FORAGES AND PASTURES SYMPOSIUM: Improving efficiency of production in pasture- and range-based beef and dairy systems[1]

J. T. Mulliniks,*[2] A. G. Rius,* M. A. Edwards,* S. R. Edwards,* J. D. Hobbs,* and R. L. G. Nave†

*Department of Animal Science and †Department of Plant Science, University of Tennessee, Knoxville 37996

ABSTRACT: Despite overall increased production in the last century, it is critical that grazing production systems focus on improving beef and dairy efficiency to meet current and future global food demands. For livestock producers, production efficiency is essential to maintain long-term profitability and sustainability. This continued viability of production systems using pasture- and range-based grazing systems requires more rapid adoption of innovative management practices and selection tools that increase profitability by optimizing grazing management and increasing reproductive performance. Understanding the genetic variation in cow herds will provide the ability to select cows that require less energy for maintenance, which can potentially reduce total energy utilization or energy required for production, consequently improving production efficiency and profitability. In the United States, pasture- and range-based grazing systems vary tremendously across various unique environments that differ in climate, topography, and forage production. This variation in environmental conditions contributes to the challenges of developing or targeting specific genetic components and grazing systems that lead to increased production efficiency. However, across these various environments and grazing management systems, grazable forage remains the least expensive nutrient source to maintain productivity of the cow herd. Beef and dairy cattle can capitalize on their ability to utilize these feed resources that are not usable for other production industries. Therefore, lower-cost alternatives to feeding harvested and stored feedstuffs have the opportunity to provide to livestock producers a sustainable and efficient forage production system. However, increasing production efficiency within a given production environment would vary according to genetic potential (i.e., growth and milk potential), how that genetic potential fits the respective production environment, and how the grazing management fits within those genetic parameters. Therefore, matching cow type or genetic potential to the production environment is and will be more important as cost of production increases.

Key words: beef, dairy, forages, livestock efficiency, pasture, range

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INTRODUCTION

Historically, livestock producers have emphasized improving output-related growth traits through genetic selection focused on increased milk production, greater calf gains, and larger cow size. These growth and milk traits have been selected based on their output potential without taking into account the input cost to achieve this production level, which, to some extent, was due to low-priced feed inputs. However, as cost of production increases, total inputs and input costs need to be considered when selecting production traits. This is even more important because the financial costs associated with feed inputs is the greatest factor influencing profitability of cow–calf operations, with feed input accounting for over 63% of the variation in total cow costs (Miller et al., 2001). Therefore, it is becoming increasingly more important for livestock producers to match cow type to their given production environment to achieve optimal efficiency and profitability.

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[2]Corresponding author: jmulli@utk.edu

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In all business types, achieving optimal efficiency is key for sustainability. In livestock production, efficiency of grazing livestock not only has to be a combination of biological and economic efficiency but also needs to be focused on increasing longevity of the cow herd. However, the challenge of pinpointing efficiency traits in livestock production is that livestock in the United States graze under a wide variety of environmental and management conditions. These differences provide a challenging situation to have a universal cow efficiency equation. For example, efficiency in one environment does not necessarily imply efficiency in a different environment. Even with the wide variation in environments existing in the livestock industry, matching cow type to production environment and decreasing reliance on harvested feedstuffs through improved grazing management should be primary goals for increasing sustainable production of grazing beef and dairy cows.

REDUCING FEED COSTS THROUGH GRAZING

In the United States, pasture- and range-based systems and their modes of use are as diverse as its climatic conditions. These systems have been constantly modified due the changing nature of the livestock industry. Diverse production systems using pastures, harvested forages, and crop residues have evolved in different regions of the United States in response to soil and climatic conditions, competing requirements for land and water resources, and the relative cost and availability of feed grains (Reid and Klopfenstein, 1983).

In recent years, livestock production has been challenged with balancing rising costs of production with output measurements, such as calf weaning weight and milk production. To increase efficiency of grazing livestock production, additional advances must occur in reproduction, genetics, management, and nutrition (Dikeman, 1984). With that being said, there is a great opportunity to improve productivity of forage-beef systems with the use of currently available research. Such improvements involve choice of appropriate forage species and improved forage and range management to provide an appropriate, continuous supply of feed to efficiently meet the nutrients needs for the physiological functions of the animals involved (Hodgson, 1977).

Lower-cost alternatives to feeding harvested and stored feedstuffs have the opportunity to provide a sustainable and efficient forage production system to livestock producers. Previous research found that feed costs were the single greatest expense in livestock production systems (Miller et al., 2001). Grazing usually is the most cost-effective way to meet nutritional needs of beef cows. To illustrate this, low-cost producers have reduced feed costs by increasing the number of grazing days while decreasing the reliance on harvested feeds. In a profit model using performance and economic data from ranches in Oklahoma, Texas, and New Mexico, an increase in feed costs and inputs resulted in a decrease in profit because production was not improved (Ramsey et al., 2005). These researchers indicated that supplementing or feeding had to be done strategically to positively alter a production trait such as conception date. Therefore, grazing management during periods of forage growth needs to accommodate grazing in the fall and winter to decrease harvested and stored feed costs.

Increased costs associated with winter feeding have renewed interest in extending the grazing season in many regions of the United States. The aim of stockpiling forage is to manage a pasture to accumulate forage produced during the growing season to be grazed at a later time (Cuomo et al., 2005). Extending the grazing season with stockpiled forage in the fall and winter has been shown to be an economical way to maintain livestock (Poore et al., 2000) because it can reduce the need for supplemental hay and its associated costs (Hitz and Russell, 1998). Therefore, grazing management on a yearly basis needs to be focused on an appropriate stocking rate and/or grazing system to be able to increase grazing days and decrease production costs.

The selection of the appropriate stocking rate for a given environment is one of the most important management decisions (Holechek et al., 1999), regardless of the grazing system being used. Achieving the correct stocking rate can have the greatest impact on the profitability of grazing livestock operations. However, a problem frequently encountered by producers in the United States is the imbalance of standing forage and stocking rate to execute the lower-cost grazing strategies. To help improve this animal-to-forage balance, livestock producers have to continually manage and monitor herbage mass. This measurement can help producers assure that pastures are being well managed, avoiding under- and overuse by grazing animals (Nave et al., 2013). Stocking rates need to be high enough to capture profits during high-rainfall years yet low enough during drought years that feed costs are not ruinous. Due to market dynamics, producers are tempted to increase stocking rates to capture increased revenue as a result of the perception that increasing stocking rate increases profitability (Jones and Jones, 1997). However, in southern New Mexico, Holechek et al. (1999) suggest that conservative grazing involving between 30 and 35% forage utilization will give greater livestock productivity and financial returns than stocking at grazing capacity. In addition, Torell et al. (L. A. Torell, New Mexico State University, Las Cruces, personal communication), using the same conservative grazing parameters as Holechek et al.

(1999), found that adding flexible yearling enterprises increased average annual net ranch income by 14% in cow–calf operations during years of above-average rainfall.

A challenge for livestock producers is the seasonal variation in forage production, which can be a fundamental constraint on grazing system management. Pasture stocking rates and supplemental feed requirements are influenced by the dynamic balance between forage growth and the amount of herbage consumed by the animals (Nave et al., 2014). In some areas of the United States, pastures and rangelands may only have 1 yearly growing season for their forage base. In most of the northern United States, cool-season grass pastures are the forage base for beef cattle production, whereas warm-season forages are the predominant forage type in the south and southwest. These pastures produce most of their growth during their primary growing periods; consequently, their yearly carrying capacity is greatly dependent on stockpiled forages from that growing season. There can be considerable variation in growth rate of pasture and rangeland forages from year to year and season to season. Therefore, grazing strategies should allow flexibility in adjusting to changes in growth of the pasture grasses over the season. Therefore, meeting animal forage demand while maintaining a stable herd size requires that stocking rates be set at least 10% below the carrying capacity in an average year (Holechek et al., 1989).

Environmental and managerial constraints may dictate what and how well a grazing strategy works in certain production and environmental conditions. The advantages and disadvantages of rotational vs. continuous grazing have been widely researched in semiarid and arid rangelands (Briske et al., 2008). In semiarid and arid rangelands, Briske et al. (2008) argues that stocking rate is the main influence on forage production and availability with no differences in animal and forage production within type of grazing system. In environments that have multiple forage growing seasons or where weather is more predictable than arid and semiarid environments, such as in subhumid grasslands, rotational grazing systems may enhance productivity (Fales et al., 1995; Paine et al., 1999; Oates et al., 2011), allowing for increased forage utilization and reduced supplemental feeding. In using intensive and rotational grazing strategies in these subhumid environments, livestock producers may be able to increase carrying capacity while extending the duration of grazing higher-quality forages. However, the benefits of grazing systems and rotational grazing may not be well captured in experimental settings due to scale of experimental pastures. The application of research founded on small-scale experimental paddocks and applied in larger grazing pastures may not be entirely appropriate because ecological responses do not respond linearly (Fuhlendorf and Smeins, 1999). In addition, experimental grazing trials are developed to be more rigid in schedule to ensure integrity and repeatability of treatments compared with grazing management in production settings that can be more adaptively managed (Briske et al., 2008). To illustrate this, Jacobo et al. (2006) and Teague et al. (2011) both demonstrated the benefit of animal and forage production with combining adaptive management and rotational grazing in ranch enterprises over continuous grazing.

Grazing research has demonstrated that a set of potentially effective grazing strategies exist, none of which necessarily have unique properties of effectiveness (Briske et al., 2008; Wyatt et al., 2012). However, the effectiveness of differing grazing strategies is confounded with the ability of the livestock managers with effective management and planning decisions. As indicated by Teague et al. (2013), grazing trials have focused least on the most important feature of the grazing management system, the human element. If progress is made in improving efficiency of grazing livestock, researchers must do a better job at integrating research ideas and typical grazing management.

Overall, successful grazing management depends on the integration of research and management experience. Due to the complexity of grazing management and ecological responses, flexible and adaptive management is a necessity in sustainable forage management. As defined by the National Ecological Assessment Team (2006), adaptive management is a model that uses a process of planning, doing, and learning to improve our knowledge of the ecology of the system and allow us to evaluate both the success of management practices, in addition to the validity of assumptions underlying management direction. As adaptive management progresses, livestock managers develop a greater understanding of their system and which techniques work best under their particular management goals and environmental conditions (Reever-Morghan et al., 2006). However, if adaptive, flexible management is not used, static management in the face of a dynamic problem will not yield the most favorable results (Boyd and Svejcar, 2009).

COW TYPE AND ENVIRONMENT

Management Strategies to Improve Lifetime Efficiency

Research has shown the benefit of management strategies that improve lifetime efficiency. Most of this research has been focused on management strategies during the heifer development period in extensive, semiarid environments (Endecott et al., 2014). In New

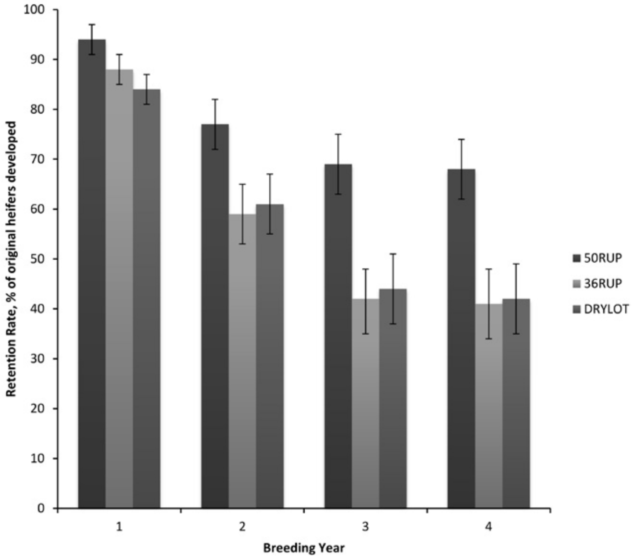

Figure 1. Retention rate of heifers grazing native dormant range with 2 types of protein supplementation (36% CP cottonseed meal base supplement fed 3 d/wk supplying 36% RUP [36RUP] and 36% CP supplement fed 3 times/wk supplying 50% RUP [50RUP]) or fed a growing diet in a drylot. Values shown in breeding yr 1 are heifer pregnancy rates. Breeding yr 2 through 4 are proportion of the original heifers treated that were remaining at end of breeding in yr 2, 3, and 4. Retention tended (*$P >$ 0.08) to differ among treatments in breeding yr 1 and 2 but was greater for 50RUP than 36RUP and corn silage diet fed in drylot to gain 0.68 kg/d [DRYLOT] cows in breeding yr 3 and 4 (**$P < 0.01$). Adapted from Mulliniks et al. (2013).

Mexico, Mulliniks et al. (2013) showed the impact that programming animals to fit their given environment and how nutritional inputs and even type of supplement (i.e., low-RUP supplements vs. high-RUP supplements) can have on cow herd longevity. These researchers developed yearling beef heifers on native range receiving 1 of 2 different protein supplements (low RUP vs. high RUP) or developed in a feedlot. During the developmental treatment period, heifers developed in the feedlot had increased ADG (0.69 kg/d) from the initiation of treatments to the start of breeding compared with range-raised heifers consuming low-quality range with protein supplementation (0.26 kg/d). Gross returns were greatest for the high-RUP supplemented range heifers and least for heifers developed in the feedlot, and feed costs were greatest for feedlot-developed heifers. Compared with feedlot-developed heifers, net returns were US$99.71 and $87.18 greater per heifer developed for the high-RUP and low-RUP supplemented heifers, respectively. Even with the low ADG until breeding, retention rate through 5 yr of age for range-developed heifers fed a high-RUP supplement was 68% compared with 41% heifers fed a lower-RUP supplement and 42% for heifers developed in a feedlot (Fig. 1). This study indicated the short- and long-term impact that developing heifers to fit their production environment instead of targeting certain BW or ADG.

Researchers from Montana and Nebraska have also shown the long-term benefit of developing heifers by restricting gain (Funston and Deutscher, 2004) or intake (Roberts et al., 2009). In Montana, developing heifers on lower levels of nutrient input (80% of ad libitum intake) improved efficiency and enhanced longevity in the cow herd up to 5 yr of age (Roberts et al., 2009). In Nebraska, restricting heifer gain during heifer development resulting in similar pregnancy rates through the fourth calf as heifers developed at an increased ADG; however, cost of development was decreased and researchers suspected lifetime nutrient requirements may be decreased by developing heifers at the restricted gain (Funston and Deutscher, 2004). Similarly, in a 10-yr study in Oklahoma, Hughes et al. (1978) reported an increase in retention rate of beef cows on a lower plane of nutrition (77% retention rate) compared with greater levels (63 and 67% retention rate for high and very high nutrition).

Flexible and opportunistic strategies are necessary for successful management in variable environments, which have to be ingrained in a clear understanding of the challenges facing the grazing animal and its natural abilities to meet and adapt to these challenges (Launchbaugh and Hunt, 2000). However, exploiting the natural ability of livestock to lose or gain weight in response to nutrient supply of lower-quality forages is an alternative strategy to manipulating the production environment and allows the cow to offset the nutritional deficiency of the forage, which may consequently enhance both economic and biological efficiency. For example, Mulliniks et al. (2012) illustrated over a 6-yr period that not all animals need to be fed to achieve a target BCS, which allows for utilizing body storage as a nutrient source during periods of energy deficiency to maintain reproductive competence. The cows from this study were offspring of cows that were managed in a low-input ($35 to 50/(cow·yr) in feed inputs) production system for multiple generations. Therefore, preplanned management strategies to allow for BW loss during periods of moderate feed restriction followed by nutrient realimentation during period of increase nutrient supply will result in improved efficiency of energy utilization (Freetly et al., 2008).

Implications of Increased Genetic Merit for Milk Production

The continual increase in selection for milk production has resulted in dairy and beef cows that are under greater nutritional stress in critical physiological periods, such as early lactation, that will ultimately reduce reproductive traits (Mulliniks et al., 2011; Dillon et al., 2006). The economic value of reproduction is reported to be 5 times greater than growth or milk traits in beef cattle (Trenkle and Willham, 1977); however, livestock

Table 1. Comparison in cow–calf performance in Tennessee and New Mexico[1]

Measurement	Tennessee	New Mexico	SEM	*P*-value
Cow BW, kg	623	535	10	<0.01
24-hr milk production, kg/d	11	6	2	0.04
Pregnancy rate, %	88	96	3	0.02
Calf BW, kg				
55-d weight	61	63	3	0.78
205-d weight	273	255	5	0.03
Kilograms weaned per cow exposed	240	245	4	0.58

[1]Data generated from the University of Tennessee's Plateau Research and Education Center in Crossville, TN, and the New Mexico State University Corona Range and Livestock Research Center in Corona, NM (J. T. Mulliniks, unpublished data).

producers are often more concerned with output traits such as weaning weight of calf or milk production than with reproductive efficiency or longevity. In some environments, selection for increased milk potential may not be fully expressed due to limited nutrient supply by the forage system (Brown et al., 2005; Brown and Lalman, 2010). In addition, as cow BW increases, there is a greater constraint on the expression of genetic potential for milk production (Brown et al., 2005). To illustrate production efficiency differences in distinct environments and management goals, data sets from New Mexico and Tennessee were used. Annual precipitation at the research station in Tennessee is 1,397 mm with an estimated 6,734 kg/ha of annual standing forage (G. E. Bates, University of Tennessee, Knoxville, personal communication). Beef cows in the Tennessee data set have been selected for high genetic merit for growth and milking potential. Tennessee manages cows in a high input system with high stocking rate (0.8 ha/cow) and high nutritional input (>100 d of full feeding of hay, haylage, or corn silage). In contrast, New Mexico relies heavily on yearlong grazing with no harvested feedstuffs fed, minimal supplementation, and low genetic potential for milk. Annual precipitation in New Mexico is 370 mm with an annual standing forage crop of 400 to 500 kg/ha (A. Cibils, New Mexico State University, Las Cruces, personal communication). In both states, milk production was estimated with a modified weigh–suckle–weigh technique using a milking machine on approximately d 58 after parturition. Cow BW at weaning were greater ($P < 0.01$; Table 1; J. T. Mulliniks, unpublished data) in Tennessee than in New Mexico. Twenty-four-hour milk production was nearly 2-fold greater ($P = 0.04$) for cows in Tennessee compared with New Mexico. However, 55-d calf BW did not differ ($P = 0.78$) between the 2 environments. Calf BW at weaning (205-d BW) was greater ($P = 0.03$) in Tennessee; however, that increase was only 18 kg with a 2-fold increase in milk production. Some of this decrease in efficiency of converting milk to calf gain could be due to calves from lower-milking cows tending to substitute milk for forage to meet their nutrient requirements (Montano-Bermudez et al., 1990). Although nutritional supply during the breeding season is much greater in Tennessee, pregnancy rates were less ($P = 0.02$) in Tennessee than in the nutrient-restricted environment of New Mexico. Kilograms of calf weaned per cow exposed to breeding bulls has been suggested to be a key indicator of cow efficiency. In these 2 environments, calf weaned per cow exposed was not different ($P = 0.58$) among production settings. However, input cost to achieve these production measures has to be taken into account in calculating efficiency differences. Current annual cost of production in Tennessee is $800/cow (A. Griffith, University of Tennessee, Knoxville, personal communication) whereas New Mexico is roughly half that at $440/cow (L. A. Torell, New Mexico State University, Las Cruces, personal communication). In addition, Mayfield (2012) reports that longevity in the Tennessee herd was only 3.5 yr, which is quite a bit lower than the 61% retention rate of the heifers remaining in the herd after 5 yr of age (Mulliniks et al., 2013). To be profitable, production females must remain in the herd beyond their breakeven age of 5 yr of age or remaining females have to compensate for cows culled early (Snelling et al., 1995). However, longevity of cows is somewhat overlooked in genetic evaluation programs. Therefore, taking in account the cost of production difference and longevity, the economic efficiency and production efficiency in Tennessee is substantially less than in New Mexico. Granted, cows grazing endophyte-infected tall fescue can lead to decreased animal performance due to the ergot alkaloids present in the plant (Porter and Thompson, 1992); however, in semiarid environments such as New Mexico, cows will graze low-quality forages (<7% CP and >80% NDF) for 9 mo of the year. All environments in which livestock are used for production bring a different environmental challenge or combination of challenges (i.e., heat stress, cold stress, endophyte-infected fescue, nutrient restricted environments, etc.); however, management within these given environments needs to be focused on selecting cows for that specific environment and associated challenges and not manipulating environments for a specific cow type. These 2 environments and management practices may illustrate the differences in selecting for growth traits and selecting for animals that fit their environment and how these genetic selections affect efficiency of grazing livestock.

In dairy cows, developing lactating cows that fit their respective environment and management style is as crucial as with beef cattle. Macdonald et al. (2008) compared 3 strains of Holstein-Friesian grazing under different feed allowances. The strains used in this experiment were 1) a 1970s strain of New Zealand Friesian with high genetic potential for combined yield of fat and protein for 1975 but low genetic potential relative to the genetic capacity of strains in 1998, 2) a 1990s strain of New Zealand origin and selected for high genetic potential of combined fat and protein yield, or 3) a 1990s strain of North American origin that was selected for high genetic potential of combined fat and protein (**NA90**). Across strains, a range of feed allowances were allocated to each strain, ranging from moderate feed restriction up to generous feeding levels (4.5 to 7.0 t of DM/cow per yr). Even at the greater feed allowances, the NA90 cows had shorter lactations and reduced fertility, leading to lower profitability and lower feed conversation efficiency. Ultimately, under the current farm systems used in this study, environmental and managerial practices would have to be modified to allow the NA90 strain of cows to survive in the New Zealand grazing management system, where forage makes up nearly 100% of the diet. These authors concluded that dairy cows with high genetic potential selected from systems of generous feeding scenarios may be more severely affected by feed restrictions than cows of high genetic potential that were selected in pasture-based grazing systems.

Higher-milking cows are expected to require higher levels of feed energy to maintain that level of milk production (NRC, 2000). Research at the Meat Animal Research Center in Clay Center, NE (Ferrell and Jenkins, 1984, 1985), has shown that efficiency of energy use is reduced in higher-milking beef cows. This research indicated that decrease in efficiency is due to increased size of visceral organ mass (i.e., heart, liver, kidney, rumen, and small and large intestines). In addition to the decreased energy utilization, Brown et al. (2005) reports that even with increased genetic potential for milk production, nutritional environments may suppress full expression of the selected level of production. Therefore, environments will have to be manipulated with additional harvested feedstuffs for that given cow type to succeed or meet their genetic potential as suggested by Macdonald et al. (2008) with their New Zealand grazing dairy system. In addition, financial records from beef ranches in Oklahoma, Texas, and New Mexico indicate that increased feeding of harvested feedstuffs to livestock increases per unit cost without improving production (Ramsey et al., 2005).

SUMMARY AND CONCLUSIONS

One limitation of most data sets that may illustrate differences in efficiency is the lack or limited number of long-term studies in the literature. However, grazing management strategies need to be focused on decreasing feed costs by extending the grazing season through improved grazing and forage management strategies. To achieve this, grazing management needs be strategic, well planned, and integrated with science-based management decisions. Selection of production traits that exceed the capacity of the production environment will lead to decreased efficiency in grazing livestock schemes. Overall, increasing efficiency of livestock grazing range or pasture settings has to be focused on managing and selecting animals that fit their given environment and management that decreasing reliance of harvested feedstuffs through grazing management and forage management systems.

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