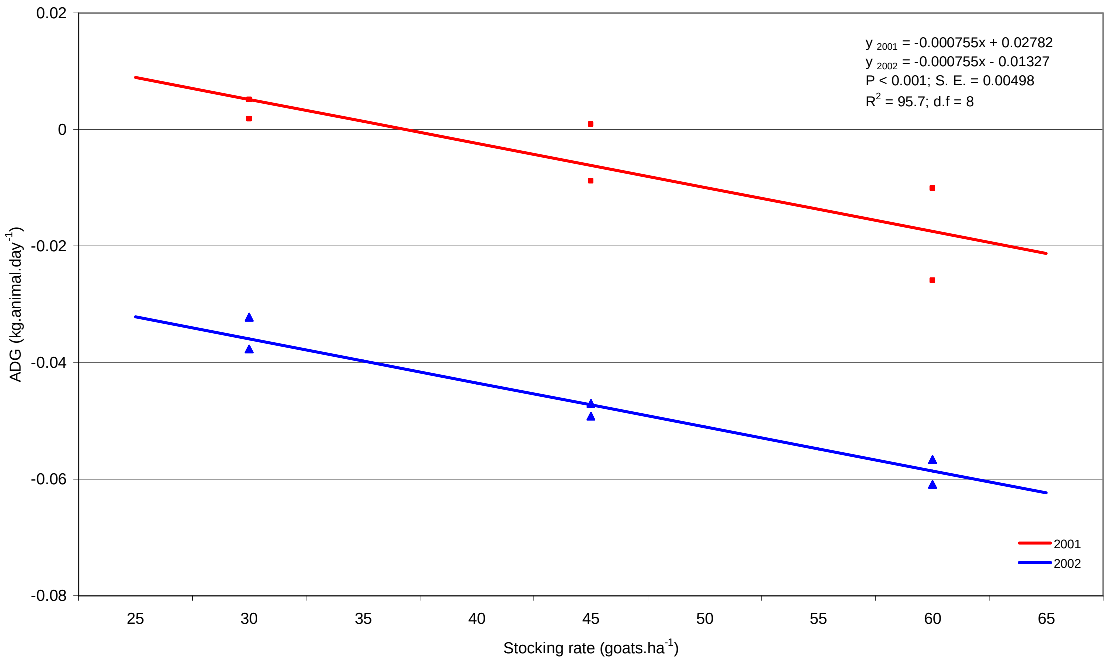


Figure 5: Regression analysis of mean ewe ADGs to weaning (y) on stocking rate (x) for goats grazing kikuyu until weaning for 2001 and 2002 combined.

For both the 2001 and 2002 years, the ewes lost weight to weaning. The rate at which ewes lost weight while stocking rate increased was the same for both the 2001 and 2002 years (R^2=95.7%; P<0.001) (Figure 5). This is shown by the regression lines for both years being parallel (Figure 5). The weight loss in the 2002 year was more pronounced than that experienced in the 2001 year (Figure 5). The high R^2 figure obtained during the analysis (R^2=95.7%)(Figure 5) indicates that 95.7% of the variation observed in the ADGs is related to the variation in stocking rate, while the low P value indicates that there is almost certainly a true difference (>99.9% chance) between ADGs at the various stocking rates.

The data for the full grazing period for both years was combined and analysed using ANOVA, which showed a significant effect on ADG to weaning for both year and stocking rate but no interaction, so the stocking rate/year stratum was dropped from the ANOVA to increase the degrees of freedom (Ndiwa *et al*., 2003).

Table 4: An analysis of variance of goat ewe mean ADGs[*] for the full grazing period using 2001 and 2002 data combined.

Year 2001/2002 ($kg.animal^{-1}.day^{-1}$)	-0.0145 [a]
Year 2002/2003 ($kg.animal^{-1}.day^{-1}$)	-0.0262 [b]
P	0.03
LSD (5%)	0.01058
Ewe ADG ($kg.animal^{-1}.day^{-1}$) at 30 $goats.ha^{-1}$	-0.0145
Ewe ADG ($kg.animal^{-1}.day^{-1}$) at 45 $goats.ha^{-1}$	-0.0199
Ewe ADG ($kg.animal^{-1}.day^{-1}$) at 60 $goats.ha^{-1}$	-0.027
Grand mean ($kg.animal^{-1}.day^{-1}$)	-0.0205
P	0.137
LSD (5%)	0.01296
d.f	8
S. E.	0.00795
CV%	38.7

* Ewe ADGs excluding kid ADGs

[a] and [b] are significantly different from each other when using the LSD method (5%).

There were no significant difference between ADGs between stocking rates but there was a significant difference between the years evaluated (P=0.03)(Table 4 and Figure 6). Since there was a significant difference between stocking rates to weaning (P<0.001)(Table 3) but no significant difference between stocking rates at the end of the grazing period (P=0.137)(Table 4), this would imply that the ewes had managed to regain some of the weight that had been lost during the period of lactation and had a similar weight loss to the high stocking rate treatment by the end of the grazing period.

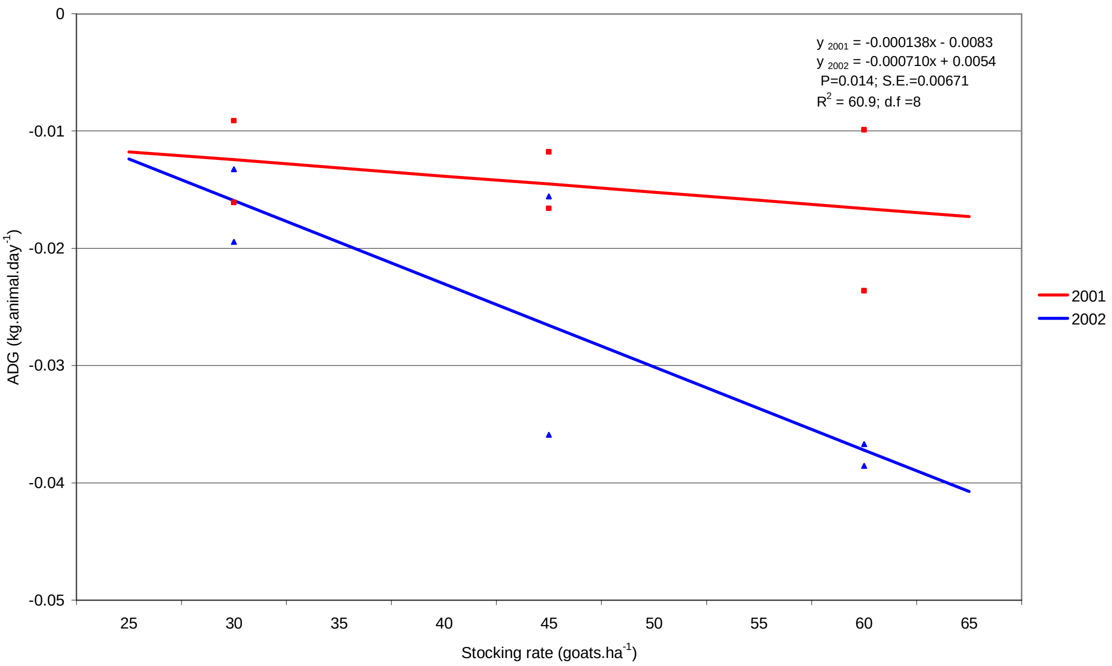


Figure 6: Regression analysis of ewe ADG (y) on stocking rate (x) for goats grazing kikuyu for the full grazing period for 2001 and 2002 combined.

The effect of stocking rate on ADG was more pronounced in the 2002 year (Figure 6) with more extreme weight loss at the higher stocking rate than that experienced in the 2001 year, with both years having a negative rate of weight gain as stocking rate increased.

Using an unbalanced regression analyses of kid performance, year showed a significant influence on weaning weights (P<0.001; R^2=21.8%). However, kid ADG was not a simple relationship, other factors had an influence, namely ewe start mass (P<0.001) and whether the kid was a single or multiple (P=0.015). Kid ADG at the high stocking rate was significantly different to the low and medium stocking rates (P=0.007) while gender had no contributing effect to ADG (P=0.446). However, the low R^2 obtained in this experiment means that only 21.8% of the variation accounted for in the data is due to kid ADG, the balance is due to chance.

The total ewe mass at weaning was added to the total kid mass at weaning per treatment and per year, converted to a per hectare basis and differences between these figures were analysed (Table 5 and Figure 7). Since there were no significant differences between the years, the stocking rate/year interaction was removed from the ANOVA to increase the degrees of freedom (Ndiwa *et al*., 2003).

Table 5: Analysis of variance of ewe weight plus kid weight at weaning (per hectare) for goats with kids grazing kikuyu pastures for 2001 and 2002 combined.

Year 2001/2002 ($kg.ha^{-1}$)	2306
Year 2002/2003 ($kg.ha^{-1}$)	2448
P	0.060
LSD (5%)	149.7
Total weight ($kg.ha^{-1}$) at 30 $goats.ha^{-1}$	1715 [a]
Total weight ($kg.ha^{-1}$) at 45 $goats.ha^{-1}$	2324 [b]
Total weight ($kg.ha^{-1}$) at 60 $goats.ha^{-1}$	3092 [c]
Grand mean ($kg.ha^{-1}$)	2377
P	<0.001
LSD (5%)	183.3
d.f	8
S. E.	112.4
CV (%)	4.7

[a], [b] and [c] are significantly different from each other when using the LSD method (5%).

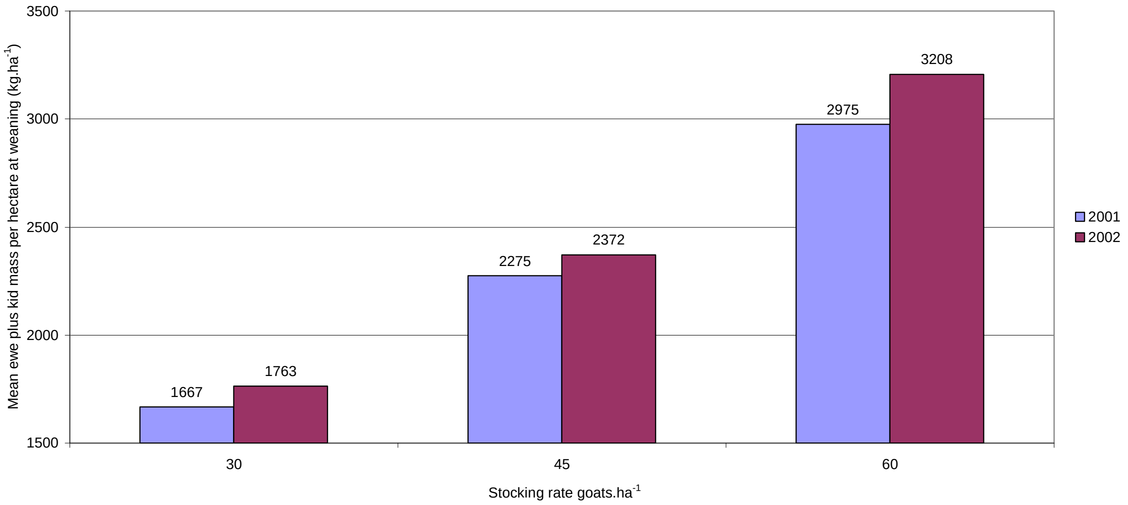


Figure 7: Mean total ewe mass plus total kid mass per hectare at weaning for goats with kids grazing kikuyu at three stocking rates for 2001 and 2002.

There was a significant difference between stocking rates on a per hectare basis (P<0.001; CV=4.7%) (Table 5) when both years were combined, with the heavy stocking rate producing the highest total mass and the light stocking rate producing the lowest total mass per hectare (Table 5 and Figure 7), with a grand mean of 2377 $kg.ha^{-1}$. The low probability value indicates that less than 0.1% of the variation in data being due to chance, which means that there is a greater than 99.9% chance of the weight gains being repeatable. There were no significant differences between the years (P=0.060) (Table 5) when comparing total mass of ewes plus kids per hectare. The low CV obtained in the combined data indicates consistent data (CV=4.7%) (Table 5).

When evaluating total weight gain per hectare (Figure 7 and Table 5), the high stocking rate produced the highest mass per hectare for both years. This is supported by O'Reagain & Turner (1992) who stated that heavier stocking rates result in greater gains per hectare. Jones & Sandland (1974) state that due to the linear relationship between production per animal and stocking rate, two stocking rates are sufficient to predict gain at the optimum stocking rate. However, since the ewes were losing weight on the kikuyu and not increasing in weight (as per the animal performance model), the data did not produce an acceptable model.

Discmeter readings

Pasture height (both "in" and "out" readings) and "pasture loss" of ewes ("in" minus "out" readings) was regressed on ewe ADG and kid ADG.

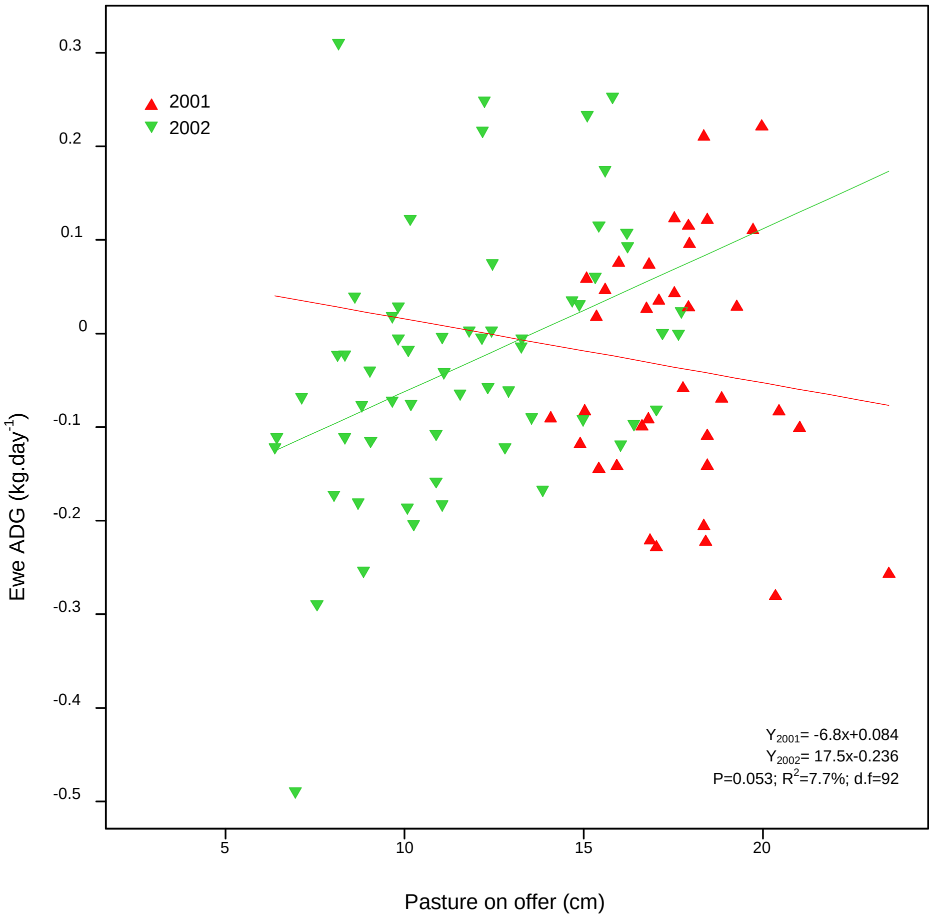


Figure 8: Regression of ewe ADG (y) on pasture on offer (x) for goat ewes with kids grazing kikuyu during 2001 and 2002 combined.

On assessment of the height of the pasture on offer (actual data points), there was a significant difference between the height of the pasture on offer (Figure 8) between the two years, with the 2001 year having taller pasture on offer. When regressing ewe ADG on pasture height, there was a significant difference between the two years (P=0.053; R^2=7.7%) with ADG in 2001 having a negative relationship and ADG in 2002 having a positive relationship with pasture height (Figure 8). Since the 2001 year had higher rainfall over the season, this may have influenced pasture growth rates resulting in the pasture growing at a faster rate than during 2002 and hence the taller pasture on offer during 2001. There were significant differences between the height of the pasture on offer between the two years and the rate of change of ewe mass between the two years (P=0.053; R^2=7.7%)(Figure 8). Ewe ADGs in 2001 decreased as pasture on offer increased, and the ewe ADGs in 2002 increased as pasture on offer increased.

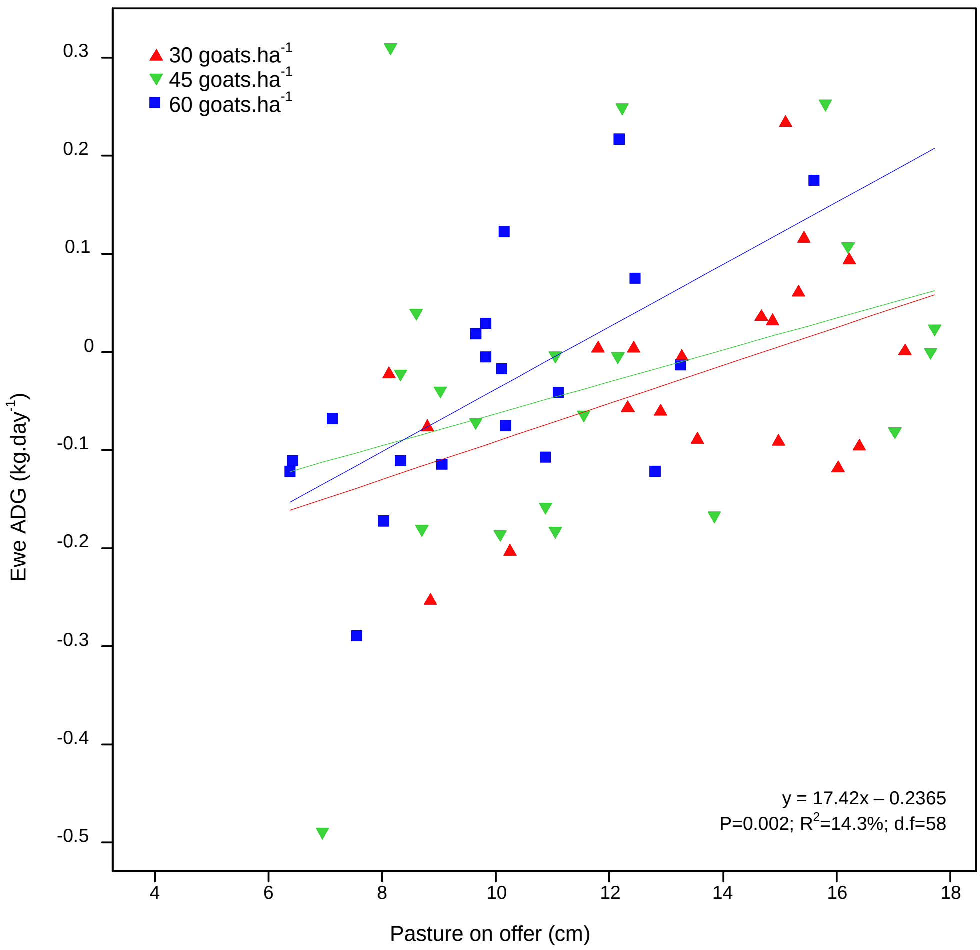


Figure 9: Regression of ewe ADG (y) on pasture on offer (x) for goat ewes with kids grazing kikuyu pastures during 2002.

Regression of ewe ADG on pasture on offer showed no significant relationship during 2001.

There was a significant difference between the amount of pasture on offer initially between stocking rate treatments during 2002. Ewe ADG during the 2002 year was significantly correlated to pasture on offer (P=0.002; R^2=14.3%)(Figure 9) while the response of ewe ADG to pasture on offer was the same for all treatments. This is the predicted response of the more pasture offered, the better the performance of the individual animals.

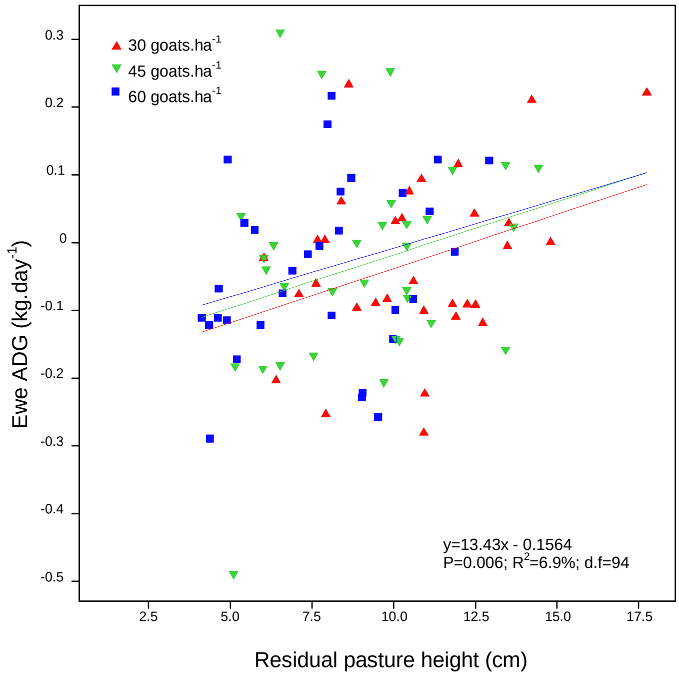


Figure 10: Regression of ewe ADG (y) on residual pasture height (x) for goat ewes with kids grazing kikuyu pastures for 2001 and 2002 combined.

Ewe ADG was significantly correlated to residual pasture height ("out" reading)(P=0.006; R^2=6.9%)(Figure 10) while stocking rate had no effect on residual pasture height. The pasture remaining after grazing was not significantly different between the two years. The response rate of ADG to residual pasture height was the same over the two years (the gradient of the regression lines).

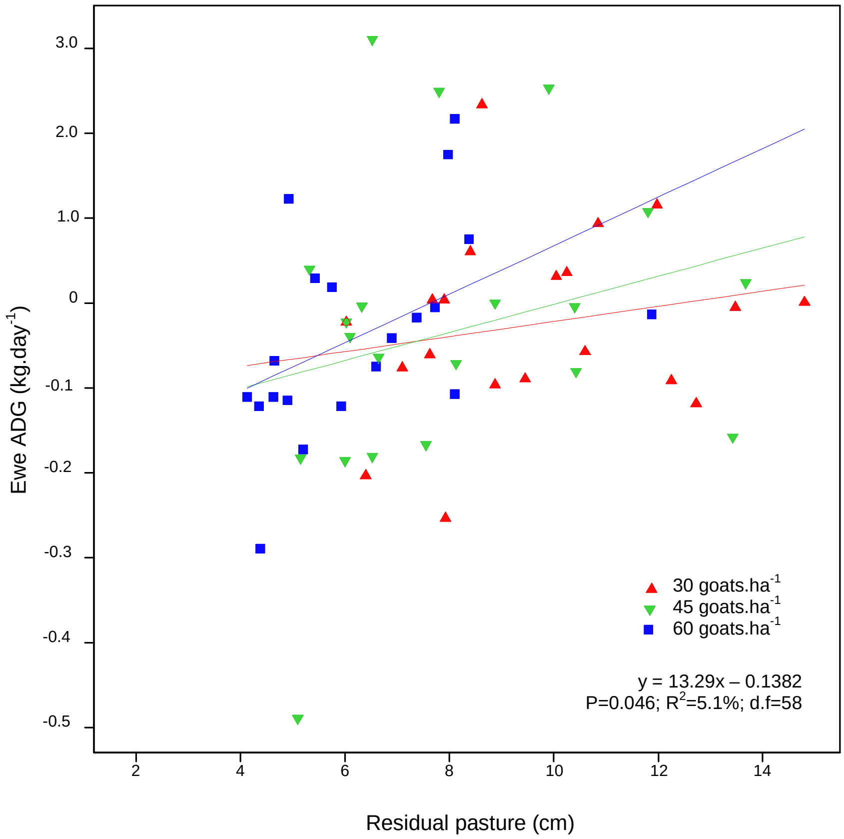
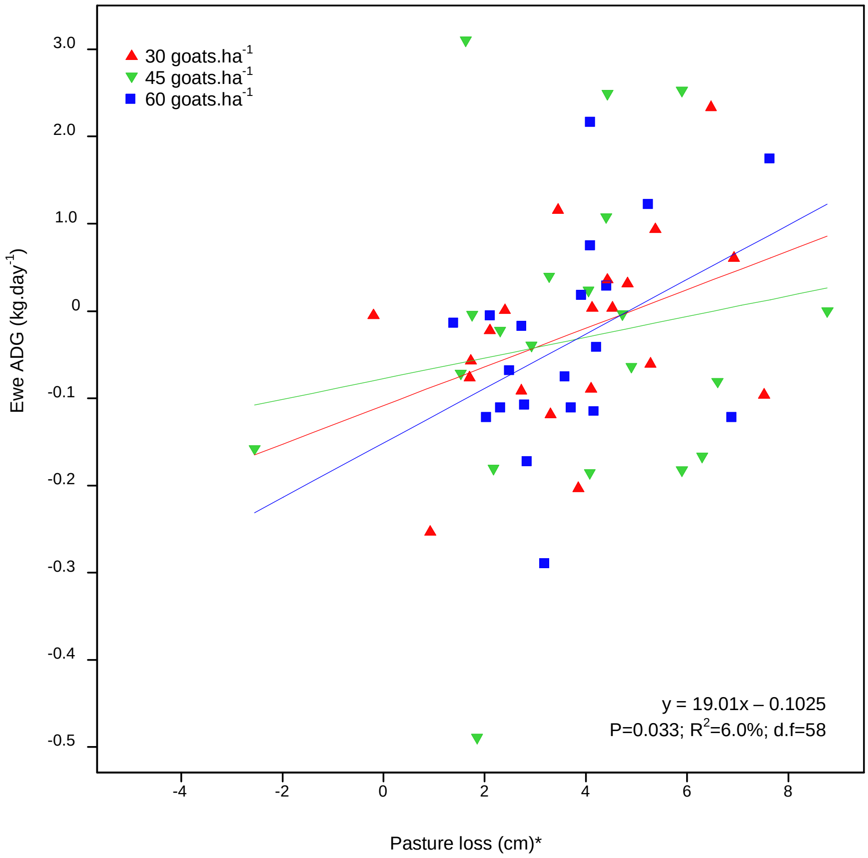


Figure 11: Regression of ewe ADG (y) on residual pasture height (x) for goat ewes with kids grazing kikuyu pastures during 2002.

Ewe ADG during the 2002 year was significantly correlated to residual pasture height (P=0.046; R^2=5.1%)(Figure 11) and there were no significant differences between stocking rate treatments. This implies that the more pasture left behind, the better the ADGs of the individual animals, probably due to the increased ability to select. Stocking rate did not affect the amount of pasture remaining during 2002, which means the goats ate the pasture down to a standard height.

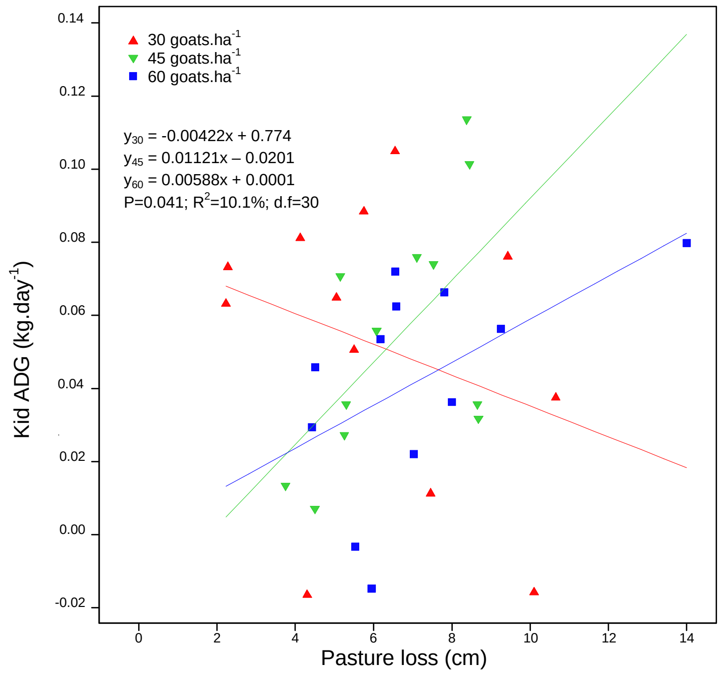
There were no significant correlations between pasture loss and ewe ADGs for the combined years. Regression of ewe ADG on pasture loss during 2001 showed no significant relationship.



* The difference between the initial and residual pasture height after grazing as measured with a disc meter.

Figure 12: Regression of ewe ADG (y) on pasture loss (x) for goat ewes with kids grazing kikuyu pastures during 2002.

Ewe ADG during the 2002 year was significantly correlated to pasture loss (P=0.033; R^2=6.0%)(Figure 12) and the response of ewe ADG to pasture loss was the same for the three stocking rates. The more the ewes ate, the better the individual performance.



* The difference between the initial and residual pasture height after grazing as measured with a disc meter.

Figure 13: Regression of kid ADG (y) on pasture loss (x) for goat kids (with ewes) grazing kikuyu pastures during 2001.

Kid ADG was significantly related to pasture loss, with the medium and high stocking rates having significantly higher ADGs than the low stocking rate treatment (P=0.041; R^2=10.1%)(Figure 13) during the 2001 year. The rate of change of kid ADG was significantly different between stocking rate treatments (Figure 13). Kid ADG was not significantly correlated to pasture on offer or residual pasture during the 2001 year. This implies that the amount of fodder consumed by the ewes had a significant effect on the rate of growth of the kids, probably due to the influence of intake on milk production. Since pasture loss has no influence on ewe ADG, it must have affected milk production in order to influence kid ADG.

The 2002 year showed no significant relationships between kid ADGs and pasture on offer, residual pasture or pasture loss. There were no significant correlations between pasture loss and kid ADGs for the combined years.

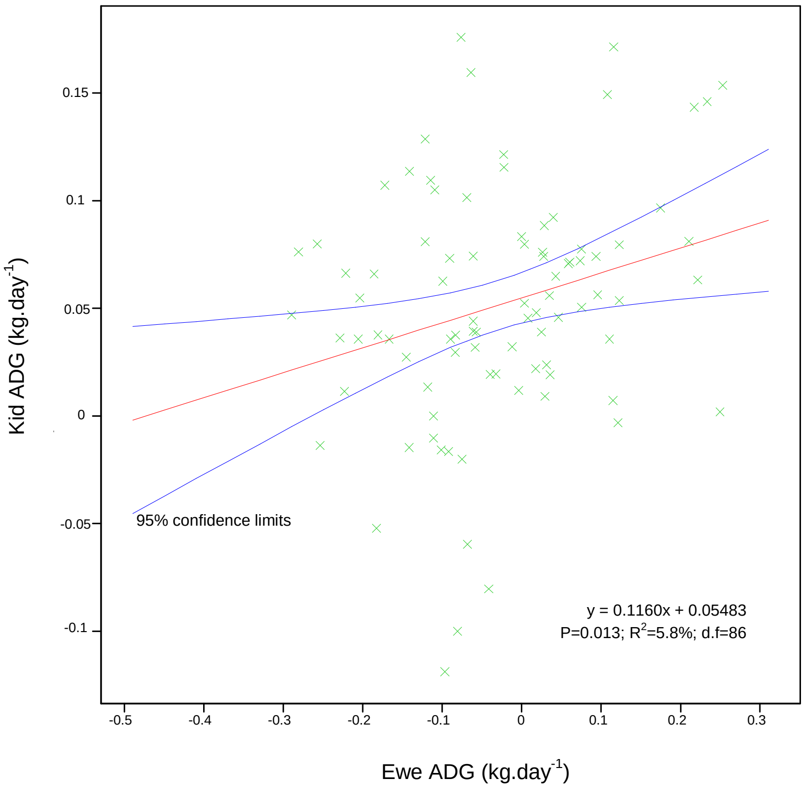


Figure 14: Regression of kid ADG (x) on ewe ADG (y) showing 95% confidence levels for goat ewes with kids grazing kikuyu pastures during 2001 and 2002 combined.

Kid ADG was significantly correlated to ewe ADG (P=0.013; R^2=5.8%)(Figure 14) while stocking rate had no effect on kid performance. The relationship between kid ADG and ewe ADG was not a strong relationship (ewe ADG accounted for 5.8% of the variability in kid ADG) but there was a relationship between the two variables (P=0.013)(Figure 14).

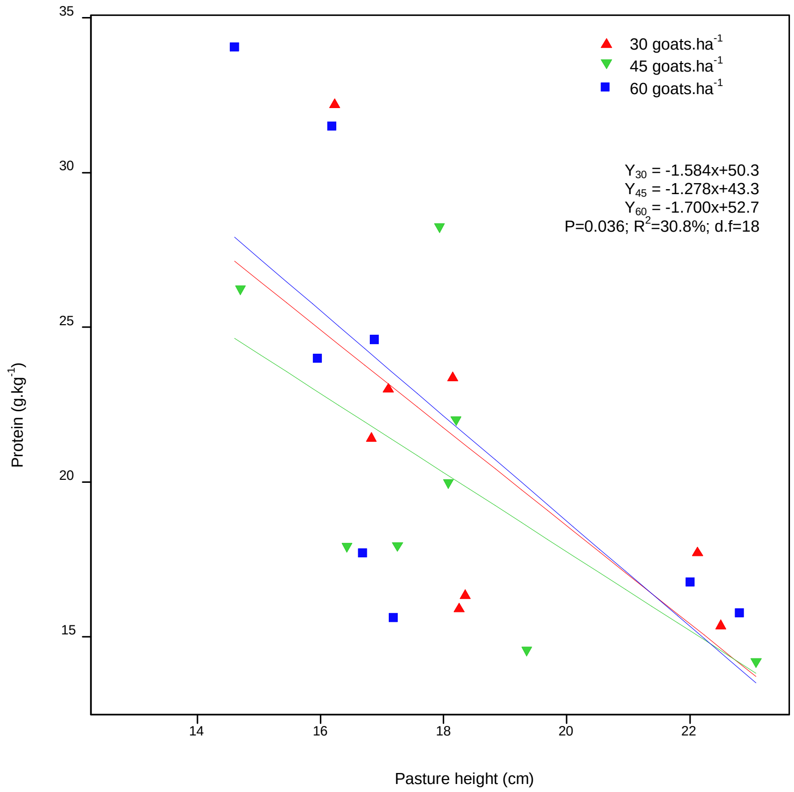


Figure 15: Regression of protein concentrations (y) on pasture height (x) for 2001 and 2002.

Regression of protein concentrations on pasture height showed a decrease in protein levels as pasture height increased, with a significant difference between stocking rates ($P=0.036$; $R^2=30.8\%$) (Figure 15). The high stocking rates had significantly higher protein levels, which probably relates to the pasture age, with the high stocking rate pastures being in an active growth stage due to the high grazing pressure on the forage.

Herbage quality

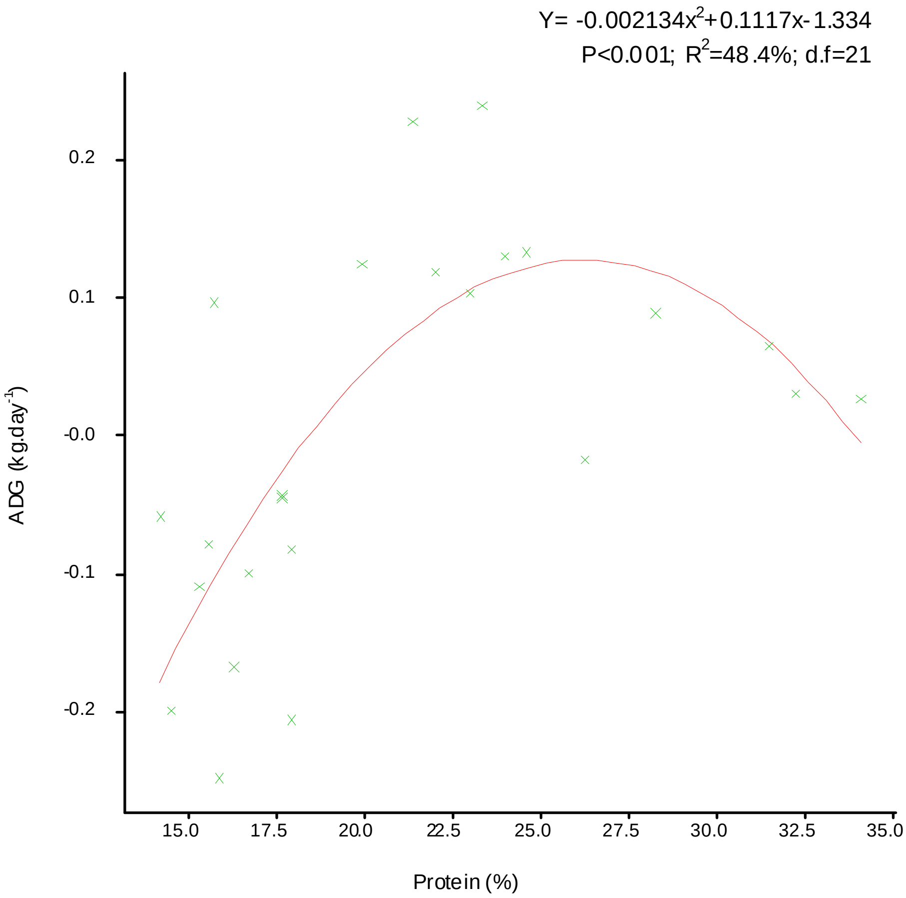


Figure 16: Regression of mean average daily gain (y) on protein levels of kikuyu during 2001.

Regression of ADG on protein levels in the pasture during the 2001 year showed a quadratic nature, with ADG increasing to a point and then decreasing as protein became a limiting factor to animal growth (Figure 16). This is probably due to the fact that beyond a certain level, high protein levels limit forage intake (Marot & Miles, 2001; Wilson *et al*., 1975). Marot & Miles (2001) found that protein levels above 15% limit intake. This is substantiated by Dugmore *et al.*, (1986) who found that kikuyu with crude protein levels of 20% or greater tended to reduce production. This experiment indicates that ADG is restricted at protein levels beyond 26.17% with corresponding ADGs of 0.128kg.day^{-1}.

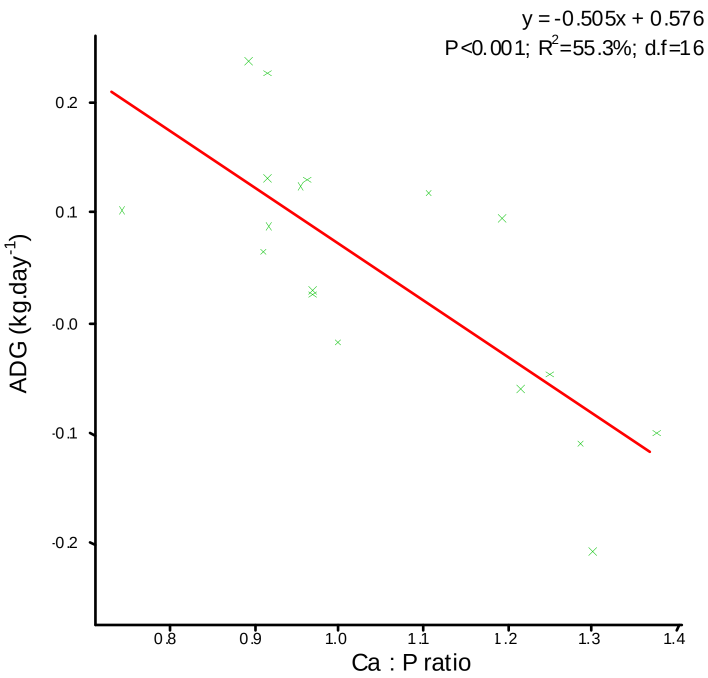


Figure 17: Regression of mean average daily gain (y) on Ca : P levels of kikuyu during 2001.

There was a significant relationship between ADG and the ratio of calcium (Ca) to phosphorus (P) with a negative trend ($P<0.001$; $R^2=55.3\%$)(Figure 17). There were no significant differences in calcium or phosphorus levels between treatments through out the trial period, with a mean Ca level of 0.3352 $g.kg^{-1}$ ($P=0.852$) and a mean P level of 0.324 $g.kg^{-1}$ ($P=0.529$). Fulkerson *et al*. (1998) reported Ca: P ratios in kikuyu of 0.9:1 in summer-autumn and 2.5:1 in early spring, not considering the binding of calcium by oxalate. Therefore the levels obtained in this experiment can be considered within the normal range.

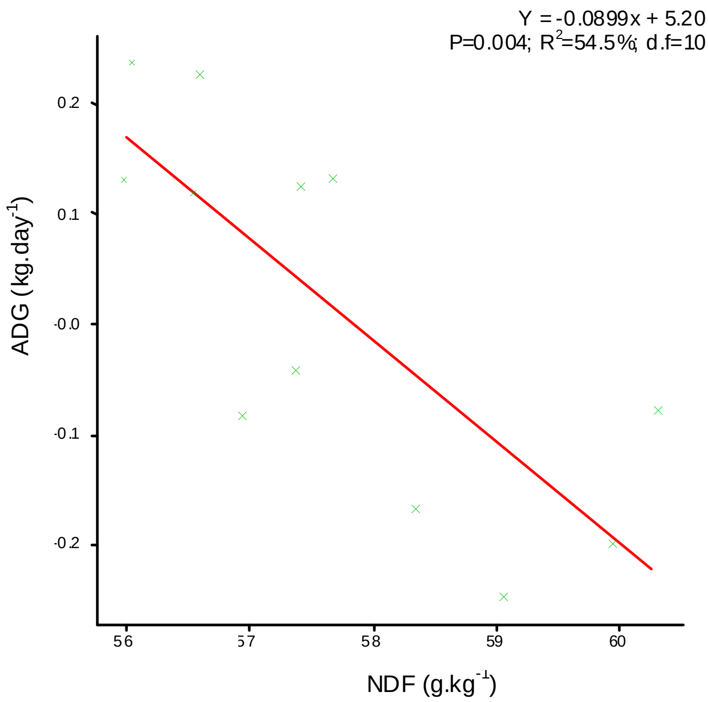


Figure 18: Regression of mean average daily gain (y) on NDF levels of kikuyu during 2001.

NDF was significantly correlated to ADG (P=0.004; R^2=54.5%)(Figure 18) with a negative linear trend. When forage ages, the cell content decreases and the cell wall content increases (the NDF portion), resulting in an increase in forage retention time and an increase in fill effect (Baumont *et al.*, 2000) and hence a decrease in ingestibility. Moore & Mott (1972) stated that there is a strong negative correlation between NDF, or cell wall concentration, and digestibility of grasses. Digestibility and fill effect factors would have resulted in a negative correlation between ADG and NDF which is what was determined in this experiment (Figure 18).

There was no correlation between ADF and average daily gain (P=0.374), but NDF was highly correlated to average daily gain (Figure 18), as were protein (Figure 16) and the ratio of calcium to phosphorus (Figure 17). There were fluctuations in herbage quality during the season (ADF, NDF and protein) but this was not a stocking rate effect.

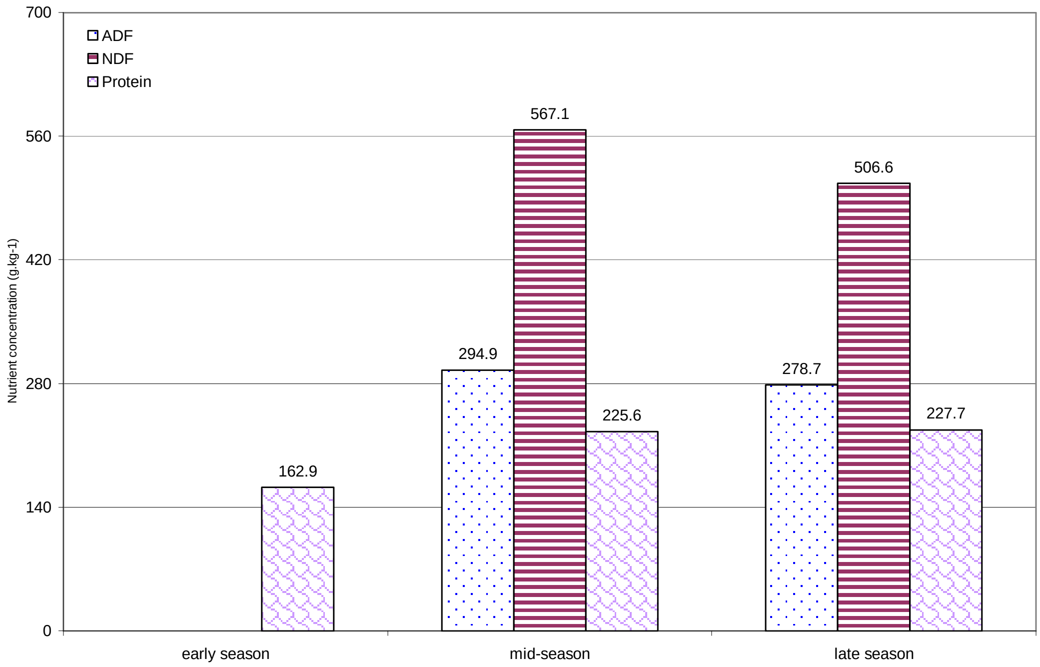


Figure 19: Seasonal fluctuations in kikuyu quality during 2001*.

* Herbage samples from early in the season were misplaced in the laboratory.

In mid-season, the kikuyu had high NDF levels (567.1 $g.kg^{-1}$) (Figure 13), which would limit ewe intake (due to a fill-effect) which would have a detrimental effect on animal performance since insufficient nutrients would be consumed. Both ADF and NDF levels decreased as the season progressed resulting in a corresponding increase in ability to ingest more forage (and hence the possibility of improved performance). The increase in kikuyu protein levels as the season progressed would have a corresponding increase in ewe weight gain since the herbage quality improved. Langlands & Bennett (1973) found that nitrogen (and hence protein) content was greatest in spring but did not change consistently with increasing stocking rate. Dugmore *et al*., (1986) found that kikuyu with crude protein levels of 20% or greater tended to reduce production which is possibly why the animals in this experiment were not gaining weight.

In forages with high protein levels (over 15%), energy deficiencies can result in the loss of ammonia from the rumen and its excretion as urea, causing a loss in total available nitrogen (Walker, 1970; van Soest, 1994; Marais, 1998). Fodder intake is reduced when dietary urea exceeds 1.5%, suggesting that high levels of non-protein nitrogen (NPN) from excessive fertilization could decrease forage intake (Wilson *et al*., 1975; Marot & Miles, 2001).

Discussion

It is evident in Figures 5 and 6 that the ewes lost weight throughout the trial period. During this period, the ewes were using energy to produce milk for their offspring and were losing body weight. The live weight of goats has been observed to fall by up to about 6 kg during the first 6 to 12 weeks after parturition (Agricultural & Food Research Council, Undated).

As stocking rate increases, pasture availability becomes limiting and therefore intake is limited. The decrease in availability and therefore intake will result in a decrease in energy intake. Since energy is allocated to milk production over weight gain, body weight will decrease at the expense of milk production. The level of energy intake is the major factor affecting milk production (Hadjipanayiotou & Morand-Fehr, 1991) and will therefore have a large influence on kid performance during the suckling phase.

South African Indigenous goats produce low volumes of milk and the quantity produced is often difficult to measure, with short lactations that barely supply enough milk to feed their kids (Cissé *et al.,* 2002). Productive animals (lactating and growing animals) are those most affected by restricted intake, which has the effect of decreasing milk production and results in malnourished goats (Singh *et al.*, 1991). Selective grazing allows animals to consume a diet of a higher nutrient quality than that on offer (Baumont, *et al.*, 2000).

Stocking rate influenced the rate of weight loss of the ewes to weaning (Table 3 and Figure 5) in both years. The level of weight loss was significantly different ($P<0.001$)(Table 3 and Figure 5) between the years. The ewes during the 2001 year lost less weight than the ewes during the 2002 year even though the 2002 year appeared to produce more fodder (Figure 7), possibly due to the higher early rains (Figure 1).

When evaluating the full grazing period, stocking rate had an effect on ewe performance and the rate of weight loss was slower for both years (Figure 6), indicating that the ewes were able to slow down the rate of weight loss once the kids had been weaned. This can be contributed to the removal of the milk production demand after weaning. The ewes were able to allocate energy to maintenance and weight gain instead of milk production.

There was a significant difference between kid performance during the two years ($P<0.001$; $R^2=21.8\%$) with ewe start mass ($P<0.001$) and whether kids were singles or multiples ($P=0.015$) having an effect. The kids at the heavy stocking rate treatment had significantly lower ADGs to the medium and low stocking rate treatments ($P=0.007$; $R^2=21.8\%$). The kids gained weight during both 2001 and 2002. Since 2001 appeared to have higher total rainfall than 2002 (Figure 2), one would assume that forage availability would be a limiting factor in 2002 and therefore differences in treatments would be more significant.

Marais (2001) stated that milk yield and dam kidding weight were positively and significantly correlated, probably because heavy dams have the ability to mobilize reserves towards milk production. Therefore, the expected trend would be that the more milk a ewe produces, the higher the ADGs the kid would achieve.

A heavy stocking rate treatment has high competition for available forage and therefore restricted intake. Broadbent (1964) found that lambs' rate of live-weight gain was related negatively to stocking rate and the total live-weight of lamb produced per hectare was related positively to stocking rate, and that the ewes' live weights were similarly affected, there being the highest losses of live weight under the heavy stocking rate. Improving milk yield of dams by providing adequate nutrition can alleviate pre-weaning kid mortality and improve growth of offspring (Akinbamijo *et al*., 1994). Preweaning growth of lambs is largely dependent on the amount of milk consumed from the dam (Aboul-Naga *et al*., 1981).

When the total change in weight per treatment (ewes plus kids) was converted to a per hectare basis, the heavy stocking rate had the highest production per hectare (Figure 7) during both years. This is consistent with the theory that the heavy stocking rate has lower production per animal but higher production per hectare (up to a maximum stocking rate) (O'Reagain & Turner, 1992). The Jones Sandland model (Jones & Sandland, 1974) shows that the peak gain per animal (i.e. ADG) occurs at stocking rate that is lower than that at which maximum gain per hectare occurs. In this experiment, the light stocking rate had higher production per animal (Figures 5 and 6), but lower production per hectare (Figure 7). The loss of weight of the ewes is a factor for concern, but when the total mass of the ewes plus the kids is assessed, there is a large difference between the low and high stocking rates, which would compensate financially for any loss of body mass of the ewes (Figure 7). This loss of weight could also be detrimental to reconception rates and needs to be explored further.

There were no noticeable differences in temperature during the trial period between the two years. It would appear that the main factor affecting grass production was therefore early season rainfall and as a result, 2002 had a higher level of grass production (Figures 1 and 4). When assessing discmeter readings, there was a significant difference between the heights of the pasture on offer between the two years (Figure 8) with 2001 having taller pasture offered at each grazing cycle. This would indicate that the growth rate of the pasture was higher during 2001 than 2002 which resulted in better ewe performance in 2001 than 2002 (Figures 5 and 6). However, this contradicts the findings that 2002 produced more fodder than 2001 (Figure 4). Disc meter regressions for the combined years showed no significant differences between pasture loss and no significant differences between pasture remaining between treatments.

Regression of protein on pasture height showed that the shorter the grass, the higher the protein level in the grass (Figure 15). However, protein has a quadratic relationship with ADG and protein levels above 26.17% limited ADG (Figure 16). These protein levels were present in the shorter grass with a height of 15.23 cm (Figure 15). Therefore, the shorter grass in 2002 resulted in lower individual ewe ADGs due to the higher protein levels in the plant and therefore lower kid ADGs.

NDF is an indication of fibre content in the plant. Nyamukanza & Scogings (2008) stated that an increase in ADF and NDF usually results in a decrease in digestibility, intake and animal performance. An increase in NDF indicates an increase in fibre and hence a larger fill-effect which will restrict intake. The regression of NDF on average daily gain is negative ($P=0.004$; $R^2=54.5\%$) (Figure 18), indicating that the more NDF in the plant, the lower the average daily gain, which supports the statement made by Nyamukanza & Scogings (2008). The decrease in ADG is a direct result of a decrease in herbage quality and corresponding reduction in intake.

The calcium to phosphorus ratio was evaluated since calcium is known to be deficient in kikuyu (Miles *et al*., 1995) and can cause hypomagnesaemic tetany when imbalances occur. The regression shows there is a significant correlation between average daily gain and the Ca:P ratio ($P<0.001$; $R^2=55.3\%$) (Figure 17) with an increase in phosphorus (and decrease in calcium) resulting in a decrease in average daily gain.

Due to the high cost of establishing and maintaining a pasture, it is important that the value added to the product is more than the cost of establishing and maintaining the pasture. To maximise gain per hectare, one needs to stock at a stocking rate of at least 60 goats.ha^{-1} (ewes with kids). Since the stocking rates tested were not heavy enough for the good years experienced, the stocking rate at which maximum gain per hectare occurs was not reached and can therefore not be stipulated, only extrapolated. The choice of an optimum stocking rate must be a compromise between production per hectare, stability of pasture, stress to livestock, soil conservation and appearance of livestock (de Villiers & Botha, 1993).

4 INDIGENOUS GOAT PRODUCTION ON STOOLING RYE *(Secale cereale)*

Introduction

Traditionally, goats are kept by a large part of the population in the rural areas of South Africa. They are used to fulfil important roles for subsistence farming systems in rural areas and are used to maintain social bonds with the community, e.g. as lobola (dowry) and as exchange with relatives. Goats are also used for ceremonial and religious purposes and provide a source of income, meat and milk for the household (Braker *et al.,* 2002). Goat production is considered a feasible option in rural communities for providing an income (Devendra, 1991). The adaptability of the goat with regards to environment and product makes the goat probably the most versatile of the domestic animal species (Quartermain, 1991). In KwaZulu-Natal in 1999 there were approximately 616 000 goats and their primary use was for meat, fibre and milk (Ramsay & Donkin, 2000).

When converting pasture to animal products on high-producing pastures, three major factors can be manipulated to improve efficiency: grazing method, stock type and stocking rate. The efficiency of the animals used to convert grass to meat or milk can be a major factor affecting output per hectare. Stocking rate is the most powerful weapon of the three influencing efficiency on a per hectare basis (Kirkman & Carvalho, 2003). Stocking rate has a considerable effect on liveweight production when grazing animals are used to evaluate pasture treatments (Kirkman & Carvalho, 2003). As stocking rate increases, liveweight gain per head increases to a critical point, beyond which gain per head is inversely related to stocking rate. Gain per hectare increases linearly to a critical point after which it decreases linearly as stocking rate increases (Kirkman & Carvalho, 2003).

Goats under rotational grazing system (semi-intensive) have been observed to have fewer worm-egg counts than those kept under the free-range grazing or extensive system (Magona *et al.*, 2002). In goats fed *ad libitum* the main factor influencing performance is the level of dry matter intake (Masson *et al.*, 1991). Church (1991) stated that protein is usually the first limiting nutrient for animals (nonpregnant, nonlactating) producing at a low level.

If forage is given *ad libitum*, the level of intake depends on refusal rate that is often higher in goats than in other ruminants. Generally, goats eat more slowly than sheep since they are more selective. In goats, meals are more numerous, but they do not last so long. Goats are able to compensate for poor quality forages offered *ad libitum* by selecting those plant parts highest in protein and lowest in cell-wall carbohydrates (Morand-Fehr *et al.*,1991).

Baumont *et al.* (2000) had the following comments about forage and its quality. "Forages decrease in ingestibility due to the increase in fill effect. As plants mature, development decreases the amount of cell content (which is soluble, rapidly degraded and has almost no fill effect) and increases the amount of cell walls. Hence rumen retention time increases and therefore fill-effect increases (Grenet & Demarquilly, 1987). Rumen retention time is a factor of degradation rate and the volume of the undegradable fraction (Baumont et al., 1997)".

Cultivated rye (*Secale cereale*) originated from either *S. montanum*, a wild species found in southern Europe and nearby parts of Asia, or from *S. anatolicum*, a wild rye found in Syria, Armenia, Iran, Turkestan, and the Kirghis Steppe. Stooling rye was initially found as a weed in wheat and barley fields in southern Asia and had co-evolved with wheat and barley for over 2,000 years until its value as a crop was recognized (Oelke *et al*., 2000). Stooling rye is a member of the grass family *Gramineae*, the genus *Secale*, the tribe *Triticeae* and the sub-tribe *Triticinae* (Evans & Scoles, 1976). Only one species of stooling rye, *Secale* (S.) *cereale* L., is extensively cultivated (Bushuk, 1976).

Kassier & Goodenough (2002) described forage cereals as a collective term given to some of the rye, stooling rye, oats, triticale and a few wheats that are suitable for herbage production as opposed to grain production. Rye and stooling rye are both of the species *Secale cereale* and within these species are types with different flowering behaviours. Longevity of the pasture and also the time of peak herbage production are affected by flowering behaviour. The three forage cereal types are short-, medium- and long-duration types. The long-duration types (for example, the stooling rye Mac Blue cultivar) have the longest time from establishment to flowering and require a specific combination of daylength and low temperature to flower. The long-duration types therefore remain vegetative (good quality herbage) the longest and provide grazing up to late winter/early spring. The long-duration types, like the medium-duration types, have a prostrate growth form and are densely tillered, and are well suited to sheep grazing. They are slow to start growing after establishment but have the advantage of lasting the longest and providing herbage in late winter when the other two types are already either dead or in the reproductive stage (Kassier & Goodenough, 2002).

Stooling rye has been grown for many years for early spring grazing. Stooling rye can make a direct contribution to early grazing and have an indirect benefit on grassland management by bearing the brunt of heavy grazing (Anon, 1983). Stooling rye can be grown in a wider range of environmental conditions than most small grains (Oelke *et al*., 2000). Stooling rye is extremely hardy and is often grown where other grains will not grow (Bushuk, 1976). It does well on sandy soils and thrives on infertile areas (Duke, 1983). Stooling rye generally does better than other cereals in poorly prepared soils (Briggle, 1959). Diseases in stooling rye are not common, with the possible exception of ergot caused by the organism *Claviceps purpurea* (Evans & Scoles, 1976).

The objectives of the investigation were to determine the optimal stocking rate for goats grazing stooling rye and to determine the level of production that can be achieved in the KwaZulu-Natal midlands of South Africa. The potential of an annual winter pasture for goat production was also evaluated.

Objectives

There has been minimal research of intensive goat production systems on pastures. For this investigation, a winter growing pasture was evaluated to test the potential for intensively farming the South African indigenous goat. This investigation was designed to determine what species are suitable for goat production in South Africa.

Stooling rye was selected as a winter pasture due to its stooling nature and its high quality as a feed source. It has the potential for high production if correctly managed, is winter-hardy and is drought tolerant. For many farmers it is the cheaper option in comparison to other winter species currently available in South Africa.

This experiment was not designed as a follow-on experiment from kikuyu, but as a stand-alone evaluation of stooling rye as a feed source for goats. This experiment ran concurrently with the kikuyu experiment and evaluated stocking rates suitable for stooling rye.

The objectives of the investigation were to:

1. investigate the relation between stocking rate and animal production;
2. investigate the relationship between stocking rate and herbage availability; and
3. evaluate the potential of an annual winter pasture for goat production

in the KwaZulu-Natal Midlands of South Africa.

Procedure

Management levels affect pasture productivity, persistence and therefore animal performance levels (Tainton, 1988). It is therefore important that all factors are optimized to obtain a realistic evaluation of the true potential of the South African indigenous goat on stooling rye. The Ministry of Agriculture, Fisheries & Food (Anon, 1983) stated that sheep should be stocked when stooling rye is about 10cm high and a carrying capacity under this system of 50 or more lactating ewes per hectare is quite feasible. Using this stocking rate as a guideline, four stocking rates lighter than those recommended by Ministry of Agriculture, Fisheries & Food (Anon, 1983) were evaluated. During the second year of the experiment, visual evaluation of the first year's stocking rates were used to determine if those stocking rates that were initially applied were either too heavy or too light and the stocking rate was adjusted accordingly.

Study area

The trial was conducted on the same site for two consecutive years (2001, 2002). The site for the trial was located on the Cedara Research Station (29^{o}32'S, 30^{o}17'E) of the KwaZulu-Natal Department of Agriculture and Environmental Affairs in the midlands of KwaZulu-Natal province in South Africa. The research station lies at an altitude of 1076 m above sea level, with long-term annual means of 885 mm, 1577 mm, 22.3^{o}C, 9.4^{o}C and 16.2^{o}C for rainfall, mean annual evaporation and maximum, minimum and average daily temperatures respectively (Agromet)[1]. Severe frosts occur during June and July.

Table 1. Long term average means of maximum temperature, minimum temperature, monthly rainfall and hours of sunshine experienced at Cedara Research Station [1].

	Average maximum temperature (^{o}C)	Average minimum temperature (^{o}C)	Average rainfall (mm.month^{-1})	Average sunshine hours (hours.day^{-1})
Summer (December to February	25.2	14.5	128.4	6.3
Autumn (March to May)	22.8	10.3	62.5	7.3
Winter (June to August)	19.9	4.4	18.8	8.0
Spring (September to November)	22.9	10.6	81.1	6.5

Land preparation

The initial land preparation was done in early autumn with a plough and disc harrow. Weeds were allowed to germinate and the site was worked to eradicate the weeds that had germinated. Partial control of the weeds was obtained. The stooling rye seed (Mac Blue cultivar) was row-planted into the trial site at a seeding rate of 50 kg.ha^{-1} and the site was rolled using a Cambridge roller. The site was irrigated immediately with 25mm to encourage germination.

Irrigation

The site was given supplementary irrigation (25mm per week) using a dragline irrigation system.

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[1] Agromet, ARC – Institute of Soil, Climate and Water, Private Bag X79, Pretoria, 0001, South Africa.

Fertilization

The soil P and K levels were raised to the recommended levels in accordance with soil analyses[2], which are 120 mg.L^{-1} for K and 11 mg.L^{-1} for P (AMBIC). The P (single superphosphate (10.5% P)) and K (KCl (48% K)) fertilizers were spread onto the site and incorporated into the soil to correct mineral imbalances. The acid saturation was 2%, sample density was 1.01 g.mL^{-1} and the pH (KCl) was 4.85. Nitrogen was applied in the form of Limestone Ammonium Nitrate (LAN (28% N)) at a rate of 50 kg N.ha^{-1} after each grazing cycle. Total nitrogen application levels over the season were 200 kg N.ha^{-1}.

Treatments and measurements

Aiken & Bransby (1992) conducted an experiment in Winfield, Alabama, to evaluate weight gain of steers grazing Bermuda grass oversown with *Secale cereale* and *Lolium multiflorum* at stocking rates ranging from 1.6 AU.ha^{-1} to 4.9 AU.ha^{-1}. Poland *et al*., (1997) evaluated the grazing potential of *Secale cereale* for beef production in Dakota, USA, at 3 AU.ha^{-1}. The stocking rates assessed in this experiment were based on other experimental stocking rates and on the norms recommended for sheep on pastures in KwaZulu-Natal. Stocking rates ranged from 2 AU equivalents.ha^{-1} to 6.6 AU equivalents.ha^{-1} for evaluating goats grazing *Secale cereale.* Four stocking rates were evaluated in an unreplicated randomized block design. Ewes were blocked according to weight and randomly allocated to treatments. The stocking rates evaluated in 2001 were 12, 20, 28 and 39 goats.ha^{-1}, with nine pregnant goat ewes per treatment and camp size varying to achieve the various stocking rates. The camp sizes were 0.75 ha, 0.45 ha, 0.32 ha and 0.23 ha for the stocking rates 12, 20, 28 and 39 goats.ha^{-1} respectively. Each treatment was divided into four equally sized paddocks that were grazed on a rotational basis. The grazing period per paddock was seven days and the period of absence was 21 days. All goats were weighed at two weekly intervals. During the 2001 year, the two lighter stocking rate treatments (12 and 20 goats.ha^{-1}) were stopped (after 69 days) due to the pasture going to seed and the animals found it difficult to graze. The remaining two treatments (28 and 39 goats.ha^{-1}) continued to 97 days. The 2002 stocking rates were based on experiences in the 2001 year, and stocking rates were adjusted to 20, 25, 30 and 35 goats.ha^{-1} and continued for the duration of the grazing season (112 days). The respective camp sizes were 0.5 ha, 0.4 ha, 0.33 ha and 0.28 ha with nine pregnant goat ewes per treatment. Blood samples were taken during the 2002 year from all trial animals and analysed for Calcium, Phosphorus, Magnesium, Copper, Zinc, Iron, Selenium, Packed Cell Volume (PCV), TSP, Albumin and Globulin. Some of the animals in this experiment were used in the kikuyu experiment (Chapter 3) and some were young animals.

Samples of grazed herbage were collected once a month (before grazing) using the hand-plucking method (Cissé *et al*., 2002) to determine forage quality. Herbage samples from each

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[2] Fertrec Laboratory, KwaZulu-Natal Department of Agriculture and Environmental Affairs, Private Bag X9059, Pietermaritzburg, 3200.

camp were oven-dried (at 60^{o}C) for 48 hours, milled (to pass a 1mm screen), dry ashed and analysed for Potassium (K), Calcium (Ca) and Magnesium (Mg) by atomic absorption, and Phosphorus (P) by colorimetric methods. The Kjeldahl method was used for the determination of N prior to ashing (Kjeldahl procedure: AOAC, 1980). Discmeter readings were done weekly to measure the height of pasture on offer ("in" reading) and residual pasture ("out" reading), using a falling plate discmeter.

Animal management

All ewes were dewormed (using Fenbendazole 5% m/v and Levamisole hydrochloride 2.5% m/v) and a multivitamin (Embamin©) was given (in accordance with recommendations) upon commencement of the trial. Ewes were drenched with 2 ml concentrated Iodine prior to kidding due to an Iodine deficiency that had been determined in the previous year. Tetanus and Pulpy Kidney vaccinations had been administered six months prior to the commencement of this investigation. Animals were moved on a weekly basis and weighed fortnightly. The goats were given a sodium (salt), calcium (bonemeal) and phosphorus supplement *ad libitum*.

Statistical analysis

An regression analysis using the statistical package, Genstat 6.1 (copyright 2002, Lawes Agricultural Trust, Rothamsted Experimental Station) was used to determine the effects of stocking rate and days on pasture on animal mass. The experimental unit was the smallest unit to which a treatment was imposed (Fisher, 2000, 1999; Rayner, 1969), namely the group of animals, and the four stocking rates provided the source of variation. The assumptions that were made were that the animals would display correlated responses to treatment variables and that the pastures were uniform. Due to the logistics of grazing research, there were limited degrees of freedom for treatment differences. The mean weight of the group was used (at each weighing date) in the analysis of variance so only the variation between the treatments was considered in the analyses. The mean average daily gain per animal per treatment was used in a regression analysis with the year as a grouping factor to regress ADG on stocking rate.

Rainfall and temperature data

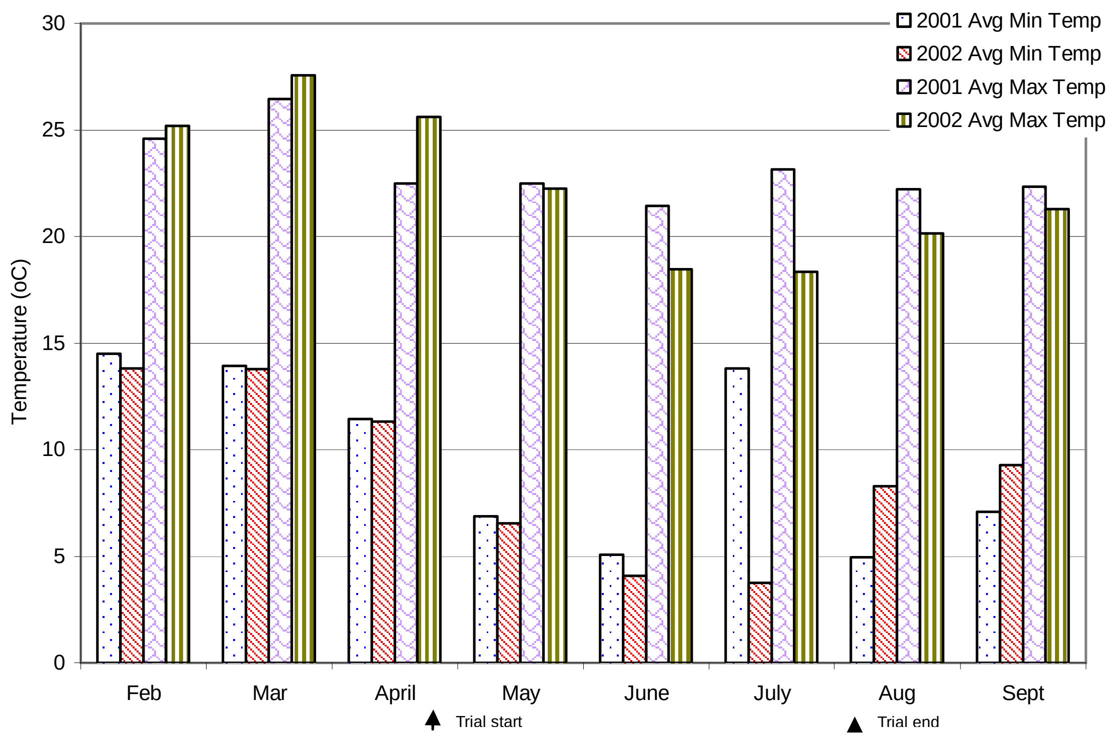


Figure 1: Average maximum and minimum temperatures experienced preceding and during the stooling rye trial for 2001 and 2002.

The temperatures experienced prior to the trial were not vastly different between the years (Figure 1) hence any variation in growth and forage availability could have been a factor of moisture availability. Temperatures experienced during the trial period did not differ significantly, except for July in 2001 being warmer than the 2002 year (Figure 1). This would have had an effect on pasture growth, with the 2001 year having a higher growth rate (as a result of temperature) than the 2002 year would have experienced. As a result, the animal performance models would have differed between years due to differing herbage availability, with 2001 year having more herbage on offer. Since optimal growth of stooling rye occurs at temperatures above 25^{o}C, the difference between the growth rates experienced in the two years should not have been excessive, since temperatures seldom exceeded those for optimal growth.

Since the stocking rates evaluated during the 2002 year were based on experiences in the 2001 year, the stocking rates evaluated may well have been too light for the warmer average minimum temperatures experienced during the 2002 year.

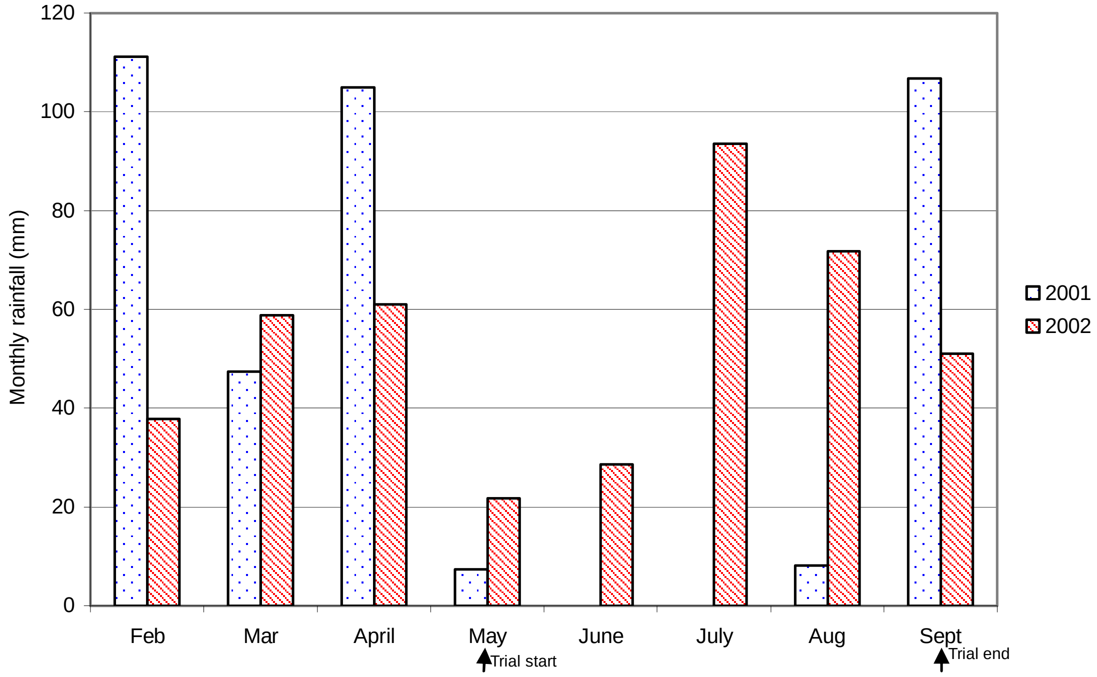


Figure 2: Rainfall preceding and during the stooling rye trial for 2001 and 2002.

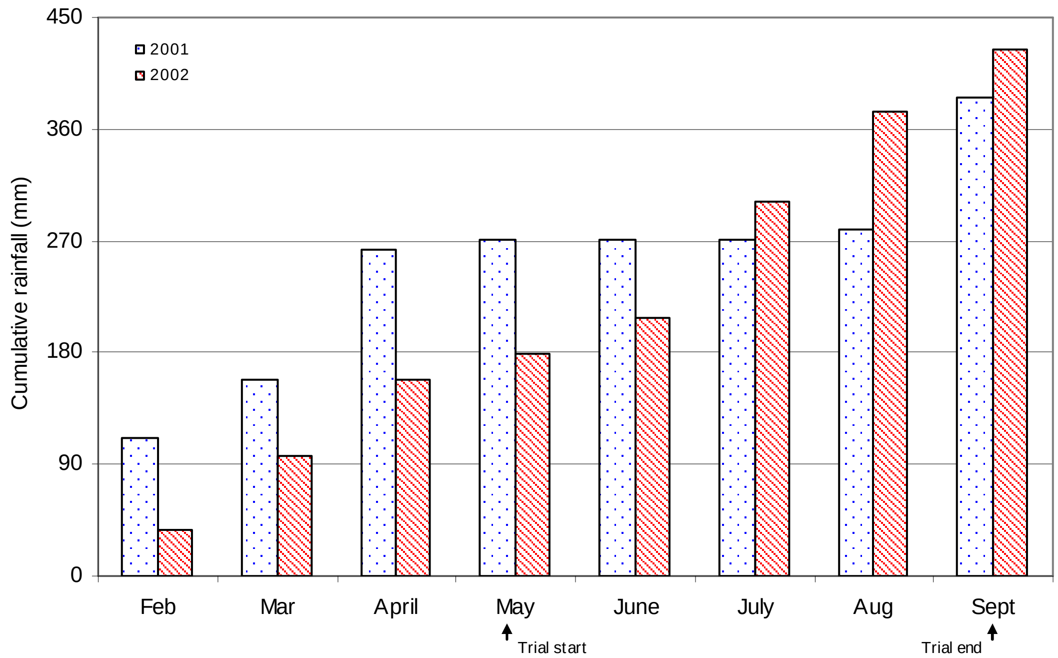


Figure 3: Cumulative rainfall (excluding supplementary irrigation) experienced during 2001 and 2002.

The 2001 year experienced better rainfall in the period prior to the trial (Figures 2 and 3) and that may have given the stooling rye plants a better start initially, due to more soil moisture being available for germination. The 2002 year experienced higher rainfall during the trial period than the 2001 year (Figure 2) although this should not have affected pasture growth since supplementary irrigation was applied during both years. The 2002 year experienced more late-season rainfall which would have kept the stooling rye in a vegetative state since moisture stress would not have been an issue. Therefore, one can conclude that temperatures experienced played a larger role in the differences in animal performance (due to the higher growth rates) than rainfall did.

Results and discussion

Animal performance

There were no significant differences in ewe start masses since animals were evenly distributed between treatments, based on mass. The average start mass was 38.8 kg. The two years were analysed together to determine whether there was a year effect and whether there was an interaction between stocking rate and years. Since there was no interaction between years, the 2001 and 2002 years' data were combined and a regression of ADG on stocking rate was determined for the combined years (Figure 4) that provided more degrees of freedom (d.f.) (Ndiwa *et al*., 2003). The years were evaluated for the shortest grazing period used during both years, namely 69 days, which occurred at the stocking rate of 12 goats.ha^{-1} during 2001.

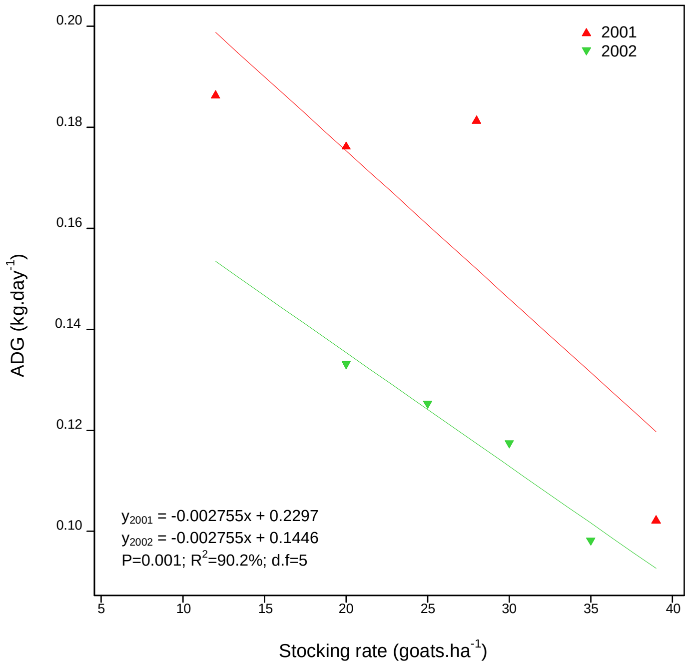


Figure 4: Regression of ADG (y) on stocking rate (x) for the 2001 and 2002 years data combined for pregnant goats grazing stooling rye.

The rate of weight gain between the two years (as stocking rate increased) was not significantly different (Figure 4) and showed a similar response for both years. However, the ADGs achieved differed significantly between years (P=0.001; R^2=90.2%)(Figure 4). The years behaved the same but the intercepts of the regressions on the y axis were different (Figure 4). Both quadratic and linear regressions were used to determine the relationship between mean ewe mass and days on pasture, but the linear regression was statistically significant and had higher correlation values (R^2=90.2%)(Figure 4), indicating that 90.2% of the variation between ADG data was due to the effect of stocking rate. The probability level was 0.001 which meant there was a 99.9% chance that the same result would be achieved on repeating the experiment. Gaussian models were used to evaluate the data and were non-significant. Since both years only had one stocking rate in common and the years were significantly different (P=0.001; R^2=90.2%) the two years could not be combined to get an overall regression for ADG. There was no year-stocking rate interaction which meant the response of ADG to stocking rate was the same for both years.

The relationship between stocking rate and ADG and between stocking rate and gain.ha^{-1} determined for the shortest grazing period used during both years (69 days during 2001 and 106 days during 2002) is illustrated in Figure 5.

To determine the maximum stocking rate according to the Jones & Sandland (1974) model and since there was only one stocking rate in common, the years were not combined. The stocking rate (x): ADG (y) relationship took the form $y = a - bx$ for rotational grazing (Figure 5). The equations are:

$y = 0.2340 - 0.00293x$

$y = 0.1292 - 0.002198x$

with R^2 values of 58% (P=0.151) and 61.6% (P=0.137) for the 2001 and 2002 years respectively.

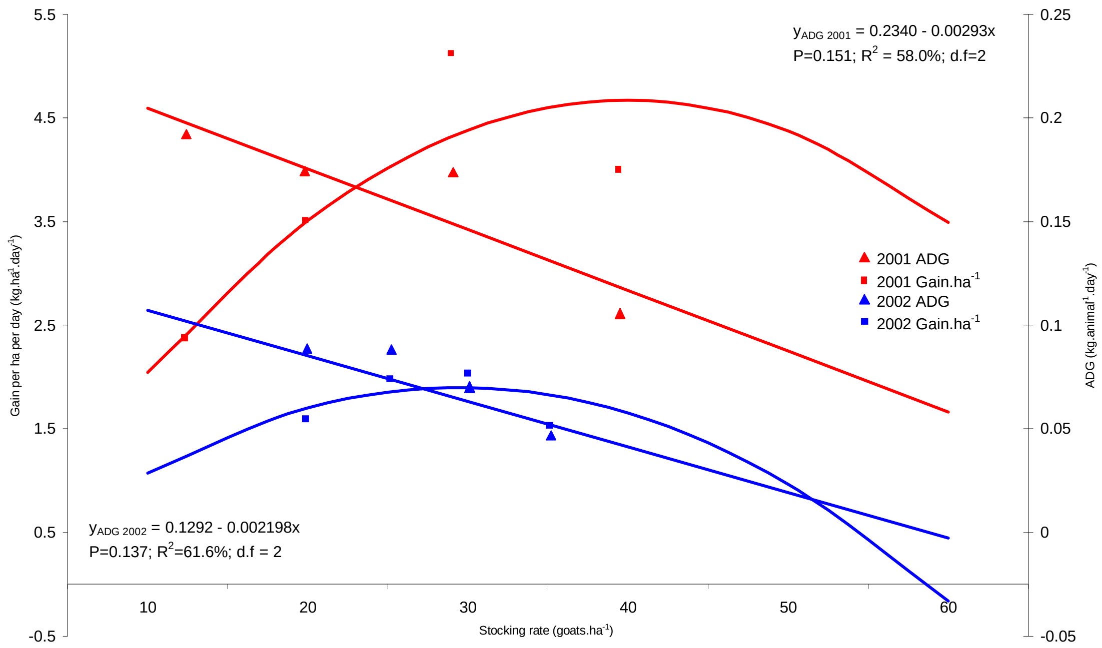


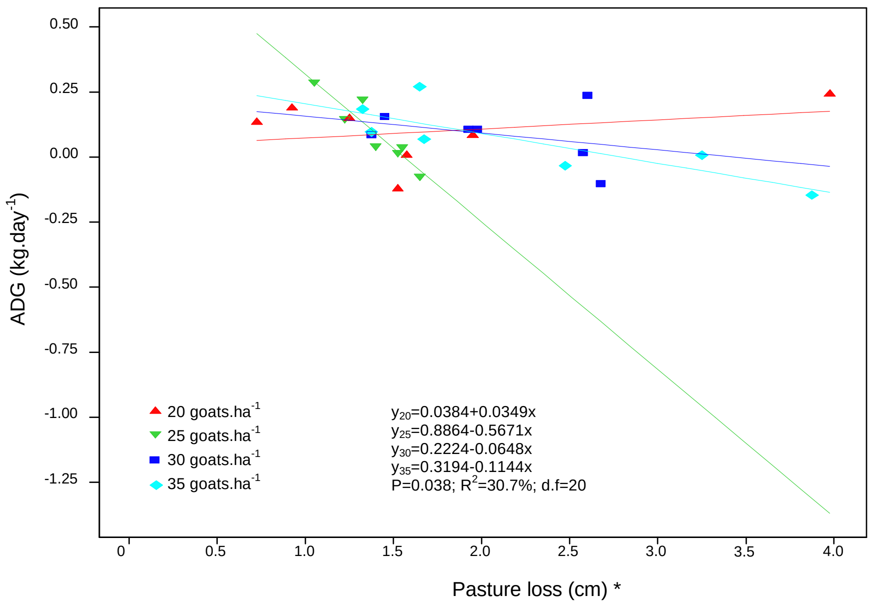
Figure 5: The relationship between gain per hectare per day (y_1) and ADG per animal (y_2) and stocking rate (x) for pregnant goat ewes grazing stooling rye during 2001 and 2002.

Gain.ha.day^{-1} (z) was calculated using the equation $z=ax-bx^2$, where the "a" and "b" values were obtained from the corresponding linear regression described above (de Villiers *et al.*, 1994; Jones & Sandland, 1974). Analysis of the data showed that SR_{max} occurred at 40 goats.ha^{-1} during 2001 and 29 goats.ha^{-1} during 2002. At SR_{max} during 2001, the ADG of the goats was 0.1168 kg.day^{-1} with a daily gain.ha^{-1} of 4.672 kg.ha^{-1}.day^{-1} (Figure 5) and 0.0633 kg.day^{-1} with a daily gain.ha^{-1} of 1.898 kg.ha^{-1}.day^{-1} for 2002 (Figure 5).

Discmeter readings

Discmeter readings were used to determine "pasture loss" ("in" minus "out" readings) which were regressed on the ADG achieved during the corresponding weeks, not on the end weight minus start weight (whole period) as was done in Figure 5.

The 2001 year showed no significant relationship between ADG and herbage availability or pasture loss.



* The difference between the initial and residual pasture height after grazing as measured with a disc meter.

Figure 6: Regression of ADG (y) on pasture loss (x) of goats grazing stooling rye pastures in 2002.

Pasture loss and ADG were significantly different between the four stocking rates during 2002, with the ewes at the low stocking rate treatment having a positive relationship to ADG, while the goats at 25, 30 and 35 goats.ha^{-1} had a negative relationship with Pasture loss ($P=0.038$; $R^2=30.7\%$)(Figure 6). This indicates that the low stocking rate treatment of 20 goats.ha^{-1} had access to more fodder, which is evident by the higher "Pasture loss" figure recorded (Figure 6). This allowed them to consume more fodder and to select better quality grass, which in turn resulted in an increase in ADG. The goats at the stocking rate of 25 goats.ha^{-1} had less forage available than goats stocked at 30 goats.ha^{-1} (Figure 6) and therefore had a lower ADG. The low stocking rate (20 goats.ha^{-1}) had consolidated points, while the other three stocking rates were more widely spread. Stocking rate affected animal performance through its influence on herbage availability and plant part selection.

Herbage quality

Herbage samples taken during the 2002 year were analysed for chemical composition and regression analyses conducted on the data.

Table 2: The average chemical composition (% DM) of hand-clipped stooling rye samples taken during 2002.

Component (%)	20	25	30	35	Mean	Norms*
Protein	33.14	33.83	34.28	34.23	33.87	22.17
Ash	10.06	10.23	10.37	10.61	10.32	-
ADF	22.36	22.10	21.42	22.04	21.98	24.25
NDF	44.92	45.19	44.15	45.49	44.94	48.2

* (Beck *et al.*, 2008)

It is noticeable that there are no differences in the chemical composition between the stocking rates during 2002 (Table 2). Protein levels in the pasture were extremely high (33.87%) compared to 22.17% found by Beck *et al.* (2008), even though the pasture was not excessively fertilised. Beck *et al.* (2008) found NDF levels of 48.2% and ADF levels of 24.25% in stooling rye pastures (Table 2). Füle *et al* (2004) assessed the chemical composition of a perennial variety of rye available in Hungary and found the crude protein values changed substantially, with the highest value of 30.7% during early stem extension with protein values dropping rapidly during late developmental stages. NDF and ADF levels in the pasture were lower than the norms found by Beck *et al.*, (2008). Overall, this experiment had higher protein and lower fibre levels than those pastures evaluated by Beck *et al.* (2008) which indicates better quality forage. This may also be due to the fact that the experiment ended when seeding started, hence fibre levels had not increased significantly and protein levels had not dropped to levels Füle *et al.* (2004) identified.

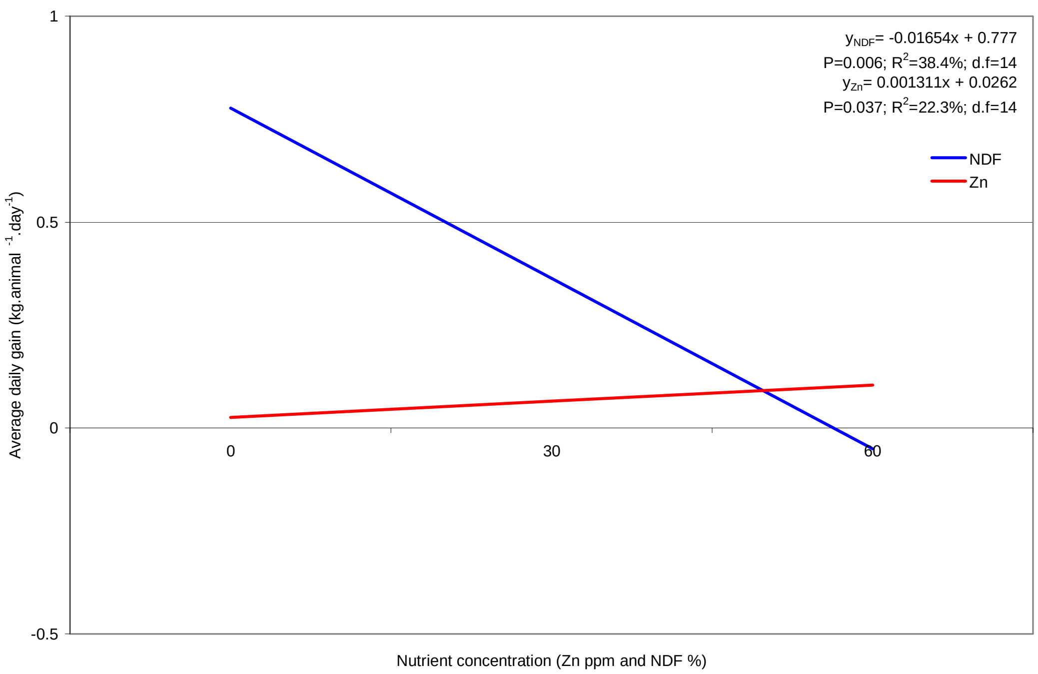


Figure 7: Regression of ADG (y) on NDF levels (x) and Zn (x) for stooling rye pastures in 2002.

ADG was negatively related to NDF levels (P=0.006; R^2=38.4%)(Figure 7). NDF levels accounted for 38.4% of the variation in ADG levels. As NDF levels increased, there was a corresponding decrease in ADG. This would be especially important towards the end of the trial periods, when the herbage became reproductive and more fibrous and the NDF levels increased accordingly. Marais (2001) stated that there is a strong negative correlation between NDF and pasture digestibility. NDF levels would therefore affect intake and correspondingly, ADG. Zinc was positively related to ADG (P=0.037; R^2=22.3%)(Figure 7). Zinc levels in the pasture accounted for 22.3% of the variation in ADG levels.

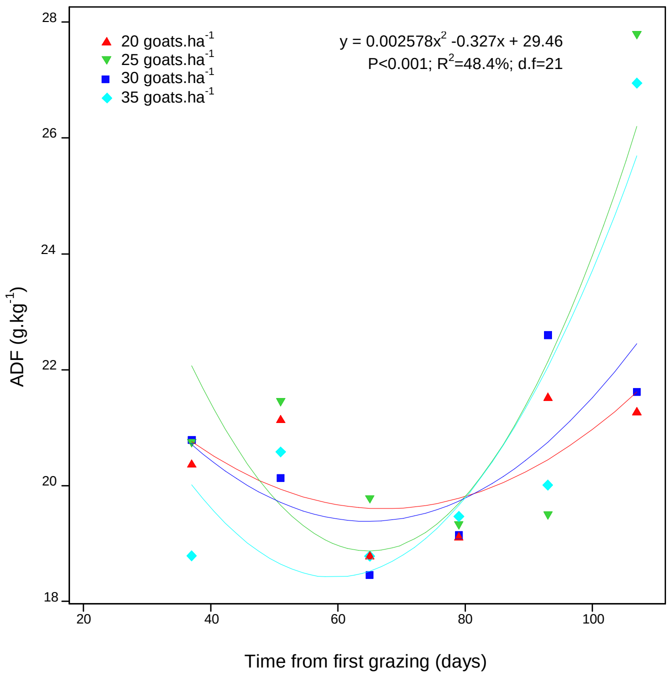


Figure 8: Regression of ADF levels (y) on time from first grazing (x) for stooling rye pastures during 2002.

ADF levels varied throughout the season, and had a quadratic relationship with time from first grazing (P<0.001; R^2=48.4%) while stocking rate had no significant effect on ADF levels (Figure 8). ADF levels give an indication of the digestibility of the pasture, therefore the lower the value, the more easily digested the pasture is. It is interesting to note the high levels of ADF obtained at the end of the trial period, indicating a more fibrous plant due to the commencement of seeding.

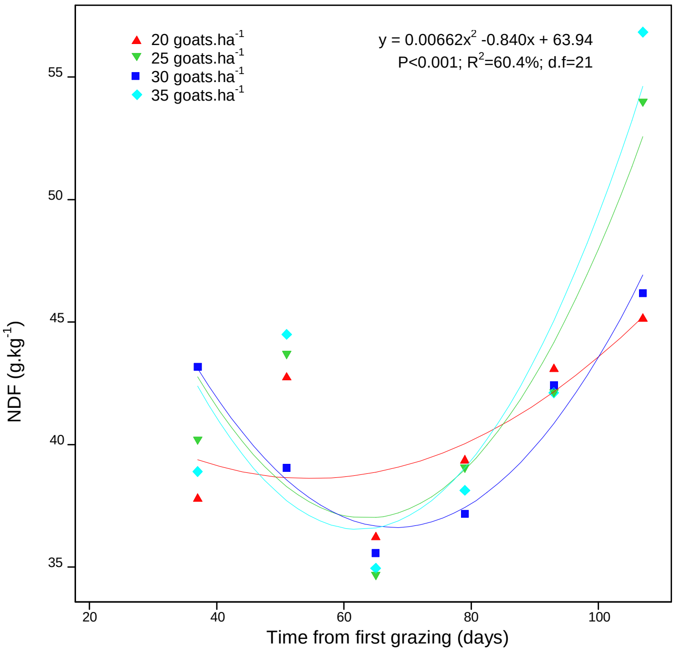


Figure 9: Regression of NDF levels (y) on time from first grazing (x) for stooling rye pastures during 2002.

NDF levels had a quadratic relationship with pasture age (time from first grazing) (P<0.001; R^2=60.4%) while stocking rate had no significant effect on NDF levels (Figure 9). Pasture age accounted for 60.4% of the variation in NDF levels. The high NDF levels found at the end of the experiment were probably due to the commencement of seeding, when the pasture becomes more fibrous. Generally, as NDF levels increase so dry matter intake decreases.

In a correlation matrix, ADF was positively correlated to NDF (0.641; P<0.001) which was to be expected since NDF is made up of the ADF fraction plus the hemicellulose portion. Nitrogen was positively correlated to protein (1.000; P<0.001) which was also to be expected, since nitrogen levels are used to determine crude protein levels in the forage. This calculation is based on the facts that carbohydrates and fats do not contain nitrogen and that nearly all of the nitrogen in the diet is in the form of amino acids in proteins.

The Mac Blue cultivar would be reproductive towards the end of the trial period, especially in the lighter stocking rate treatments. This resulted in a corresponding increase in ADF and NDF levels which caused a decrease in Pasture loss (due to an increase in the fill effect).

Blood metabolites

Vitamins and minerals affect the growth of animals and their physiological functions and reproductive performance (Gabryszuk & Klewiec, 2002). The metabolites analysed represent major metabolic pathways in production. Blood glucose measures energy status. Urea, albumin and haemoglobin measure protein status; calcium, magnesium and phosphorus give a guide to mineral balance; sodium and potassium indicate electrolyte deficiencies or excesses. Packed cell volume, or percentage cells in the blood, can give a useful guide to hydration and thus to water balance (Payne, 1972). In contrast to glucose, urea, albumin and haemoglobin concentrations are all lower in winter than in summer, which is believed to reflect the higher protein intakes common on summer pastures, as compared with winter feed (Payne, 1972).

Calcium, phosphorus and magnesium are closely associated with one another. High concentrations of one tend to be reflected in low concentrations of the other two. So, a diet containing excessive phosphorus may lower magnesium concentration, even though there is ample magnesium intake. Calcium concentrations are closely controlled endocrinologically so deviations from normal are not easy to interpret (Payne, 1972). Abnormalities in the concentrations of calcium, phosphorus and magnesium may have several effects. The most important is a high incidence of parturient hypocalcaemia (Payne, 1972). Serum magnesium is probably one of the most important components in the metabolic profile test because deviations from the normal are very important clinically (Payne *et al.*, 1970).

Table 3: Mean levels of blood metabolites for goats on stooling rye for 2002 at four stocking rates.

	Ca (mmol.L^{-1})	PO_4 (mmol.L^{-1})	Mg (mmol.L^{-1})	Cu (umol.L^{-1})	Zn (uol.L^{-1})	Fe (umol.L^{-1})	Se (ng.ml^{-1})	PCV (%)	TSP (g.100ml^{-1})	Albumin (g.100ml^{-1})	Globulin (g.100ml^{-1})
20 goats.ha^{-1}	2.47	2.01	1.12	18.58	11.57	32.91	37.21	35.56	7.11	3.34	3.77
25 goats.ha^{-1}	2.50	1.99	1.13	15.16	12.75	40.73	26.48	36.67	7.30	3.57	3.76
30 goats.ha^{-1}	2.50	2.08	1.14	16.50	12.29	40.67	50.71	36.22	7.00	3.48	3.52
35 goats.ha^{-1}	2.44	2.68	1.13	18.01	11.96	36.03	36.69	36.11	6.94	3.41	3.52
Means	2.48	2.19	1.13	17.06	12.14	37.59	37.77	36.14	7.09	3.45	3.64
Normal range	**2.22-2.92**	**1.23-5.70**	**1.15-1.48**	**12.58-18.89**	**9.95-41.31**	**19.71-41.21**	**80-200**	**15-30**	**6.4-7.8**	**2.7-3.9**	**3.7-3.9**

The PCV was slightly higher in all treatments (36.14%) than was desired (targets of 15 – 30%) (Table 3), which indicates mild dehydration although the reason for this is unknown, since water was available at all times. Magnesium was marginally lower than the targeted range (Table 3). All other minerals were within normal ranges. Blood selenium levels were lower than desired (37.77 ng.ml^{-1} with targets ranging from 80 to 200 ng.ml^{-1}) and magnesium levels were slightly low (1.13 mmol.L^{-1} with targets ranging from 1.15 to 1.48 mmol.L^{-1}) (Table 3). None of the above metabolites should have had an effect on animal performance since deficiencies or excesses were not extreme, except for Selenium, which was deficient (Table 3).

Table 4: Correlation matrix of blood metabolites for goats on stooling rye in 2002.

Correlation Coefficient	Number of kids born	PO_4	Fe	TSP	Ca	Zn	PCV
TSP	NS	-0.409*	NS	1.00	NS	NS	NS
Globulin	NS	**-0.451****	-0.357*	**0.810****	NS	NS	NS
Ca	**-0.612****	NS	-0.328*	0.358*	1.00	NS	NS
Mg	**0.461****	NS	NS	NS	NS	NS	NS
Cu	0.337*	NS	**-0.511****	NS	-0.367*	NS	NS
Zn	**-0.504****	NS	NS	NS	**0.652****	1.00	NS
Se	**-0.448****	NS	NS	NS	NS	NS	NS
PCV	**-0.698****	NS	NS	**0.513****	**0.652****	**0.565****	1.00
Albumin	**-0.575****	NS	NS	**0.538****	**0.747****	**0.716****	**0.693****

* = significant at 5% level ** = significant at 1% level

The number of kids born was significantly correlated (at 1% level) to calcium (-0.612), magnesium (0.461), zinc (-0.504), selenium (-0.448), PCV (-0.698) and Albumin (-0.575) (Table 4). Magnesium was positively correlated to the number of foetuses, indicating as Mg increased, so did the number of foetuses, while Ca, Zn, Se, PCV and Albumin were negatively correlated, (the number of foetuses decreased as respective mineral levels increased). However, blood selenium levels were found to be deficient in the goats (Table 4). Since selenium does not appear to have any significant effects on the oestrus, fertility, prolificacy and the number of lambs born (Gabryszuk & Klewiec, 2002) this would not have had an effect on the number of foetuses but may have affected animal performance.

Discussion

The Jones Sandland model theory (Jones & Sandland, 1974) indicates that liveweight gain per head is constant as stocking rate is increased to a critical point. Beyond this point, gain per head is inversely related to stocking rate. Gain per hectare increases linearly as stocking rate is increased to the critical point and then decreases linearly with further increases (Petersen *et al.*, 1965). The light stocking rate treatment had lower gains per hectare due to the lower number of animals per hectare. Average daily gain was highest at the light stocking rate (Figures 4 and 5) on a per animal basis, while lower on a per hectare basis. Since there were no significant differences in pasture quality (Figures 7, 8 and 9) the variation in ADG must be due to the variation in Pasture loss (Figure 6), with the low stocking rate animals appearing to consume more fodder. Grazing systems that utilise more mature grass are likely to result in lower production per animal, but this loss can be compensated by a greater number of animals per unit area (de Alba, 1959).

Riewe (1961) stated that, as stocking rate increases, there is a tendency for liveweight gain per head to decrease. Broadbent (1964) found that lambs rate of live-weight gain was negatively related to stocking rate and the total live-weight of lamb produced per hectare was positively related. The ewes' live weights were similarly affected, with the highest losses of live weight under the heavy stocking rate. This substantiates the findings reported in Figure 5, where the heavier stocking rates had the lowest ADGs.

Osoro *et al.* (2009) evaluated a *Lolium perenne* and *Trifolium repens* mixed pasture (in Asturias, Spain) and the effect of heather supplementation on gastrointestinal nematodes in non-lactating, non-pregnant cashmere goats grazing these pastures at varying stocking rates. Their findings were that liveweight changes were significantly ($P<0.001$) affected by stocking rate.

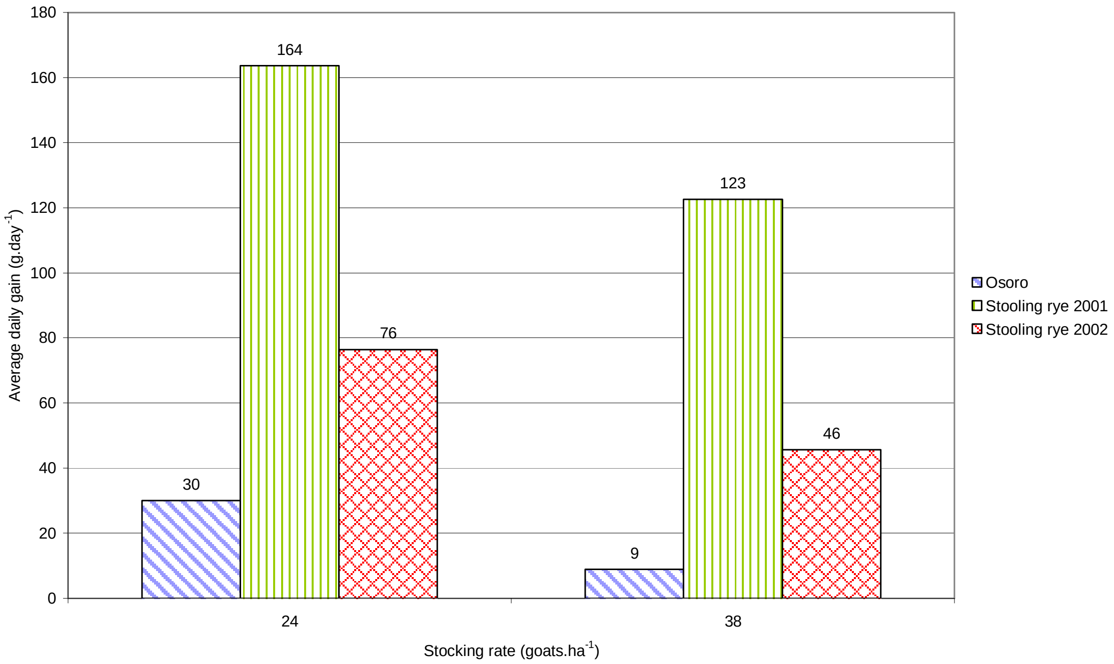


Figure 10: Average daily gain (ADG)(y) in relation to stocking rate (x) presenting data from Osoro *et al.* (2009) and the stooling rye trial for 2001 and 2002.

When comparing the ADGs achieved by Osoro *et al.* (2009) on *Lolium perenne* and *Trifolium repens* mixed pastures to those achieved during the stooling rye trial during 2001 and 2002 (using the regressions obtained in Figure 5), the stooling rye goats have far outperformed the cashmere goats on mixed pastures (Figure 10).

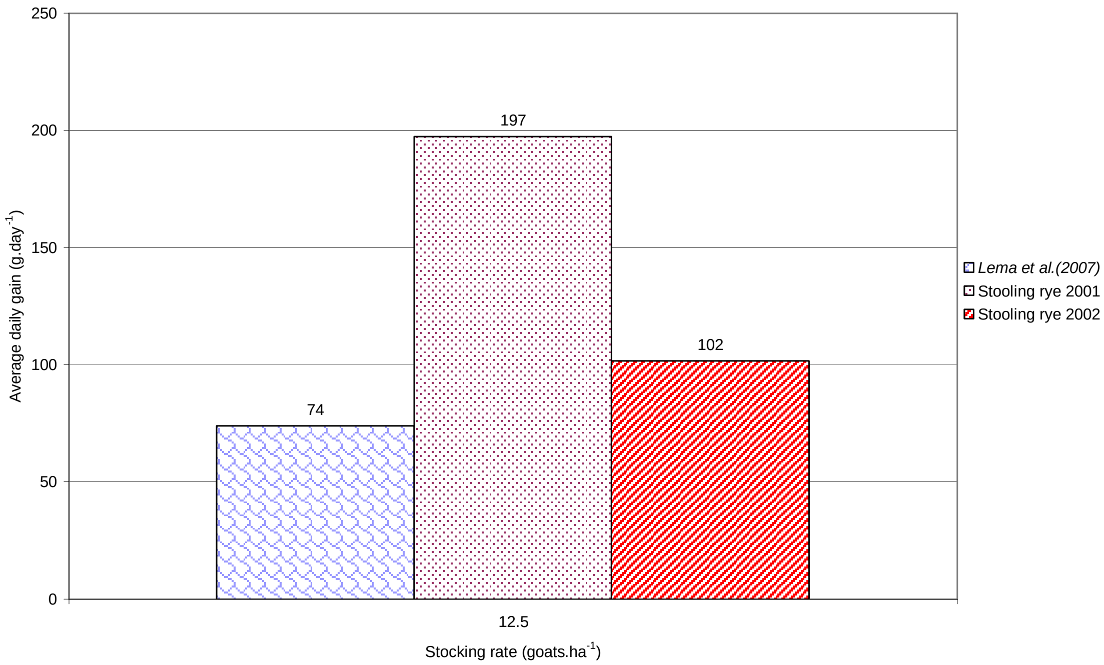


Figure 11: Average daily gain (ADG)(y) in relation to stocking rate (x) presenting data from Lema *et al.* (2007) and the stooling rye trial for 2001 and 2002.

Lema *et al.* (2007) evaluated stooling rye as a source of forage for continuous grazing of meat goats (weaned doe kids) in Nashville, Tennessee, USA. Their findings were that an average daily gain of 74.00 $g.day^{-1}$ could be achieved at a stocking rate of 12.5 $goats.ha^{-1}$ on stooling rye and that performance of goats on stooling rye was significantly higher than on fescue. The performance achieved during this study at 12.5 $goats.ha^{-1}$ (using the regressions obtained in Figure 5) was 197 $g.day^{-1}$ and 102 $g.day^{-1}$ for 2001 and 2002 respectively, much higher than that achieved by Lema *et al.* (2007)(Figure 11).

Due to the differing weather patterns between years, the 2001 year grew more herbage, which in turn allowed the lighter stocking rate treatments to select to a greater degree and therefore experience higher average daily gains than the 2002 year. By the end of the 2002 year, the performance in the lighter stocking rates was similar to that experienced in the 2001 year. However, the heavier stocking rate treatments were vastly different between the two years, with those in the 2002 (poorer) season far outperforming those in the 2001 year. The slightly higher temperatures experienced towards the end of the 2001 year would have caused the herbage to become reproductive sooner than the 2002 year, which would have had a corresponding decrease in herbage quality and therefore animal performance. The 2001 year had a grazing season of 97 days (for the lower stocking rate treatments) and the 2002 year had a grazing season of 112 days for all stocking rate treatments but these differences in grazing days were removed during the analyses.

Selenium is the only nutrient that showed as deficient in all treatments. Therefore, goats grazing stooling rye should be supplemented with selenium either through vaccination or applied to the pasture. This study has shown that stooling rye is a suitable pasture for over-wintering pregnant goat ewes and acceptable performance levels can be achieved.

5 DISCUSSION AND CONCLUSIONS

To be in a position to make management decisions relating to animals grazing pastures, it is important to know the predicted response of all factors that affect both the animal and the pasture. Many management factors can be manipulated to improve production, pasture quality and pasture quantity. However, environmental factors, which affect both animals and pastures, cannot be controlled or manipulated and the responses of both animals and pastures to changes in environmental conditions need to be determined. Kid potential for growth is one of the most important traits in genetic improvement schemes for goat production and this is affected by a number of non-genetic factors (Thiruvenkadan *et al.*, 2009). Thiruvenkadan *et al.* (2009) stated that planning kidding seasons would improve production efficiency, due to the effect of birth month on ADGs.

The response of goat performance levels to changes in stocking rate was determined by measuring the response of animal mass to stocking rate. Stocking rate is an important management variable and has a large impact on animal productivity and therefore economic profitability. Stocking rate affects forage availability, animal performance and intake and also affects the vegetation and therefore the economic viability of the system (Morris *et al*., 1999). Lighter stocking rates are better for reproductive animals due to the improved survival and growth rates of offspring (O'Reagain & Turner, 1992) while heavier stocking rates result in greater gains per hectare. Snyman (2007) found that preweaning management systems had a significant effect on weaning weights. Thiruvenkadan *et al.* (2009) found that pre-weaning average daily gain was significantly affected by period, season, type of birth, sex and parity, while post-weaning efficiency of growth was influenced by period and season. Thiruvenkadan *et al.* (2009) also stated that the maximum growth rate occurred during the pre-weaning stage.

Rainfall and temperature play an important role in pasture production. Temperature affects both germination and plant growth rate and in the case of annuals, it affects the longevity of the pasture. Atmospheric temperature affects soil temperature that in turn affects plant growth rate. Rainfall influences yield. Both rainfall and temperature were recorded during the trial period and these were compared to determine if they had any affect on pasture production and therefore animal performance.

Kikuyu (*Pennisetum clandestinum*) was the summer pasture of choice for the study. Kikuyu is widely used in KwaZulu-Natal and is highly suited to grazing. It's suitability for goat production has not been determined. It is easy to establish and is useful for controlling erosion. Management input levels are low but fertilisation is necessary. During the study, it was determined that the second year experienced later spring rains and had higher rainfall overall than the preceding year during the trial period, with negligible differences in temperature. As a result, the second year produced more dry matter than the first year since growth could commence earlier due to moisture availability. Temperature differences were negligible and did not appear to affect pasture and animal production. Since stocking rates for the second year were based on the results of the first year, those stocking rates evaluated in the second year were too light for the high dry matter that was produced. As a result, the stocking rate at which animal production is maximised was not reached and therefore not determined.

In the study, the ewes lost weight to weaning, with a significant difference between years and a significant difference in the rate of weight loss between treatments. The rate of weight loss between the two years was the same as stocking rate increased, but the mean losses at each stocking rate were significantly different with the first year (with the later spring rains) having lower ADG losses than the second year (Figure 5). When analysing the full grazing period, there was still a significant difference between the years but no significant differences between stocking rate treatments (Table 4). This indicates that any differences in ADG that were evident at weaning were no longer evident at the end of the trial period, therefore the ewes at the medium and high stocking rate treatments had managed to increase their ADGs to match those of the low stocking rate treatment. Therefore, the effect of the kid suckling on the ewe was the reason why there were significant differences in ADG. Over the whole grazing period, the two years behaved differently, with the first year (with later spring rains) having negligible ADG differences between stocking rate treatments, while that in the second year had more pronounced differences between treatments (Figure 6). The herbage produced in the second year at the low stocking rate treatment (Figure 4) was significantly higher than that produced in the first year, probably due to the effect of later spring rains during the first year. Had the herbage production been higher in the first year at the low stocking rate, there would probably have been a larger difference in ADGs between treatments in the first year, so the regression of ADG on stocking rate (Figure 6) would probably have been more alike for both years. On a per hectare basis, the predicted response of the higher the stocking rate, the higher the gain per hectare achieved (O'Reagain & Turner, 1992). The theoretical animal performance model (Edwards, 1981) (Figure 1) shows that as stocking rate increases (to a critical point), gain per hectare increases while individual animal performance decreases.

Since yield is highly correlated to animal production, one can expect an increase in animal performance as yield increases, up to a maximum yield, and thereafter, quality will decline as yield increases and therefore animal performance will decrease with decreasing pasture quality. As stocking rate increases, pasture availability becomes limiting and therefore intake is limiting. The decrease in availability and therefore intake will result in a decrease in energy intake. Since energy is allocated to milk production over weight gain in high genetic merit animals, body weight will decrease at the expense of milk production.

When evaluating the height of the pasture on offer, the first year had taller pasture on offer than the second year (Figure 8) and ewe ADG decreased as pasture height increased. There was a significant difference in the rate of change of ewe ADG between the two years as pasture height increased. This is probably due to the quality of the pasture, since as pasture height increased so protein levels decreased (Figure 15) resulting in a corresponding decrease in ADG. Regression of pasture loss on ewe ADG showed a positive linear relationship with no significant differences between stocking rate treatments in 2002 (Figure 12) which shows that as intake increases, so ADG increases. This indicates that fill factor issues had not had an effect since the ewes still had the potential to consume more forage and forage availability was the limiting factor for ADG, not intake capacity.

There were no significant differences in kid performance between treatments. Kid ADG was positively correlated to ewe ADG (Figure 14)(P=0.013; R^2=5.8%) which would be due to the milk production from the ewe, although this was not a strong relationship. Therefore, stocking rate affects ewe ADG which in turn affects milk production and therefore kid ADG.

Herbage samples were taken throughout the year and nutrient status determined. It was found that NDF was highly correlated to average daily gain, as were protein and the ratio of calcium to phosphorus. Demarquilly *et al*. (1981) stated that ingestibility decreases as the plant matures due to an increase in its fill effect. The increase in NDF levels as the season progressed would have resulted in a corresponding decrease in ingestibility and therefore a decrease in average daily gain. Protein was positively correlated to average daily gain with a quadratic relationship (Figure 16)(P<0.001; R^2=48.4%). Therefore, an increase in protein levels would have an increase in average daily gain, but each additional increase in protein levels would increase average daily gain at a decreasing rate, until a maximum threshold is reached and thereafter protein would limit ADG. The maximum threshold was found to be 26.17 $g.kg^{-1}$ crude protein.

The winter pasture of choice was stooling rye (*Secale cereale*), a pasture not widely researched and not often utilised outside of South Africa. Stooling rye is a high quality temperate species that requires a medium level of management. It grows relatively easily in average quality soils and has a good yield. It is higher in dry matter content than ryegrass (*Lolium multiflorum* spp.) with negligible differences in nutritional quality, but does not produce the yield that the ryegrasses can. During the study, only one month during the trial period had a noticeable difference in temperature between the two years and this difference occurred in what is normally the coolest month of the year. This would have affected pasture growth since temperate species normally slow their growth rate down considerably over this period. The warmer temperatures experienced in the first year would have increased the mid-season growth rate and therefore increased both herbage an animal production in the first year. There were differences in rainfall prior to planting, which may have affected germination of the seeds. Supplementary irrigation was given throughout the season which should have negated any influence rainfall differences may have had. Therefore, temperature was the main variable affecting pasture production in both years.

The rate of weight gain between the two seasons was not significantly different and had a similar response for both years (Figure 4). However, the ADGs achieved differed significantly, with the 2001 year having higher ADGs than the 2002 year. Pasture loss was significantly different between treatments with ADG decreasing (for the three higher stocking rate treatments) as intake increased (Figure 6). The ADG at the low stocking rate treatment had a positive relationship with pasture loss – ADG increased as intake increased (Figure 6). Herbage quality analyses showed that the low stocking rate treatment had slightly lower protein levels than the other stocking rate treatments, although protein levels in all treatments were much higher than the norms found by Beck *et al.* (2008). The levels in the stooling rye pasture were sufficient for production. Acid detergent fibre and NDF levels were marginally lower than the norms according to Beck *et al.* (2008). Since NDF levels were significantly negatively correlated to ADG, this would imply that one could expect an improvement in individual animal performance with shorter, higher quality forage, since NDF levels increase as pasture height increases. Therefore, the lower pasture loss would imply that the fodder is short (since availability would limit intake) which would result in a higher quality feed and therefore a higher ADG (Figure 6). This is substantiated by de Alba (1959) who stated that grazing systems that utilise more mature grass are likely to result in lower production per animal. The number of grazing days in each year differed, with 2001 having a shorter grazing period of 97 days and 2002 having 112 grazing days.

Blood samples were taken from the ewes to evaluate the mineral status at the end of the trial. There were no significant differences between the treatments. Magnesium was positively correlated to the number of kids born, indicating an increase in Mg resulted in an increase in the number of kids, while Ca, Zn, Se, PCV and Albumin were negatively correlated, thereby resulting in a decrease in the number of kids as blood mineral levels increased. Selenium levels were found to be deficient in the goats. Since selenium does not appear to have any significant effects on the oestrus, fertility and prolificacy this would not have had an effect on the number of kids born but may have affected animal performance.

South African indigenous goats are a valuable resource for the rural farmer in South Africa. However, the potential to develop this into commercial enterprises for the rural farmers has not been exploited. Goat meat and goat milk markets need to be determined and encouraged, to facilitate marketing of the products. There is little information relating to South African indigenous goats on pastures. Their potential for intensive production has not been evaluated and needs to be explored further. The suitability of various pasture species for goat production needs to be evaluated, as does the optimum stocking rate for each pasture. There are advantages and disadvantages to intensification of goat production systems. The advantages relate to an increase in the quality of feed provided. Some of the advantages are: increased animal weight gains (due to the mothers producing more milk), increased kid birth weights (due to better feeding of the mothers during gestation) and decreased diseases and deaths (due to healthier animals), which results in an increase in income. The use of pastures may increase body condition, which in turn may boost ovulation and reproductive performance (Landau *et al.,* 2000). Some of the disadvantages of utilising pastures are: increased levels of management required, increased cost of production, increase in intestinal parasite infectivity risk at high stocking rates (Osoro *et al.* 2009) and an increase in foot problems (due to intensive conditions). There are five categories of non-chemical anthelmintic control methods, namely grazing management, biological control, nutrition, vaccination and genetic approaches (Osoro *et al.* 2009). Osoro *et al.* (2009) evaluated intestinal nematode infection levels in goats on mixed pastures and found a significant interaction between stocking rate and time on pasture. The justification for this finding was because animals at the high stocking rate graze closer to the manure, thereby ingesting a large number of nematode larvae and therefore have a large egg output rate and higher infection risk. With anthelmintic resistance levels in South Africa being amongst the worst in the world (Vatta & Lindberg, 2006) it is important that a high level of parasite control be implemented in intensive systems. The economic viability of including pastures in livestock systems can be questionable so it is important to ensure that the value added to the marketable product is greater than the cost of the pasture (Kirkman & Carvalho, 2003) and should be economically attractive (Payne *et al.*, 2006). Since feed costs account for between 50% to 70% of variable costs, the profitability of a meat goat enterprise depends on the ability to provide as much grazing throughout the year with little dependence on stored feed (Lema *et al.*, 2007).

Snyman (2007) conducted an investigation into reproductive performance and kid mortality in South African angora goats and found that kids that were kept on pasture until weaning were 5.7 kg heavier than kids that were kept on veld and 4.6 kg heavier than kids that were kept on pasture for a few weeks and then moved onto veld. The mean average daily gain for both angora ewe kids and angora ram kids from birth to weaning was 97.8 $g.day^{-1} \pm 2.3$ under varying management systems, while those on pastures exclusively achieved 132.3 $g.day^{-1} \pm 3.4$.

Thiruvenkadan *et al.* (2009) collected data from 566 Tellicherry goats grazing natural vegetation in Tamil Nadu, India, over a period of 20 years. The mean pre-weaning ADGs obtained over this 20 year period was 72.41 ± 1.68 $g.day^{-1}$. Payne *et al.* (2006) performed a study at the Texas Agricultural Experiment Station in Texas, evaluating the effect of supplementation on intake and animal performance in three month old meat goats. They reported that there were significant increases in ADGs when comparing non-supplemented goats fed only forage (sorghum-sudan hay) to supplemented goats fed a complete ration, however there is substitution effect of forage with supplement. The forage-based feeding system achieved a weight gain of 21.8 $g.day^{-1}$ which was insufficient to allow goats to reach 30 to 50 kg by one year of age.

The maximum ADG achieved during this study on kikuyu pastures was 80 $g.day^{-1}$ at the stocking rate of 30 $goats.ha^{-1}$ during 2002. The maximum ADG achieved on the stooling rye pastures was 168 $g.day^{-1}$ at 20 $goats.ha^{-1}$ during 2001. These compare favourably with the performance levels achieved by Snyman (2007) and exceed those achieved by Thiruvenkadan *et al.* (2009) and Payne *et al.* (2006).

Animut *et al.* (2005) evaluated four to five month old goats' performance at three stocking rates on a *Cynodon dactylon* and *Sorghum halepense* mixed pasture in Oklahoma, USA. Their findings were that ADG decreased linearly ($P<0.10$) on all stocking rates as stocking rate increased. The explanation for this decrease was decreasing forage mass and nutritive value since as availability declines, biting rate and grazing time increases. This is in agreement with the findings of this study, where stocking rate had a significant effect on ADG on both kikuyu ($P<0.001$) and stooling rye pastures ($P=0.001$). In a similar experiment conducted by Animut *et al.* (2006) using goat weathers on *Cynodon dactylon* and *Sorghum halepense* mixed pasture, their findings were that initial and final body weight were not influenced by stocking rate and mean ADG was not affected by stocking rate ($P>0.05$). This is not in agreement with the findings of this study, where stocking rate had a significant effect on ADG on both kikuyu ($P<0.001$) and stooling rye pastures ($P=0.001$).

Yiakoulaki *et al.* (2007) evaluated the effect of stocking rate on performance of ewe goats with kids rotationally grazing mixed pastures (*Cynodon dactylon* and *Sorghum halepense*) in Oklahoma, USA. Their findings were that final ewe weight decreased linearly ($P<0.10$) as stocking rate increased, as did kid body weight ($P<0.06$), with the change in kid weight being less than the change in ewe weight. Their findings were similar to that found in this study, with ADG decreasing as stocking rate increased. Morand-Fehr (2005) stated that better use is made of pastures in a cut-and-carry system for suckling goats in the tropics as opposed to a grazing system. Lefrileux *et al.* (2008) stated that it is essential to stimulate high intake capacities in grazing goats, since there is a high correlation ($r>0.80$) between dry matter intake and milk production. In this study, the higher stocking rate would have resulted in less dry matter per animal and correspondingly lower milk production, which caused the lower kid weight gains at the high stocking rate ($P=0.007$; $R^2=21.8\%$) in comparison to the medium and low stocking rate treatments. Lefrileux *et al.* (2008) also stated that in young female goats grazing pastures, weight gains can be more than 100 $g.day^{-1}$ and that would allow the females to reach a weight suitable for mating at seven to eight months of age.

Stocking rate is one of the important management variables affecting forage availability (Animut *et al.* 2006), animal performance and economic viability of livestock enterprises (Yiakoulaki *et al.*, 2007). High stocking rate decreases forage availability and therefore lessens selectivity, resulting in low growth rates and possibly weight loss (Animut *et al.* 2006). Since peak gain per animal occurs at a stocking rate that is lower than that at which maximum gain per hectare occurs, it is important to identify these two stocking rates to ensure economic viability of the enterprise. However, it is not well known how lactating females are affected by stocking rate, since they can compensate for low nutrient uptake by mobilising tissue reserves (Yiakoulaki *et al.*, 2007). Since there were no significant differences in the rate of weight gain of goat ewes with kids on kikuyu pastures, the maximum stocking rate that was evaluated is recommended, with 60 goat ewes.ha^{-1} when implementing a four camp rotational grazing system. Likewise, since there were no significant differences in the rate of weight gain for pregnant goat ewes on stooling rye pastures, the maximum stocking rate is recommended, with 39 goats.ha^{-1} in a four camp rotational grazing system.

The two pasture species evaluated in this study can be used in conjunction with each other to provide high quality feed at different times of the year to animals at different physiological stages. In combination, these pastures can provide feed for the majority of the year and any excess fodder can be harvested and stored for use at a later stage. In addition, the pastures can be used as a complementary fodder source for animals grazing veld.

Stocking rate affects individual animal performance by an amount that varies from year to year and from season to season. The optimum stocking rate depends on maximum production per unit area, maximum stability of the pasture, minimum stress to livestock, soil conservation and livestock appearance (Morley, 1981), so the choice of the optimum stocking rate must be a compromise between these criteria. The grazier must be clear on whether he/she wishes to maximise production per hectare or production per animal, since each requires a different stocking rate. Selenium deficiency is a common problem in South Africa and needs to be addressed.

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