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Biological and Economic Effects of Grazing Spring-Calving Cow-Calf Pairs on Improved Irrigated Pastures Using Creep Supplementation

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BIOLOGICAL AND ECONOMIC EFFECTS OF GRAZING SPRING-CLAVING COW-CALF PAIRS ON IMPROVED IRRIGATED PASTURES USING CREEP SUPPLEMENTATION

by

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ABSTRACT

Biological and Economic Effects of Grazing Spring-Calving Cow-Calf Pairs on Improved Irrigated Pastures Using Creep Supplementation

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Recent trends to develop farmland into improved irrigated pastures raise questions regarding the profitability of creep supplementing terminal-sired calves on these production systems. This study was initiated to answer these questions. Two previously established adjacent sprinkler-irrigated plots were separated into 2 paddocks. One plot (3.4 ha) consisted of a monoculture of Seine tall fescue while the other plot (3.9 ha) consisted of a mixture of Seine tall fescue, AC Grazeland Alfalfa, and Norcen birdsfoot trefoil. The mixture of the second plot consisted of 50% tall fescue, 37.5% alfalfa, and 12.5% birdsfoot trefoil. Plots were designated as monoculture no-creep supplement (MONOC) (1.7 ha), monoculture with creep supplement (MONOS) (1.7 ha), mixed forage no-creep supplement (MIXC) (1.95 ha), and mixed forage with creep supplement (MIXS) (1.95 ha). Twenty-four spring calving cow-calf pairs were stratified into 4 groups based on calf body weight, sex, breed, dam body weight, dam BCS, and breed. Management-intensive grazing practices were implemented with cattle receiving a new allotment of forage at 0800 daily. Cattle grazed in a west-to-east direction across the pasture completing a grazing circuit every 24 to 30 d. Pasture forage production was estimated using a 0.163 m^2 clip-plot. Forage production each period was highest for cattle grazing MIXS (4492 kg DM/ha) followed by MIXC (4116 kg DM/ha) (P=.58). Production from the MIX plot differed from MONO plot (P<.0001). Similar to MIX pasture production MONOC (3154 kg/ha) and MONS (3058 kg/ha) did not vary (P=.4324). Carrying capacity differed among all treatments. The highest carrying capacity was observed in the MIXS group with 3.37 pair/ha. The next highest carrying capacity was in the MIXC group at 3.05 pair/ha, which differed from MIXS (P=.0404). There was a difference between MIXC and MONOS (2.38 pair/ha) (P=.0051). The lowest carrying capacity was observed in the MONOC group (2.07 pair/ha), differing from MONOS (P=.0450). Calf end weight was highest for the MIXS group (343 kg) and differed from MONOC group (298 kg) (P=.0272); no other groups differed. Profitability did not follow pasture productivity completely. Due to high supplemental feed costs MIXC was the most profitable management strategy ($72.03 cow/yr) and was $137.50 cow/yr more profitable than the least profitable strategy, MONOS. Results from this study show that grass-legume mixtures are much more productive than grass monocultures under irrigation and management-intensive grazing of cow-calf pairs. In addition, on these forage resources the practice of supplying creep supplementation to high-growth, terminal calves is not economically profitable.

(63 pages)

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Adam F. Summers

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Figure Page

INTRODUCTION

Due to changes in federal land policies and increases in feed and maintenance costs, producers are investigating methods to reduce costs. Asay et al. (2001) and Waldron et al. (2002) show that using livestock to harvest forages instead of machinery can decrease operating costs. This is further reiterated by Drake and Oltjen (1994) who identified intensive grazing systems as one of the most cost effective management activities for pastures. The objective of cow-calf production systems is to carry as many animal units as possible without hindering cow and calf performance or degrading the land resources (Preston and Willis, 1974). To be successful producers must consider plant varieties, composition, fertility and water management.

Beuselinck et al. (1994) found that many producers preferred monoculture grass pastures due to their ease of management. However, Mouriño et al. (2003) showed that inclusion of legume in pasture mixes can increase both pasture and animal productivity. Water availability is also crucial to help maximize pasture productivity (Waldron et al., 2002), especially in desert states like Utah. Stocking rates and length of graze also influence pasture yield and health. Sanderson et al. (2005) stated that forage livestock operations are shifting to management-intensive grazing for three reasons: first, lowered production costs; second, improved animal health; and third, a perceived better quality of life for the farm family.

Other management factors may be considered regarding increased calf productivity. Wagner (1974) reported that supplementing calves through creep feed increases calf weaning weight, but the increase might not always be economically favorable. Each producer’s situation varies and factors such as forage availability, cow and calf genetics and price of supplement as well as delivery must be considered prior to supplementing.

The objective of this study was to determine the biological and economic viability of creep feeding spring-born, high-growth beef calves grazing with their dams on improved, irrigated pastures. The pastures were composed of either a monoculture of grass or of a mixture of grass and legumes when management-intensive grazing procedures are being used.

LITERATURE REVIEW

Management-Intensive Grazing

Management-intensive grazing is a pasture management system utilizing rotational grazing with short graze periods, typically 1 to 3 days. This stayle of pastoral agriculture requires disciplined care for both livestock and pasture, increasing management requirements, but potentially improving both livestock and pasture productivity. Gerrish and Morrow (1999), Clark et al. (1993), and Fales et al. (1995) all reported a positive correlation between rotational grazing and animal production; however, several studies indicate that there is little to no difference in animal performance resulting from rotational grazing or continual grazing (Hull et al., 1967; Bransby, 1991). This discrepancy is most likely due to improper management practices such as overstocking (Young and Newton, 1975), or lack of compensation for effects of season on pasture quality (Marshall et al., 1998).

Popp et al. (1999) found that grazing management can improve the nutrient content of grazed herbage by influencing plant maturity and yield. Rotationally grazed grass pastures are typically higher in quality of forage when compared to continuously stocked pastures (Walton et al., 1981; Sharrow, 1983). The reason for increased quality in rotationally grazed pasture is thought to be due to the uniform re-growth of the pasture when compared to the patchwork of grazed and ungrazed plants in continuously stock pastures (Popp et al., 1999).

Due to the lack of uniformity in seasonal yield in monoculture grass pastures, it is challenging for producers to estimate forage resources (Hermann et al., 2002; Leep et al., 2002). Monoculture pastures are also more susceptible to disease and environmental stress (Harmoney et al., 2001), which results in a stand that is more susceptible to the invasion of less productive species (Clark, 2001). Leep et al. (2002) showed that grasses that yield well as in monocultures typically perform well when mixed with legumes. Although introducing legumes into grass monocultures can improve pasture productivity and help minimize effects of environmental factors or disease, the practice does not necessarily lead to improved animal performance (Clark, 2001). Lauriault et al. (2005) stated that although legume inclusion may improve seasonal yield and distribution of grass pastures, balance between the grass and legume must be a goal of management to allow for future pasture and animal productivity.

Early research on forage mixtures versus monocultures regarding plant and animal productivity seemed to conflict. Brown and Munsell (1936) reported that increasing the number of grass and legumes in a mixture did not increase herbage yield in Connecticut. Conversely, studies in Utah indicated a positive relationship between the number of grass and legumes mixed in the mixture and their total yield (Bateman and Keller, 1956). Recently studies have shown that pastures planted with complex mixtures (six cool-season grasses and three legumes) maintain their complexity and after three years of intensive grazing management increased in productivity compared to corresponding monocultures (Sanderson et al., 2005).

Including forage legumes in grass pasture mixes has increased pasture and livestock outputs (Kunelius and Narasimhalu, 1983; Karnezos et al., 1994; Popp et al., 1999). Ruminants grazing legumes versus grasses tend to display faster growth and increased productivity per unit of land area (Campbell, 1981; Popp et al., 1999; Wen et al., 2002; Mouriño et al. 2003). Karnezos et al. (1994) found that lamb production per hectare was 23% greater for animals placed on wheatgrass-legume mixture compared to lambs grazing a wheatgrass monoculture. Campbell (1981) saw similar increases in a study comparing grass and grass-alfalfa pastures. Although alfalfa only made up 15 to 25% of the sward, the mixed pasture out produced the grass pasture by nearly 35%. Legumes also provide nitrogen fixing capabilities to the pasture system, which reduces the amount of fertilizer producers are required to apply on the pasture, and decreases production costs. Alfalfa (*Medicago sativa L.*), red clover (*Trifolium pratense L.*), birdsfoot trefoil (*Lotus corniculatus L.*) and white clover (*Trifolium repens L.*) are the most important forage legumes in the United States; unfortunately, there persistance under grazing has been somewhat limited in the past (Mouriño et al., 2003).

Although most grazing land in desert states like Utah is in rangelands, irrigated pastures are becoming increasingly important forage resources for livestock grazing mainly due to public land policies and public disagreement to private owners grazing on public land. As a result, there is growing interest in research in that regard. Waldron et al. (2002) conducted a study to determine which species of cool-season grass are best for intensively grazed pasture in where irrigation is limited. They found tall fescue, orchardgrass and meadow brome are best for use under conditions where water may be limited, especially if dry matter yield is the primary selection criterion.

Irrigated pasture usually results in much higher animal production per acre compared to rangelands. Achieving high production levels requires excellent grazing management with optimal application of water and fertilizer (Nichols and Clanton, 1985; Gray et al., 2001). Meek et al. (2004) determined that for management-intensive grazing, on improved irrigated pasture to be profitable, the carrying capacity needs to exceed 3.59 pair/ha. Water application is extremely important in maximizing pasture productivity. In a two-year study, Wiedmeier et al. (2005) found that by delaying irrigation from 7 to 14 days post grazing, pasture yield deceased 20%. Carrying capacity for the 7 day pasture was 3.83 pair/ha while the 14 day pasture was 3.20 pair/ha resulting in an unprofitable situation.

Tall Fescue

Tall fescue (*Festuca arundinacea* Schreb.) is one of the most important cool season grasses in the United States (Ball et al., 2003). It originated in Europe and was brought to North and South America due to high yield as well as tolerance to cold and drought (Buckner et al., 1979). In 1943 the most prominently known tall fescue cultivar, Kentucky 31, was released (Ball et al., 1987). Kentucky 31 originated in Kentucky and was widely planted due to its adaptability, persistence, length of growing season and capability in controlling erosion (Buckner et al., 1979). Today it is known as a high yielding perennial cool-season grass (Leep et al., 2002; Waldron et al., 2002) that is among the most stable in maintaining yield across varied irrigation levels (Lauriault et al., 2005)

Tall fescue is adapted to either acidic or alkaline soils with a pH ranging from 4.7 to 9.5 (Cowan, 1962). Its extensive root system allows it to survive in drought, but it is also capable of surviving in poorly drained soils (Buckner and Cowan, 1973). Production is high in the spring and autumn, with the possibility of growth continuing into the winter in some areas, though summer production can be reduced due to heat stress (Raines, 2004). Ball et al. (2002) found that tall fescue exhbits excellent autumn growth. In addition tall fescue stems cure well making it a prime candidate for being stockpiled for fall and winter grazing. Palatability has been reported to improve with stockpiling of Kentucky 31.

Originally tall fescue posed some problems to grazing livestock due to a symbiotic relationship with the endophytic fungus *Neotyphodium coenophialum*. These endophytes are found intercellularly in tall fescue tissue but do not seem to alter growth or morphology (Ball et al., 2003). This fungus aids tall fescue by producing alkaloids that reduce insect feeding and increase resistance to nematodes. Endophyte-infected tall fescue is more drought tolerant than most cool-season grasses, this adaption is due to its deeper more extensive root system (Malinowski and Belesky, 2000), endophyte-infected plants also have increased root hair length and decreased root diameter in tall fescue (Malinowski and Belesky, 1999). Emli et al. (1981) and West et al. (1988) reported that endophyte-infected plants can also exhibit greater osmotic adjustments compared to endophyte-free plants, allowing the infected plants to maintain higher turgor pressures.

Although harmless to the plant, this ergot alkaloid can cause toxicity in livestock. The endophyte causes three main disorders: fescue toxicosis, fescue foot, and fat necrosis (Ball et al., 2002). Fescue toxicosis causes decreased forage consumption that decreases weight gain. In addition cattle exhibit a rough hair coat, with decreased heat tolerance and increased body temperature. Fescue foot is characterized by tenderness in the extremity of the legs, elevated respiration rate and can lead to gangrene, which can result in the loss of hooves, ears or tails. Fat necrosis is caused by hard masses of fatty tissue forming in the abdominal cavity of the animal (Raines, 2004).

Due to these disorders associated with livestock grazing endophyte-infected tall fescue, plant breeders have developed strains of edophyte-free tall fescue. As the alkaloid is produced by the endophyte, and not the plant, endophyte-free tall fescue does not contain the alkaloids that negatively influence animal production. Hoveland et al. (1983) found that when cattle graze a strain of Kentucky 31 that is relatively endophyte-free, average daily gain and total beef production per ha were increased compared to endophyte-infected fescue. Unfortunately, the trade-off for higher animal performance in endophyte-free tall fescue is a reduction in plant performance such as total dry matter yield and stand persistance (Hill et al., 1991).

Alfalfa

Alfalfa (*Medicago sativa* L.) one of the oldest known domesticated forages, and has been used for more than 3,300 years (Bolton et al., 1972). Michaud et al. (1988) stated that alfalfa first originated in Iran and Central Asia and was brought to the United States by early colonists in 1736. The first attempts to establish alfalfa were unsuccessful. It was not until the mid-1850's that alfalfa was established in the western United States. Alfalfa is widely grown as a hay crop in the United States today, and is known for its aggressive nitrogen fixing capabilities as well as providing high-protein, low-fiber forage for livestock (Barnes et al., 1988). It is referred to as "Queen of the Forages" by many due to its high yield potential, high levels of protein, high quality, and broad adaption (Lacefield et al., 1987).

Dougherty and Absher (1987) suggested that grazed alfalfa should be managed similar to machine harvested alfalfa, with a "harvest" occurring, followed by a rest or re-growth state. Rotational grazing of alfalfa allows for higher quality pastures due uniform removal and re-growth in the vegetative phase of growth (Popp et al., 1999). Overgrazing alfalfa, which is more common in continuously grazed systems, weakens plant crown and roots and limits stand life (Cooke et al., 1965; Brownlee, 1973; Dougherty and Absher, 1987). Alfalfa should be grazed for short periods in the late bud or early bloom stage, typically 1 to 2 days, and then rested for 28 to 35 days (Gerrish, 1997). This rest period allows alfalfa to regrow and produce new crown buds (Dougherty and Absher, 1987).

Frothy bloat is a major concern when grazing alfalfa. It is thought that legume bloat results from the rapid ruminal degradation of certain soluble protein fractions that results in increased viscosity of the digesta. This results in the trapping of fermentation gases in stable foams or froths in the rumen that cannot be affectively eructed. The elevated ruminal pressure eventually results in suffocation if the pressure is not relieved through rumenectomy or administration of defrothing agents like poloxalene (Popp et al., 1999.) Cattle are more susceptible to legume bloat than other ruminants (Clarke et al., 1974; Colvin and Backus, 1988), and the susceptibility of individuals varies widely. It also seems to be a heritable trait influenced physiologically by factors such as saliva production and behaviorally based on forage selection (Cockrem et al., 1983; Howarth et al., 1984). Animals with a greater propensity to bloat have relatively high levels of fluid in the ruminal digesta (Cockrem et al., 1987). This seems to indicate that bloat-prone animals pass digesta through the rumen at slower rates compared to animals less prone to bloating (Okine et al., 1989). Bloat can be prevented when grazing alfalfa by a number of methods including gradually adapting cattle to grazing alfalfa, adding grasses to alfalfa pastures, not turning hungry animals out on lush alfalfa, treating livestock with antifoaming agents or providing mineral blocks containing surfactants (Howarth, 1988; Ball et al., 2002).

Over the past decade strides have been made to improve the characteristics of alfalfa for grazing. Grazing-tolerant alfalfa strains have become important to producers, based on their ability to withstand grazing pressure due to deeper crowns, and also on the reduction of the concentration of soluble proteins responsible for bloat (Smith and Bouton, 1993).

The demand for grazing-tolerant alfalfa has increased with the need for improved pasture productivity, which reduces annual cow costs. According to Berg et al. (1999) for an alfalfa cultivar to be considered a grazing strain it must tolerate diverse environmental conditions and heavy grazing (high stocking densities), as well as possess nutritional quality that will enhance animal performance for grazing and yet still reduce the incidence bloat.

To reduce bloat in alfalfa scientists investigated non-bloating legumes such as sainfoin and birdsfoot trefoil which possess thicker plant cell walls and higher tannin content resulting in lower incidence of bloat. Increasing cell wall thickness in alfalfa presumably reduces the rate of rumen bacteria entering the plant cells which decreases bloat potential (Howarth et al., 1982). Tannins bind and neutralize soluble proteins when released from cell contents, which reduces bloat (McMahon et al., 1999). AC Grazeland alfalfa is a cultivar of grazing alfalfa that reduces bloat when compared to hay-type alfalfas (Berg et al., 1999). This alfalfa cultivar was produced to have a lower initial rate of disappearance compared to Beaver alfalfa, it also has thicker cell walls and 15% less DMD compared to Beaver alfalfa (Berg et al., 1999). Berg et al. (1997) found that bloat was reduced 56.1% over a 3-year period when cattle were grazed on AC Grazeland alfalfa compared to Beaver alfalfa (a hay-type alfalfa cultivar).

Birdsfoot Trefoil

Birdsfoot trefoil (*Lotus corniculatus* L.) has been recognized for centuries as a desirable forage for cattle (Ellis, 1774). Although the knowledge of its benefits was widespread in Europe, the species had several characteristics that limit the commercial harvest of seed. Consequently it was mostly found in native ranges of Europe (Anderson, 1777). Around 1920 reports of birdsfoot trefoil being cultivated were published in France (de Rothschild, 1920; Schribaux, 1922). It is unknown when birdsfoot trefoil was introduced to the United States, but it was first naturalized in eastern New York, and along the western coast of the United States (Seaney and Henson, 1970).

Birdsfoot trefoil is an excellent legume for increasing production of permanent pastures and can be used as an alternative to alfalfa due to its non-bloating characteristics (Marten et al., 1987; Wen et al., 2002). Birdsfoot trefoil is better adapted than alfalfa to soils that may be slightly acidic. It tolerates drought better than most clovers and is more tolerant to wet and infertile soils that alfalfa (Seaney and Henson, 1970). It can also be used as a high-quality stockpiled forage (Collins, 1982).

Varieties of birdsfoot trefoil are categorized into three general groups: the prostrate or grazing type, the erect hay type, and the semi-erect type. Mott (1953) showed that grazing cattle productivity increased 57% on birdsfoot trefoil-bluegrass pastures under rotational grazing compared to pastures without trefoil. Previous research has recommended timothy and Kentucky bluegrass for pasture mixtures with birdsfoot trefoil (Chevrette et al., 1960; Schlough et al., 1977). Tall fescue is also an ideal grass to plant with trefoil (McGraw et al., 1989).

Birdsfoot trefoil’s non-bloating properties are thought to be due to the presence of condensed tannins. These tannins are polymeric flavonoid molecules found in a wide range of plants. Tanner et al. (1995) explains that tannins collapse the protein foams (froths) within the rumen in a dose-dependent manner. Tannins also increase the level of ruminal bypass protein (Barry and Duncan, 1984), which can increase the productivity of livestock in an environmentally sensitive manner (Robbins et al., 1998).

Stand persistence is the major limitation of birdsfoot trefoil. Henson (1962) and Beuselinck et al. (1984) both observed substantial stand losses, reporting 68 to 90% reductions within the first 2 years of establishment. The majority of stand loss occurs during the first year of grazing. Brummer and Moore (2000) noted a 54% decrease in birdsfoot trefoil in pastures during this time. Consequently, birdsfoot trefoil is sometimes described as a short-term perennial. Beside problems with stand persistence, birdsfoot trefoil is not easily established and does not compete well with many forage plants and weeds. Reseeding at regular intervals by allowing the plants to blossom and set seed helps alleviate these problems (Wen et al., 2002).

Creep Feeding

Calf age, weight, genetics, as well as environment all influence nutrient intake. Milk production peaks somewhere between 30 day (Cole and Johanasson, 1933) and 56 day (NRC, 1996) postpartum in beef cattle, and then slowly decreases throughout the remainder of lactation. This lactation curve is influenced by breed (Melton et al., 1967), nutrition (Neville, 1962) and calving season (Stricker et al., 1979; Morrow et al., 1988). For approximately the first 90 days of age calves are able to meet their nutrient requirement through milk alone (Maddox, 1965). After 90 days of age, calves rely on forage or available creep feed to make up the difference in required nutrients. In many instances, the decrease in cow milk production during mid and late lactation takes place as forage quality and/or quantity declines due to maturity or season (Cordova et al., 1978). In these situations, calf creep feeding can provide calves with the additional nutrition required to fully express genetic potential.

Creep feeding is a management strategy that can be used to help increase weaning weight and reduce grazing pressure on pastures and rangelands and improve feed intake during the post-weaning period. Creep feeding is accomplished by offering calves a supplement of either concentrate or green pasture, usually with the use of a creep gate large enough for calves to enter the feeding area but small enough that their dams cannot enter. Faulkner et al. (1994), Lardy et al. (2001), and Loy et al. (2002) all reported that creep feeding increases weaning weight. When creep feed supplements are high in starch, Cremin et al. (1991) noted that calves consume less forage, which allows for increased stocking densities. Myers et al. (1999) also reported that creep fed calves had less respiratory morbidity during the post-weaning period compared to calves not supplemented. Creep feed type can also influence carcass quality. According to Faulkner et al. (1994) calves creep fed a corn-based diet had higher marbling scores compared with calves that received a soyhull-based creep, even though average daily gain (ADG) was similar for both groups.

Cereal grains can decrease forage intake and digestibility (Hoover, 1986). Hess et al. (1996) determined that supplements made of highly digestible fiber, such as wheat bran may be more advantageous than grain-based concentrates when cattle consume roughages. Loy et al. (2002) and Soto-Navarro et al. (2004) also noted that creep feeding with fiber type creep supplements did not influence forage intake. Horn and McCollum (1987) found that wheat bran offers the potential of increasing energy intake without the negative effects sometimes seen with cereal grain supplementation. This may be one explanation for discrepancies in the literature regarding the effect of calf creep feeding on forage intake.

Wagner (1974) has shown that the use of these supplements might not always be economically advantageous. Often the cost of added gain off sets its value. Calf genetics limit the ability of the animal to grow even with ample nutrition. Environmental conditions that result in high forage quality and quantity, as well as high cow milk production often yield poor efficiency of added gain from creep as calves are already maximizing growth. It is important to note that creep feeds do not decrease calves desires for milk, which has often been postulated to reduce the suckling stimulus on the cows and therefore reduce the post-partum interval for rebreeding. Faulkner et al. (1994) and Cremin et al. (1991) found that creep feeds replaced forage consumed by the calves but milk consumption was identical for creep-fed and non creep-fed calves. The most efficient use of creep feed has been reported in instances of poor forage quality, low milk production in cows, or any other case that does not allow calves to express their genetic potential. As a general rule the price of the calves must be 10 times the cost of the supplement. Rasby et al. (1991) evaluated 18 trials in which creep grain was offered to calves. In this report it took anywhere from 1 to 14 kilograms of creep feed per pound of extra gain with an average of 5.23 kilograms. Limiting the amount of supplement offered is a more cost effective means of creep feeding.

Ansotegui et al. (1986) and Grings et al. (1995) demonstrated that calves select higher quality forage than there dams. Blaser et al. (1977) found that green creep grazing calves might be more economically feasible, allowing calves to graze ahead of their dams in a rotation grazing setting, or having pastures adjacent to the main pastures.

Another factor to consider prior to creep feeding is heifer development. Due to the increase in energy and weight gain, replacement heifers that are creep-fed are prone to wean lighter calves than heifers that were not creep fed, this is due to an increase in fat deposited in the secretory cells of the udder decreasing tissue development and future productivity (Martin et al., 1981). The number of calves weaned by a cow over the course of her life time is also reduced if the cow was creep-fed as a calf. This lack of productivity is thought to be caused by increased deposits of fat in the udder, which reduce function at maturity (Martin et al., 1981).

The literature is lacking regarding the effectiveness of creep feed of calves with a high genetic propensity for growth. All the aforementioned creep supplement studies dealt with normal growth calves and average milking mothers, most on native rangelands. Depending on the milking ability of the dams and the quality and quantity of the available forage, high-growth calves may not fully express their genetic potential without supplemental feed. Thus, due to the limited information on the biological and economic effectiveness of the practice of creep feeding such suckling calves, especially those grazing improved irrigated pastures need to be studied. In a review of the economical benefits of producing high-growth rate calves compared to normal-growth calves Bartchi (2005) (Table 1) shows that creep feeding high-growth propensity calves could have both a biological and economic improvement as long as feed prices are relatively low.

Table 1. Calculated biological and economic outputs comparing normal-growth rate and high-growth rate calves. (adapted from Bartchi, 2005)

	Normal growth calf		High growth calf	
	Non-creep	Creep fed	Non-creep	Creep fed
Beginning wt, kg	115	116	139	138
240-d wt, kg	252	283	337	379
Creep consumed, kg	0	552	0	400
Value of creep, $/kg	-	.08	-	.08
Total value of creep, $/calf	-	44.16	-	32.00
Market value of calves, $/kg	2.09	2.01	1.88	1.82
Market value of calves, $/calf	526	576	634	689
Market value of calves minus value of creep feed	526	526	634	657

MATERIALS AND METHODS

Pastures and Pasture Management

This experiment was conducted at the Utah Agriculture Experiment Station Improved Irrigated Pasture Project Research Center near Lewiston, Utah (elevation 1371 m). Two adjacent sprinkler-irrigated plots (3.9 ha, 182.88 x 203.30 m) were divided into 2 (1.95 ha) adjacent paddocks. Pastures were established in 2005 on Lewiston fine sandy loam soil. Prior to establishment, this farm ground was cropped for alfalfa and spring wheat. One pasture was a monoculture (MONO) of tall fescue ‘Seine’ (*Festuca arundinacea* Scherb.) and the second pasture was a mixture (MIX) of tall fescue ‘Seine’, alfalfa ‘AC Grazeland’ (*Medicago sativa* L.) and birdsfoot trefoil ‘Norcen’ (*Lotus corinculatus* L.). The MIX pasture composition was approximately 50% tall fescue, 37.5% alfalfa, and 12.5% birdsfoot trefoil seeded into alternating strips (3.65m x 192m) as depicted in Figure 1, repeated throughout the pasture. All seeding was done using a 3.65m John Deere disk press drill at a rate of 22.45 kg/ha seeds. Hay and green chop was harvested from the pastures in late summer 2006 to remove biomass. Pastures were grazed by cow-calf pairs and fall-weaned calves in 2007 to determine carrying capacity and grazing persistence of legumes.

The northeast corner of the monoculture pasture was already being used for a soil nutrient flow study using deferred grazing. Three 96x23 m strips were set up as a no graze, graze once, and graze twice format. Due to this arrangement the average grazing paddock for MONO pasture was 1.70 ha over the 4 grazing periods.

↑ 192 m ↓	Tall fescue 3.65 m ↔	Alfalfa	Tall fescue	Alfalfa	Tall fesuce	Alfalfa	Tall fescue	Birdsfoot trefoil

Figure 1. Seeding pattern for planting forages in MIX pasture.

Pastures were enclosed with six-wire permanent high tensile electric fences (1.27 m tall) on insulated wood posts surrounding the perimeter. Pastures were then subdivided into two paddocks using a semi-permanent steel electric wire on insulated steel t-posts. Fertilizer (33% Nitrogen- 50% urea, 50% ammonium sulfate) was applied to tall fescue only once prior to grazing in May and then following grazing in July, August and September. Fertilizer was applied using a 3.65 m drop spreader for the first application then applied using a 1.8 m drop spreader pulled behind an ATV. Pastures were irrigated using hand-line sprinkler sets running 12 hours which applied 10.46 cm of water. Fertilization and irrigation took place on the dates indicated in Table 2 and progressed across the pasture in a west to east manner following the cattle grazing period. Drinking water from the Lewiston city water system was supplied to cattle via a 2.54 cm internal diameter black polyethylene pipe running the length of the pasture. This piping was layed the length of the pasture along the south permanent fence and along the semi-permanent fence to supply water to cattle in the south paddocks and north paddocks of each pasture. Ball valves were placed every 30.48 m to allow attachment of a 15.24 m hose fastened to a 280 L portable water tank to allow cattle access to water anywhere on the pasture. Cattle were also provided with salt and mineral blocks to maintain adequate nutrition (Table 3). A portable creep feeder was constructed, for each supplement group, from a 1.83 m long trough feeder with 2, 3.66 m panels attached to each side of the feeder with a 1.83 m creep gate attached on either end to allow calves access to the supplement while excluding their dams.

Table 2. Dates and amounts of applied fertilization and irrigation for pastures.

Month	Day	Irrigation, cm	Fertilization (tall fescue only), kg/ha
May	21	-	50.52
June	12	10.46	-
July	8	10.46	37.05
	23	10.46	-
August	11	10.46	37.05
	26	10.46	-
September	7	-	37.05

Cow-calf pairs grazed the paddocks in a west to east direction. Each day cattle were given a new section of the paddock at 0800 h. Grazing paddocks were set using two electric polywire cross fences, one in front of the cattle and one lagging behind them, thus giving cattle a 2 day section to inhabit. Cattle grazed across the pasture in 25-30 day grazing periods. The grazing period length was designed so the west end of the pasture would be ready for re-grazing as soon as the cattle finished grazing to the east end of their paddocks. Daily paddocks were calculated using the previous year’s forage production and carrying capacity.

Cattle began grazing on May 30, when forage height averaged 30 cm, finishing the first grazing period on June 23 and 27 for MONO and MIX, respectively. Following the first grazing period cattle had to be removed from their pastures due to lack of re-growth, and were placed on a sainfoin-meadow brome mixed pasture until July 7 when forage growth was sufficient to return cattle to their designated paddocks where they remained duration of the grazing season. Due to the fluctuations in pasture production

Table 3. Composition of mineral blocks[1] provided to cattle while grazing.

Ingredient	Micro minerals mg/kg	Minimum weight %
Salt	-	97.000
Zinc	3500	.350
Iron	3400	.340
Manganese	2000	.200
Copper	330	.033
Iodine	70	.007
Selenium	90	.009
Cobalt	50	.005

[1] Trace mineral salt with Selenium, Morton International Inc.

when comparing the north and south ends of the pasture, cattle treatment groups were rotated from north to south on each grazing period (Table 4).

Pasture sampling and moving the cattle was completed by 4 different individuals based on a weekly schedule. The daily routine consisted of: 1) estimating the previous day's grazed stubble by walking the width of the grazed area and estimating average height based on correct observation; 2) in the next grazing paddock determine the average forage density and height by walking the width of the paddock and taking a clip-plot sample (1.63 m^2) of each forage at the height of the previous day's stubble and place in a pre-weighed paper bag; 3) cattle were moved by advancing the front polywire line the calculated distance and moving the back fence up the appropriate distance; 4) trace mineral salt blocks, water tanks and creep feeders were all moved into the days allotted paddock; 5) calf supplement was weighed and offered at approximately 1% of calf body weight. Weekly changes to the supplement amount offered were based on the average

Table 4. Cattle group grazing rotation on MONO and MIX pastures.

	MONO[1]		MIX[2]	
Grazing Period	North	South	North	South
Period 1[3]	MONOC[4]	MONOS[5]	MIXC[6]	MIXS[7]
Period 2[8]	MONOS	MONOC	MIXS	MIXC
Period 3[9]	MONOC	MONOS	MIXC	MIXS
Period 4[10]	MONOS	MONOC	MIXS	MIXC

[1] Pasture composed of Seine tall fescue monoculture.
[2] Pasture composed of mixture of Seine tall fescue, AC Grazeland alfalfa and Norcen birdsfoot trefoil.
[3] Grazing period from 5/30- 6/23 in MONO and 5/30-6/27 in MIX.
[4] Cattle grazing monoculture pasture without calf supplementation.
[5] Cattle grazing monoculture pasture with calf supplementation.
[6] Cattle grazing mixed forage pasture without calf supplementation.
[7] Cattle grazing mixed forage pasture with calf supplementation.
[8] Grazing period from 7/7- 8/1 in MONO and 7/7- 8/5 in MIX.
[9] Grazing period from 8/2- 8/29 in MONO and 8/6- 9/3 in MIX.
[10] Grazing period from 8/30- 9/24 in MONO and 9/4- 10/4 in MIX.

calf weight at the previous weigh period then multiplying the average daily gain from the previous period with the number of days since weighing took place; 6) Forage samples were weighed and placed in a forced-air oven at 60^{o}C for 72 hours to determine forage dry matter/ unit of area.

Cattle Management

A group of 24 spring-calving cow-calf pairs were stratified into 4 groups of 6 cows-calf pairs based on calf sex, weight and breed, cow weight, body condition score (BCS) and breed. Groups were then randomly assigned to each of the 4 paddocks: monoculture no supplement (MONOC), monoculture with supplement (MONOS), mixed forage no supplement (MIXC) and mixed forage with supplement (MIXS). Calf supplement consisted of corn hominy feed, wheat middlings and limestone (Table 5). All cows were between 5 and 10 years old, had an average weight of 584 kg. Cow and calf weights were taken unshrunk to avoid stress to the cow-calf pairs and to avoid influencing milk production due to not allowing cows access to water or feed for the normal 12 hours recommend when shrinking cattle. Cows also averaged a BCS of 5.4 and were crossbred consisting of primarily Black Angus, but mixed with Hereford, Gelbvieh, and Tarentaise. Calves were out of a terminal sire Charolais bull. Average weight was 158 kg (unshrunk) and the average age of the calves was 94 d when grazing commenced. In April, all bull calves were castrated, and all calves received vaccinations of Bovi-shield Gold 5 and Ultrabac 8 (Pfizer Animal Health), and Ralgro implant (Schering Animal Health).

Most of the cows were pregnant prior to being placed on the pastures due to the late start in the grazing season. However, to account for open cows, 2 mature bulls (1on MONO, 1 on MIX) were placed on the pastures to service cows. Bulls began the study in the MONOS and MIXS pastures, respectfully, and were rotated from paddock to paddock as standing heat was detected, when sampling pastures. Bulls spent equal amounts of time with each group of cows (3.5 weeks) and were removed from the pastures on July 20.

Following each grazing period and prior to a new period, cows and calves were weighed, cows given a BCS and checked for pregnancy. The BCS was determined by one experienced evaluator to limit discrepancy. The evaluator used the method described by Wagner (1984) to rate body condition using a scale of 1 to 9, with 1 being extremely emaciated and 9 being obese. Cattle were weighed unshrunk so care was taken to weigh cattle at approximately the same time of day (0800 h) at each weighing period. The cattle

Table 5. Creep supplement formula and nutrition estimates.

Ingredient	Formula % (as-fed)	Crude Protein%[1]	Mcal NE_m/ kg[1]	Mcal NE_g/ kg[1]
Corn hominy feed	72.06	11.50	2.27	1.57
Wheat middlings	25.04	18.40	2.03	1.37
Limestone	2.90			
Total	100	12.89[2]	2.14[3]	1.47[4]

[1] Based on NRC Feed Library.
[2] (corn hominy CP x % Formula) + (wheat middlings CP x % Formula).
[3] (corn hominy Mcal NE_m/ kg x % Formula) + (wheat middlings Mcal NE_m/ kg x % Formula).
[4] (corn hominy Mcal NE_g/ kg x % Formula) + (wheat middlings Mcal NE_g/ kg x % Formula).

on the north side of the designated pasture were weighed first due to ease of moving cattle groups.

Calves in MONOS and MIXS were offered a creep supplement grain consisting of corn hominy feed, wheat middlings and limestone (Table 5) ordered through Intermountain Farmers Association and processed at their North Region Feed Mill (Trenton, Utah). The consistency of the creep was a powder to improve palatability and decrease adjustment time typically seen for more processed feeds. The creep supplement did not arrive until June 9. Due to this delay, grazing period 1 was used to help acclimate calves to creep feed and feeders. In grazing periods 2 through 4 creep supplement was offered at approximately 1% of calf body weight. Daily samples of creep grain (10 g) were taken and stored in a freezer (-18^{o}C) for later analysis. Supplement level was monitored daily to ensure only trace levels were remaining in the feeder. Creep supplement was weighed (Ohaus ES series bench scale), a sample taken for later analysis and then grain was taken to creep feeders via an ATV. ATVs were also used to push creep feeders through the pastures during grazing periods.

Laboratory Analysis

After clip-plots were harvested in the pasture, samples were weighed to the nearest .01 g (Mettler PM 11 scale, Mettler-Toledo GmbH Laboratory and Technology). All forage samples were placed in a forced-air drying oven at 60^{o} C for 72 h. Samples were then ground on a Wiley Mill (Model 4, Thomas Scientific) to pass through a 1 mm screen, and then composited by species and cattle grazing group into week-long samples by taking 5 g of each sample. These samples were analyzed by near infrared spectroscopy (NIRSystem 6500, NIRSystems Inc.) to determine CP, NDF, ADF, Ash. The NIRS 2006 Consortium equation for grass hay was used for tall fescue and legume hay for both alfalfa and birdsfoot trefoil.

Creep supplement samples were composited over the course the final grazing periods and after freezing were dried in a forced-air oven at 60^{o} C for 72 h or until completely dry. These samples were then analyzed in the laboratory for DM (105^{o} C for 8 h), NDF (Komareck and Sorois, 1993), CP using Truspec N (LECO Technologies)

(Yeomans and Bremmer, 1991) and EE determined (ANKOM^{XT15} Extraction System, ANKOM Technology).

Statistics

Data were analyzed using the Proc Mixed procedure in SAS (SAS Inst. Inc., 1996). Carrying capacity, calf beginning and end weights, calf total gain and ADG, cow beginning and end weights and cow beginning and end BCS were analyzed as a 2 x 2 factorial design with pasture and supplement being fixed effects. Pasture CP%, TDN, NE_m, NE_g and DMD were also analyzed in Proc Mixed with pasture, group grazing (control versus supplement), and grazing period being fixed effects.

RESULTS AND DISCUSSION

Pasture Performance

Pasture grazing commenced on May 30, 2008, this was approximately 30 days after the original anticipated start date of the trial. Temperatures in April and May proceeding the grazing season were lower than the 30 year average. Precipitation levels were also lower than normal (Table 6). Mean temperature throughout the grazing season was 17.2 C where as the mean 30 year average for the same period is 20.3. Precipitation levels were higher during the grazing season compared to the 30 year average (11.8 cm versus 10.1 cm) as is illustrated in Table 6, however that is due to a wetter than average August (7.4 cm compared to 2.5 cm). The other 3 months of the grazing season (June, July, and September) only received 57 % of the average rainfall. Irrigation water was not available following grazing period 4 (September 7), which resulted in the study ending approximately 1 month earlier than planned due to lack of pasture re-growth.

During the first grazing period cow-calf pairs grazed their respective paddocks from May 30 to June 23 and June 27 for MONO and MIX pastures, respectively. Due to a delay in irrigation, pasture re-growth had not reached optimum levels (approximately 30 cm) and cow-calf pairs were placed on a mixed pasture of sainfoin and meadow brome. Irrigation following the grazing period began on June 12 (Table 2). Grazing beginning on May 30 resulted in a 13-day delay in irrigating. Sub-optimal re-growth the following grazing period, and most likely the season, coincided with findings by Wiedmeier et al. (2005) showing a reduction of forage produced by 20% when irrigation

Table 6. Temperature and precipitation levels for pre-grazing and grazing months[1] versus 30-year average[2].

	Pre-grazing Season		Grazing Season			
	April	May	June	July	August	September
Temperature, C	4.5	10.9	15.6	20.42	18.8	14.0
30 y Temperature, C	8.3	13.2	18.8	22.9	22.3	17
Precipitation, cm	2.3	5.0	2.1	2.2	7.4	.06
30 y precipitation, cm	5.4	6.1	2.2	1.9	2.5	3.5

[1] Lewiston Extension weather station.
[2] Daily station normal for temperature, precipitation, and heating and cooling degree days 1971-2000.

was delayed from 7 to 14 days post grazing. Thus the true forage production potential of this irrigated pasture system using management- intensive grazing was not illustrated in this study. Cattle returned to their paddocks on July 7 and remained there for the duration of the trial. Grazing periods consisted of 103 days for MONO paddocks and 116 days for MIX paddock much shorter than the anticipated 140 to 150 days.

Forage nutrient content was determined using NIR spectroscopy (Table 7). As expected, the CP concentration of the forage was approximately 6.4 % higher in the MIX versus MONO pastures (Table 7). The creep supplementation of the calves had no effect on the CP content of either the MIX or MONO pastures (P= 0.8651). Crude Protein levels among the two different pasture types would be expected to differ due to the presence of legumes in the MIX pasture. Alfalfa protein levels averaged 27% and birdsfoot trefoil CP level averaged 24%. Although tall fescue was constant on both MONO and MIX pasture (Seine), differences were detected in CP levels among the treatments. Tall fescue CP content for MIXC paddock was 16.5 % of DM which varied significantly when compared to 14.5 in MONOC (P= 0.017). A trend was detected comparing CP % of MONOS (14.9% of DM) and MIXC (CP 16.5% of DM) (P=0.078).

These differences are likely due to the nitrogen-fixing properties of legumes and similar to results reported by Chamblee and Collins (1988). Vicini et al. (1982) reported that though there may be differences in CP levels amongst paddocks, these levels are all above the minimum levels recommended by the NRC (1976), indicating protein is not a limiting factor for beef cattle production on these pastures. The more recent NRC (1996) also validates that CP was not a limiting nutrient regarding beef cattle production on irrigated pastures using management-intensive grazing.

Neutral detergent fiber (NDF) levels were higher among the MONO pasture when compared to the MIX pasture (Table 7). The highest NDF percentage was seen in the MONOC group at 54.5 % of DM followed by MONOS at 53.8% (P= 0.7205). Differences were detected between MONOC and both MIXC (43.0%) and MIXS (43.2%) (P= 0.0011 and P= 0.0012, respectively). MONOS also differed from both MIXC (P= 0.0014) and MIXS (P= 0.0014) (Table 7). So the presence of legumes in the MIX pastures resulted in a much lower forage NDF content compared to MONO pastures. The practice of creep feeding the calves had no effect on pasture NDF levels (P= 0.5591). Lower NDF levels are usually associated with high DM intake in cattle and higher energy levels.

Total digestible nutrients (TDN) did differ when comparing MONO to MIX pastures (P= 0.01) (Table 7), but there was a strong trend in TDN to differ among MIXC and MIXS, both differing from MONOC and MONOS by a range of P= 0.058 to 0.079 (Table 7).

Table 7. Nutrient content of paddocks grazed by cattle.

	MONOC[1]	MONOS[2]	MIXC[3]	MIXS[4]	SEM[5]	P-vlaue[6]
CP, %	14.5[b]	14.9[b]	21.3[a]	20.8[a]	0.3161	.0007
NDF, %	54.5[a]	53.8[a]	43.0[b]	43.2[b]	0.3201	.0001
TDN, %	63.3[a]	63.8[a]	67.4[a]	67.0[a]	0.6302	.0103
DMD, %	62.1[c]	62.4[bc]	65.5[a]	65.3[b]	0.4460	.0057
NE_m, Mcal/kg	1.42[a]	1.43[a]	1.55[a]	1.53[a]	0.0202	.0105
NE_g, Mcal/kg	0.83[a]	0.85[a]	0.95[a]	0.94[a]	0.0179	.0105

[1] Monoculture pasture of Seine tall fescue no supplement.
[2] Monoculture pasture of Seine tall fescue with supplement.
[3] Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil no supplement.
[4] Mixed Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil with supplement.
[5] Standard error of mean.
[6] P-value greater than f score.
[abc] Within a row means without a common subscript differ (P<.05).

Dry matter digestibility (DMD) was significantly higher for MIX paddocks compared to MONO paddocks with the exception of MIXS (65.3%) and MONOS (62.4%) which showed marginal significance (P= 0.0566) (Table 7). This is not unusual in view of the close relationship between DMD and TDN.

Net energy maintenance (NE_m) and net energy gain (NE_g) are generally calculated from TDN values using regression equations. So it is not unusual MIX pastures were higher than MONO pastures (P= 0.0105 for both NE_m and NE_g) (Table 7). At a given maturity level, legumes are generally more digestible and higher in energy then grasses. Similar to TDN, NE_m and NE_g differences between MONO and MIX pastures were seen with strong trend between MIXC and MIXS differing from MONOC and MONOS (range of P=0.0584 to 0.1083) (Table 7). These trends would have been more significant had a lower proportion of tall fescue and more legumes been planted in the MIX pastures. As was shown with regard to total DM yield (Table 8) and forage CP content, additions of legumes in the MIX pastures resulted in higher overall available energy concentration in grazed forage. This is extremely important as satisfying cattle energy requirements accounts for 80% of total diet costs.

Forage harvesting methods included appraising previous day's forage stubble height and clipping forage in the next-day paddock to this level to estimate cow-calf pair intake requirements. Due to variations in forage density, individual sampling technique and forage species, sampled forages did not accurately estimate cow-calf pair daily intake. Trampling of forage was also a factor in inaccurately appraising stubble height due to cattle behavior when entering a new paddock to graze. Cattle ran through strips of tall fescue, alfalfa and birdsfoot trefoil spreading out to graze alfalfa first. Grazing of birdsfoot trefoil followed and finally, in late afternoon cattle began grazing tall fescue. Trampling could be minimized by moving fence lines forward in small increments every few hours compared to giving cow-calf pairs access to the next day's entire paddock in the morning. Of course, moving the cattle in small increments would require more labor, which must be considered for economic viability.

The forage sampling method used did not accurately estimate the forage DM removed from the pastures by cow-calf pairs as estimated by NRC (2000) equations based on animal body size and performance, however, this method did accurately estimate the forage DM available for grazing. Table 8 shows the average forage production (kg/ha) of the different paddocks over the 4 grazing periods. MIXS and MIXC produced similar amounts of forage (kg/ha) 4491 and 4115, respectively (P= 0.580).

Table 8. Average pasture carrying capacity based on calculated cow-calf pair DM intake versus harvested forage over the four grazing periods.

	MONOC[1]	MONOS[2]	MIXC[3]	MIXS[4]	SEM[5]	P-value[6]
Forage needed, kg/ ha	1521[a]	1288[a]	1466[a]	1320[a]	39.06	.0169
Forage harvested, kg/ha	3153[b]	3057[b]	4415[a]	4491[a]	38.77	<.0001
carrying capacity, pair/ha	2.07[d]	2.38[c]	3.05[b]	3.37[a]	.0435	.0002

[1] Monoculture pasture of Seine tall fescue no supplement.
[2] Monoculture pasture of Seine tall fescue with supplement
[3] Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil no supplement.
[4] Mixed Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil with supplement.
[abc] Within a row means without a common subscript differ (P<.05).

MONOC and MONOS also produced similar, 3153 and 3057 kg/ha, respectively (P= 0.4324). However, when comparing forage production between the MONO and MIX paddocks, all comparisons showed a significant increase in forage production (kg/ha) by the MIX pasture (P= 0.0004 to 0.0006).

Several methods can be used to estimate the amount of forage DM removed from pastures by cows and calves. Probably the most accurate method is the inclusion of indigestible markers such as chromic oxide into the digestive tract of the cattle followed by frequent sampling of the feces and analyzing it for marker concentration. This method is relatively expensive and labor intensive and is usually applicable with only limited numbers of cattle. The raising-plate meter method estimates forage removed by measurements before and after grazing based on forage height and forage density. This method was unsatisfactory in the study by Bateman (2007).

The clip plot method used in this study is precise and accurate but is highly dependent on the training and judgment of the individuals using it. More training and frequent validation of all of the individuals involved with these estimates on this study would have improved precision and accuracy. Generally the clip-plot method we used over estimates the amount of forage removed by cow-calf pairs. However, based on the estimated NE_m and NE_g requirements of the cows and calves, the estimates were more accurate for the MONO than the MIX pastures. This is to be expected due to the complexity of measurements on MIX pastures that were composed of three very different forage species. This complexity was of course greatly reduced on the MONO pastures.

Based on the body weight and body weight gain of the cows and calves, estimates of the NE_m and NE_g requirements of the cow-calf pairs were made using NRC equations (1996, 2000). These estimates are presented in Table 9. Based on the estimated NE_m and NE_g concentrations of the various forages (Table 7), and that of the creep supplement consumed by the calves, the amount of forage required to supply the needed energy was estimated.

Average forage needed (kg/ha) (Table 8) was also calculated by determining cattle NE_m and NE_g requirements (Table 9) (NRC, 1996, 2000). Required forage (kg DM/ha) did not differ among treatments, but trends were noticed between MONOS (1288 kg/ha) and MONOC (1521 kg/ha) ($P= 0.0714$) and between MONOS and MIXC (1466 kg/ha) ($P= 0.1034$). Forage required kg/ha did not differ among any of the other groups or show any other trends. The difference in estimated intake between the MONOS and MONOC group is due to the availability of creep supplement (Table 12) for calves grazing MONOS paddock with their dams. Creep supplementation was offered at approximately 1% of calf body weight. Intake of creep supplement (1.47 Mcal NE_g/kg

DM) decreased the amount of forage required by a calf. This decrease in calf forage intake when consuming a corn-based supplement is similar to previous studies (Hoover, 1986; Hess et al. 1996). However, this is the first such study with terminal-sired calves grazing high-quality and abundant forage on improved irrigated pasture.

Carrying capacity was calculated by taking the total forage harvested (kg/ha) and dividing by the forage needed (kg/ha) over the course of the grazing season. This will then give the number of pairs that could be grazed per ha. The highest carrying capacity was observed in the MIXS group at 3.37 pair/ha followed by the MIXC group at 3.05 pair/ha. The difference of .32 pairs/ha between MIXS and MIXC was significant (P= 0.0404). Both carrying capacities for the MIX pasture were significantly higher than the carrying capacity for the MONO treatments. MONOS had a carrying capacity of 2.38 pair/ha that did differ from the carrying capacity of MONOC, which was the lowest at 2.07 pair/ha (P= 0.0405). Supplementation increased pasture carrying capacity when compared to control groups on both pasture types (P= 0.0054).

Pasture stocking rates were calculated based on last year's forage DM yield to be able to produce enough forage for 6 cow-calf pairs to graze through the summer. Based on this year's forage totals the MIXS pasture could have carried 6.57 pairs and the MIXC 5.95 pairs. These two paddocks were then stocked at optimal rates. Results for the MONO pasture indicate that MONOC's optimal stocking rate would have been 3.50 pairs and MONOS 4.05 pairs, which suggests they were overstocked. Calf ADG on both MONOC and MONOS (Table 10) do indicate that calf growth rate was similar to that of the MIX pasture. This would indicate that pasture carrying capacity for MONO paddocks was close to optimum and forage sampling technique varied among species with tall fescue samples being the least accurately sampled.

Increased total DM harvested (kg/ha) when comparing MIX and MONO pastures is in agreement with many studies comparing binary mixtures with monocultures (Bertelsen et al., 1993; Hoveland et al., 1995; Popp et al., 1999; Brummer and Moore, 2000; Guldan et al., 2000; Mouriño et al., 2003). These studies were conducted in the midwestern and eastern regions of the United States and foreign countries. Due to a lack of such research on improved, irrigated pastures in the Great Basin it is important that comparison be made in this region. In a study conducted in New Zealand, Marotti et al. (2001) compared the milk production of dairy cows grazing grass-legume mixtures planted in two different ways. One was the commonly used interspersed method where seeds are mixed together and then planted. The other method was to plant the different species in adjacent narrow strips similar to the method used on the MIX pastures in this study. A 28% increase in milk production was reported by cows grazing the plants in the adjacent strips presumably due to a lower maintenance energy requirement because cows were not expending as much energy searching for the plants they desired. This method of planting also aids in differential weed control and fertilization, and in observing what species animals are grazing. Cows and calves in this study always grazed the alfalfa first, then the birdsfoot trefoil and lastly the tall fescue.

Animal Performance

Cow NE_m varied over the course of the study and was calculated using the basic NE_m equation found in NRC 1996 with adjustment factors included for: body condition, lactation, heat stress, activity and fetal development (Table 9). Cow average NE_m requirement over all treatments for the duration of the study was 16.25 Mcal NE_m/d. With forage NE_m levels averaging 1.48 Mcal/kg DM over the course of the study among all treatment groups cows needed to consume 11 kg DM/d, which is well below the maximum DMI level (NRC, 1996) of cattle consuming these pastures. This would infer that all cattle were able to consume enough forage to maintain BW, BCS and milk synthesis (Table 10).

Calf NE_m was also calculated using NRC (1996) equations with adjustment factors included for heat stress and activity (Table 9). To calculate NE_g requirements calf sex must be taken into consideration. Net energy gain for steers is calculated using the following equation; $0.0493 \times (BW,kg)^{.75} \times (ADG,kg)^{1.097}$. The equation for heifers is $0.0608 \times (BW,kg)^{.75} \times (ADG,kg)^{1.119}$. The Mcals of NE_g required per calf is thus a function of body weight and ADG multiplied by various factors. This accounts for the difference in NE_g amongst treatment groups and periods. Due to stratification each group had 4 steers and 2 heifer calves. To calculate the average NE_g requirement for a calf in the respective groups, the NE_g equation for steers was multiplied by 4, added to the NE_g equation for heifers, which was multiplied by 2. This number was then divided by 6 to get an average for a calf in the group. Changes in BW of the cows and calves and BCS changes of the cow are presented in Table 10. Due to stratification procedures initial calf BW did not differ (P= 0.9748). Initial cow BW and BCS were also similar between treatment groups (P= 0.9425 and P= 0.6764, respectively). Calves grazing MIXS pasture

Table 9. Calculated NE_m and NE_g requirements for cow-calf pairs during four summer grazing periods.

	MONOC[1]				MONOS[2]				MIXC[3]				MIXS[4]			
Period	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Cow NE_m requirement[5]	17.4	17.4	16.3	13.9	17.0	17.3	16.2	14.0	16.9	17.5	16.5	14.3	16.8	17.5	16.5	14.1
Calf NE_m requirement[6]	3.7	5.3	5.7	5.5	3.9	5.3	5.8	5.7	3.9	5.2	5.9	5.8	4.0	5.5	6.1	6.0
Calf NE_g requirement[7]	5.3	5.2	3.3	3.1	5.5	4.9	4.9	4.1	4.5	5.6	3.0	5.7	5.3	5.7	5.7	7.3

[1] Monoculture pasture of Seine tall fescue no supplement.

[2] Monoculture pasture of Seine tall fescue with supplement.

[3] Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil no supplement.

[4] Mixed Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil with supplement.

[5] Based on NE_m calculation NRC2000.

[6] Based on NE_m calculation NRC 2000.

[7] NE_g Requirements for calves calculated using by $(((.0493 \times (BW,kg)^{.75} \times (ADG,kg)^{1.097}) \times 4) + ((.0608 \times (BW,kg)^{.75} \times (ADG,kg)^{1.119}) \times 2)) / 6$.

with their mothers had a significantly higher end weight (343 kg) compared to calves grazing MONOC (298 kg) (P= 0.0819). Calf end weights were not different when comparing supplement calves to control calves, regardless of pasture type (P= 0.2347), however, there was a difference in calf end weight when comparing MIX pasture calves (336 kg) to MONO pasture calves (306 kg) (P= 0.0272). Calf end weights among all other groups were not significant. Calves that received creep feed while grazing with their mothers on the MONO pasture did not differ in BW change compared to control calves (P= 0.7933). Similarly MIXS calves did not benefit from creep feeding when compared to MIXC calves with regard to BW change (P= 0.8488). The only different calf BW change detected was with regard to the MONOC and MIXS calves. MIXS calves gained 42 kg more than the MONOC calves (P= 0.082).

Average daily gain (ADG) among supplemented calves (1.51 kg) and control (1.36 kg) calves differed (P= 0.0654). These differences were seen when comparing supplemented versus non-supplemented calves, there was trend when comparing MIXS calves to MONOC (P= 0.234) no differences were observed between the other groups. The differences in calf end weight but not corresponding to ADG can likely be attributed to the difference in total days grazed between the two pastures (103 for MONO and 116 for MIX). The lack of response between grazing MIX and MONO pastures disagrees with many studies comparing binary mixtures of legume and grass with grass monoculture (Bertelsen et al., 1993; Hoveland et al., 1995; Popp et al., 1999; Brummer and Moore, 2000; Guldan et al., 2000; Mouriño et al., 2003). The increase in ADG

Table 10. Performance of cow-calf pairs grazing improved irrigated pasture as affected by treatment.

	Treatment					
	MONOC[1]	MONOS[2]	MIXC[3]	MIXS[4]	SEM[5]	P-value[6]
Initial Calf BW, kg	158[a]	156[a]	160[a]	161[a]	9.481	.9748
End Calf BW, kg	298[b]	314[ab]	329[ab]	343[a]	12.43	.0272
Calf BW Change, kg	138[c]	151[bc]	160[abc]	179[a]	7.935	.0048
Calf ADG, kg	1.35[a]	1.47[a]	1.39[a]	1.55[a]	.063	.0654
Initial Cow BW, kg	583[a]	584[a]	590[a]	584[a]	36.31	.9425
Cow BW Change, kg	72.4[a]	74.6[a]	95.5[a]	80.0[a]	11.30	.5640
Initial Cow BCS	5.2[a]	5.4[a]	5.3[a]	5.6[a]	.394	.6764
Ending Cow BCS	6.6[a]	6.8[a]	7.2[a]	7.4[a]	.311	.4305

[1] Monoculture pasture of Seine tall fescue no supplement.
[2] Monoculture pasture of Seine tall fescue with supplement
[3] Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil no supplement.
[4] Mixed Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil with supplement.
[5] Standard error of mean.
[6] P-value greater than f score.
[abc] Within a row means without a common subscript differ (P<.10).

energy than control calves. Lusby (1981) compared 31 different studies conducted throughout Kansas and Oklahoma, dealing with creep supplementation and found calves fed supplement gained approximately 0.17 kg/d more when compared to non-supplemented calves on native rangelands and meadows.

Similarly, cow ending BCS were different for the two pasture types. Cows grazing the MIX pasture had a higher BCS (7.29) when compared to cows grazing the MONO pasture (6.71) (P= 0.0751). No difference was reported among supplemented versus non-supplemented groups.

Average calf gain/grazing period did not differ (P= 0.18): 122, 133, 123, 138 kg/ha for MONOC, MONOS, MIXC, and MIXS, respectively (Table 11). Calves in

MONOS group received 217 kg/head of supplement over the course of the 4 grazing periods while calves grazing in the MIXS group received 237 kg/head of supplement.

Creep supplement used for MONOS and MIXS calves was determined by using NRC table values (Table 5). The majority of the creep supplement was composed of grain by-products, which vary in quality based on use and location. The nutrient content of the supplement was determined by wet chemistry in the laboratory (Table 12). Values for CP % and NDF vary in the supplement sampled when compared to the average values given by the NRC (1996), however, fat levels were similar as well as DM. Three different batches of creep supplement were ordered but no significant variation was observed between batches, which were ordered during the grazing season. Due to high forage protein levels, the reduced protein content of the supplement did not adversely affect calf protein requirements, however, care should have been taken to sample each batch after arrival to determine nutrient levels and modify the supplement formula accordingly.

Determining efficiency of creep supplementation was calculated by taking the kg of added gain and dividing it by the amount of creep supplement offered ((MONOS calf gain- MONOC calf gain)/ creep supplement offered). The efficiency of the creep supplement was determined using the same equation for MIXS calves using the respective values. In this study calves in the MONOS group had an efficiency of .058 while MIXS calves were 0.078. This means that for every kg of creep supplement offered calves gained 0.058 and 0.078 kg, respectively. This efficiency is also expressed in kg creep/ kg added gain (Table 11). For MONOS calves it required 17.3 kg of creep feed for

Table 11. Calf productivity as effected by treatment type and creep supplement efficiency.

	Treatment			
	MONOC[1]	MONOS[2]	MIXC[3]	MICS[4]
Calf gain, kg/ha	489	533	494	553
Average calf gain, kg	138	151	161	179
Creep supplement offered[5], kg/calf	-	216	-	237
Kg added gain/ kg creep	-	.058	-	.078
Kg creep/ kg added gain		17.3		12.8

[1] Monoculture pasture of Seine tall fescue no supplement.
[2] Monoculture pasture of Seine tall fescue with supplement
[3] Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil no supplement.
[4] Mixed Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil with supplement.
[5] Mixed at 72.06% corn hominy, 25.04% wheat mids, and 2.90% limestone.

1 kg of gain and MIXS calves required 12.8 kg creep feed for each kg of added gain. Creep efficiency in this study was lower than that seen in other studies (Crosthwaite et al., 1978; Lusby 1981). The high quality of pastures offered is most likely the cause of the lack of efficiency as calves were already performing near their genetic potential.

Terminal calves used in this study were sired by Charolais bulls with across-breed expected progeny differences (EPD) for yearling weight in the top 20% of the breed. Had higher growth potential bulls (i.e. the top 2% of the breed) been used an increase in calf genetic potential would have most likely resulted in increased weight gains and the more efficient use of creep supplement to reach genetic potential (Table 1).

Calf average daily DM intake was calculated using NE_m and NE_g requirements (Table 9). Intake was similar across all treatments MONOC (5.39 kg), MONOS (5.12), MIXC (5.74) and MIXS (6.12) when adding average daily creep intake to MONOS and

Table 12. Amount of total creep supplement offered per grazing period and nutrient analysis.

Pasture	Period	Supplement offered, kg		%DM	%CP	NDF	EE
MONOS	1	73		89.05	9.55	16.21	2.88
	2	344		88.90	9.54	17.18	2.96
	3	428		88.65	9.82	19.48	3.00
	4	460		88.65	9.71	18.54	2.85
	Total	1305	Average	88.81	9.65	17.85	2.92
MIXS	1	26		89.12	9.51	16.91	3.18
	2	343		89.25	9.73	18.19	3.08
	3	495		88.82	9.53	18.22	2.82
	4	557		88.98	9.68	19.57	2.90
	Total	1421	Average	89.04	9.61	18.22	2.99

MIXS intakes. Assuming cow milk production was similar, these results shows calves substituted palatable creep feed for forage intake, which is in agreement with other studies (Cremin et al.,1991; Tarr et al., 1994).

Economic Analysis

This study addressed questions concerning the economic viability of creep feeding terminal-sired calves grazing improved, irrigated pastures with their mothers. Profit/loss calculations show creep feeding was $70.20 cow/yr and $53.28 cow/yr less profitable for MIXS and MONOS compared to MIXC and MONOC, respectively (Table 13). Difference in profitability between MIX and MONO pastures is caused mainly by the need to apply fertilizer to all the forage in the MONO paddocks while only the tall fescue (50% of MIX forage composition) required fertilization. One disadvantage of planting the MIX pasture in adjacent strips was that nitrogen-fixing legumes could only help supply nitrogen to grass plants near the boarders of the strips. Had the MIX pastures been seeded using interspersed seeding method, use of commercial fertilizer would not have been necessary decreasing MIX pasture maintenance costs further and resulting in higher profit margins compared to the MONO pastures. Pasture feed costs or the value of the pasture forages was based on the cost of establishing and maintaining forages. This value was then divided by the grazeable kg DM/ha and multiplied by number of days grazed and dry matter intake of the cattle. Other feed costs include supplementing cattle with grass hay when they were not grazing on the pastures, in the case of this study October 1 to May 29, a much longer period than normal. Calf supplement costs were calculated based on $/kg. Non-feed costs included: veterinary medicine, machinery, labor, interest, improvements, depreciation, etc. To determine the non-feed costs, the average for producers in the state of Utah were used (Utah Ag Statistics). Grazing cattle on pastures is considerably cheaper than feeding cattle grass hay. Grazing cattle starting May 1 or continuing the grazing through October would have decreased feed costs and improved profitability, which is normally the situation in northern Utah. Also alternative grains or green creep feeding calves could be implemented to decrease supplement feed costs to calves.

The MIXC group was $84.22 cow/yr more profitable than MONOC and $137.5 cow/yr more profitable than MONOS. The difference in profitability can be explained by increased maintenance costs for the monoculture due to fertilization and lower total DM yields when compared to the MIXC paddock as well as calf supplement costs for MONOS. This economic analysis differs from that of Meek et al. (2004) in which tall

Table 13. Economic analysis for cow-calf production on improved irrigated pastures and total cost/year on four treatments.

	Pasture			
	MONO[1]		MIX[2]	
	Control	Supplement[3]	Control	Supplement
Pasture Feed Costs, ($/ pair)	105.17	92.02	64.81	56.67
Other Feed Costs[4], ($/ pair)	293.89	293.89	293.89	293.89
Calf Supplement Cost[5], ($/ calf)		93.26		101.56
Total Feed Costs, ($/ pair)	399.06	479.17	358.70	452.12
Non-Feed Costs[6], ($/ pair)	155.65	155.65	155.65	155.65
Total Annual Cow Costs, ($)	554.71	634.82	514.35	607.77
Profit/(Loss)[7] ($/ cow)	(13.19)	(66.47)	71.03	0.83
Profit/(Loss) ($/ha)	(16.06)	(93.06)	111.10	1.43

[1] Monoculture pasture of Seine tall fescue.
[2] Mixture 50% Seine tall fescue, 37.5% AC Grazeland alfalfa, 12.5% Norcen birdsfoot trefoil.
[3] Mixed at 72.06% corn hominy, 25.04% wheat mids, and 2.90% limestone.
[4] Grass hay diet (October 1 to May 29) at 1.1Mcal NE_m/kg and $.088/kg.
[5] Calf supplement $.429/kg.
[6] Average for cow-calf producers in Utah (Utah Ag Statistics).
[7] Calculated based on (market value[8] of calf - ranch breakeven value of calf).
[8] Based on calf prices for Salina Utah October 14, 2008.

fescue monoculture was more profitable then the mixed forages. The higher profitability seen in this study with the MIX pastures compared to the monoculture of tall fescue is likely caused by the exclusion of meadow brome, which comprised 25% of the mixed forage in Meek's study and does not produce well with tall fescue under any conditions. Meek et al. (2004) also used Empire birdsfoot trefoil with lower production potential than Norcen cultivar used in this study. Lastly, in the mixed pasture used by Meek et al. (2005) Alfagraze alfalfa was used compared to AC Grazeland alfalfa in this study. Unlike AC Grazeland alfalfa, Alfagraze was not selected for bloat resistance thus cattle could have been suffering from sub-clinical bloat in the study conducted by Meek et al. (2004).

When comparing the profit/loss per ha to determine the economic viability of a cow-calf operation on this land compared to using it for crop production, the trend remains similar for that of cow productivity for treatment groups. However, with MIXC being the greatest return ($/ha) 111.10 returns could have been much higher had forage produced on these pastures been harvested as hay and sold for use. This difference in income must be considered prior to turning crop land into grazing pastures.

As noted, creep efficiencies in this study were very low (0.058 and 0.078 for MONOS and MIXS, respectively). Creep supplement costs were relatively high ($0.429/kg) and this inefficiency in supplement gain as well as high feed costs resulted in decreased profitability for creep feed calves. For creep-supplemented calves to breakeven, creep efficiencies would have had to be 0.492 (MONOS) and 0.505 (MIXS), based on adjusted calf market price divided by creep supplement costs, compared with efficiencies of 0.034 and 0.041 (Table 11) for MONOS and MIXS, respectively. These high efficiencies (0.492 and 0.505) have been reported in other studies (Lalman and Gill, 2002), but are typically seen in calves supplemented on native rangeland pastures where forage quality is low or in other situations where dam milk production might be inadequate for calf growth needs.

IMPLICATIONS

With the treatments tested in this experiment it was apparent that biological performance and economic viability were not directly correlated. Calves that grazed mixed pastures with their mothers and received creep supplement (MIXS) had the highest end body weight, ADG, and total weight gain, with end body weight being significantly different from calves grazing a monoculture of tall fescue with their mothers and no creep supplementation (MONOC) (P= 0.0272) and average daily gain indicating a trend to differ (P= 0.234). However, cow profitability for the MIXS group was only $0.83 cow/yr. Due to high grain prices, creep supplementation was not economically feasible, nor did it increase total weight gain to levels of significance. Using pastures mixed with legumes and grasses yielded the highest profitability when creep supplementation was not used (MIXC) ($71.03/cow/yr).

For management-intensive grazing practices to be profitable on improved, irrigated pastures management must be willing to pay close attention to details. Water application must be consistent and as soon as possible post-grazing. High-quality forages need to be used that can withstand high stocking rates and stocking densities. In this study, mixed pastures of grass and legumes could stock 3.05 and 3.37 pair/ha on control and supplement paddocks where as pastures consisting of a monoculture of tall fescue could only stock 2.07 and 2.38 pair/ha on control and supplement paddocks, respectively.

Thus based on this study it is recommended that producers graze spring-calving cow-calf pairs on a mixed forage pasture and the use of creep supplementation, although capable of producing larger weaning weights, is economically unfavorable.

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