

The effect of precipitation received during gestation on progeny performance in *Bos indicus* influenced beef cattle

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ABSTRACT: The objective of this retrospective study was to determine the effect of precipitation level during key fetal development periods on beef progeny performance. The hypothesis that was precipitation level during different periods of gestation would program subsequent calves for an environment similar to that experienced in utero resulting in altered growth and reproductive performance. Data were collected on Brangus cows ($n = 2,429$) over a 46-yr span at the Chihuahuan Desert Rangeland Research Center. Recorded precipitation values were used to calculate average precipitation associated with total gestation (April–March), early gestation, (July–September), and late gestation (December–February). These values were used to classify treatments: low (z value ≤ -1.00), average (z value -0.99 to $+0.99$), and high (z value $\geq +1.00$) for each time period. Calves experiencing high precipitation throughout gestation had heavier

body weight (BW) at birth ($P = 0.02$), weaning ($P = 0.05$), and adjusted 205-d BW ($P = 0.04$) than those experiencing low precipitation. Female progeny gestated during low precipitation throughout gestation were more likely to remain ($P < 0.0001$) in the herd and calve after the age of 8 yr when compared to heifers experiencing high precipitation levels in utero (38% vs. $16\% \pm 5\%$, respectively). In addition, a greater percentage ($P < 0.0001$) of heifers experiencing low precipitation levels during the early gestation period produced a calf within the herd after 8 yr of age. Similarly, calves experiencing low precipitation during those same time points also had a greater number of calves while in production ($P < 0.0001$) when compared to the average and high precipitation groups. These results indicate that selection of heifers exposed to lower than average precipitation levels in utero may result in increased herd retention and productivity.

Key words: beef, fetal programming, longevity

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INTRODUCTION

Cattle producers are dependent on adequate precipitation for sustaining herds. Nutrient composition of range pastures fluctuates with time of year and annual precipitation (Murphy, 1970; Marshal

et al., 2005). Variability in precipitation can cause negative effects on forage growth and quality (Oelberg, 1956). Forages undergo a translocation process under normal precipitation circumstances, which pulls nutrients from the root network into the stem and leaf system dictating mineral and nutrient quality. During times of prolonged drought stress, this process is hindered and such compounds cannot be properly allocated through the plant creating a dormant physiological status preventing

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plant growth. This relationship is especially critical in desert areas where precipitation values are generally low or seasonal. Therefore, drought can represent a major economic burden to cattle producers, with animal performance being altered due to low nutrient availability (Scasta et al., 2015).

Stresses experienced in utero affect fetal growth and development through a process referred to as fetal programming (Barker et al., 1993). Investigators have well documented that maternal nutrient intake during gestation can alter progeny calf health and performance (Corah et al., 1975; Martin et al., 2007; Funston et al., 2010). Decreased dam nutrient intake can also influence female offspring puberty attainment and pregnancy rates (Sasser et al., 1988; Selk et al., 1988). Although the influences of nutrient intake in gestating range cattle have been reported, little is known regarding the direct effects precipitation levels, and thus forage production may have on fetal growth and programming. The objective of this study was to determine the effect of precipitation level during specific time points during gestation on subsequent progeny growth and lifetime performance of female progeny.

MATERIALS AND METHODS

Precipitation data and cattle performance data on 2,429 Brangus cows were collected from 1969 through 2015 at the New Mexico State University Chihuahuan Desert Rangeland Research Center (CDRRC; Las Cruces, NM). All animal procedures and facilities were approved by the New Mexico State University Institutional Animal Care and Use Committee.

Precipitation Data

Precipitation data were gathered and compiled from 25 standard rain gauges located in subdivided pastures. Precipitation averages were calculated for each month and parameters set to analyze a time frame for the first trimester of gestation, which coincides with early gestation (July–September), late gestation (December–February), and total duration, which would account for a production

year from breeding to calving (April–March; Figure 1). Using the methods reported by Palmer (1965) a z value was given based on the overall precipitation mean for each time period, creating three classes of treatments defined as low (“Low”; z value ≤ -1.00), average (“Avg”; z value -0.99 to $+0.99$), and high (“High”; z value $\geq +1.00$). Standard deviation (σ) was calculated using the overall precipitation variance from the 46-yr period using the following formula:

$$\sigma = \sqrt{\frac{\sum^n (x_i - \mu)^2}{n}}$$

A z value was determined using the formula next, for each designated period. Each period mean was calculated based on the calf’s birth year.

$$Z = (\bar{X} - \mu) / \sigma$$

Z represents the z value and \bar{X} is the mean precipitation for the period specific to year and μ represents the overall mean precipitation for the period over the 46-yr span.

Cattle Data

Cow performance data obtained from the CDRRC included cow weaning body weight (BW), yearling BW, and corresponding calf’s weaning BW, yearling BW, adjusted 205-d BW and calf sex. Cows ($n = 2,429$) were stratified by production year and calf data were grouped and averaged together by production year. Progeny data included calf weaning BW, yearling BW, and adjusted 205-d BW were analyzed within year. Likewise, age at time of first calf, productive years in the herd, number of total calves, and calving 8 yr of age was evaluated for female progeny. Treatments were applied to animal records based on precipitation levels during the early gestation, late gestation, and total time periods.

Statistical Analysis

Data were analyzed using the PROC MIXED and GLMMIX procedure of SAS (SAS Inst. Inc.,

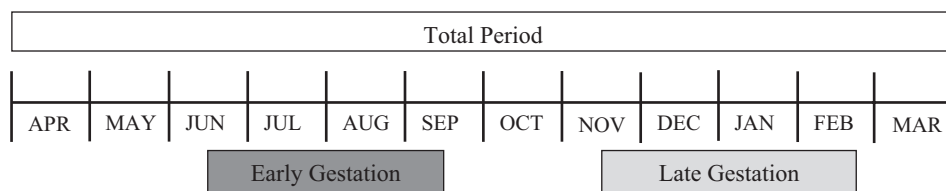


Figure 1. Treatment periods throughout 1 yr of a cow’s production cycle. Total period encompasses breeding to calving, early gestation corresponds with conception through the first trimester, and late gestation accounting for the last trimester of pregnancy that parallels with when forage quality is typically the lowest for the year.

Cary, NC). For reproduction and growth performance, cow was considered the experimental unit with precipitation treatment and year as the fixed effects. Calf birth BW, weaning BW, and adjusted 205-d BW means were separated using the LSMEANS procedure of SAS and *P* values less than or equal to 0.05 were considered significant and tendencies were considered at a *P* value greater than or equal to 0.05 and *P* value less than or equal to 0.10. There were no interactions observed between treatment groups ($P > 0.05$), therefore, only the main effects will be reported.

RESULTS AND DISCUSSION

Average precipitation for the CDRRC during the reporting period (1969–2015) was 168 ± 13 mm (Figure 2). During the 46-yr span Avg precipitation accounted for 63% of years, High precipitation represented 22% of years, and Low precipitation accounting for 15% of the designated years. Traditional precipitation patterns in the southwest result in 50% of total precipitation during the designated monsoon season from July through September, with very little precipitation during the off-season; although it should be noted that winter precipitation can account for up to 30% of total precipitation (reviewed by Sheppard et al. [2002]). However, the location of the experiment station in the Chihuahuan desert typically receives

very little snowfall/snowpack and thereby receiving much less than the expected 30% of total precipitation levels during these months. Monsoon season rains, coinciding with the early treatment period account for 53% of precipitation reported during the total treatment period. However, precipitation during the late gestation period (December through February) only accounted for approximately 17% of all precipitation received.

Calf Performance Data

Calf growth performance is reported in Table 1. Calves experiencing low precipitation throughout gestation had decreased ($P \leq 0.05$) birth and weaning BW compared to calves exposed to high precipitation levels while in utero. In addition, calves had greater ($P = 0.04$) weaning BW and adjusted 205-d weaning BW ($P = 0.03$) if precipitation levels were high during the early gestation period when compared to the low-treatment group. Previous research conducted by Gatson et al. (2016) investigated dry and wet conditions on beef cattle performance and revealed similar BW differences from cool season dry and wet classes of calves entering the feedlot with normal and wet classes being heavier. The effect precipitation has on forage yield would indicate that cool and wet conditions offer a greater plane of nutrition for grazing

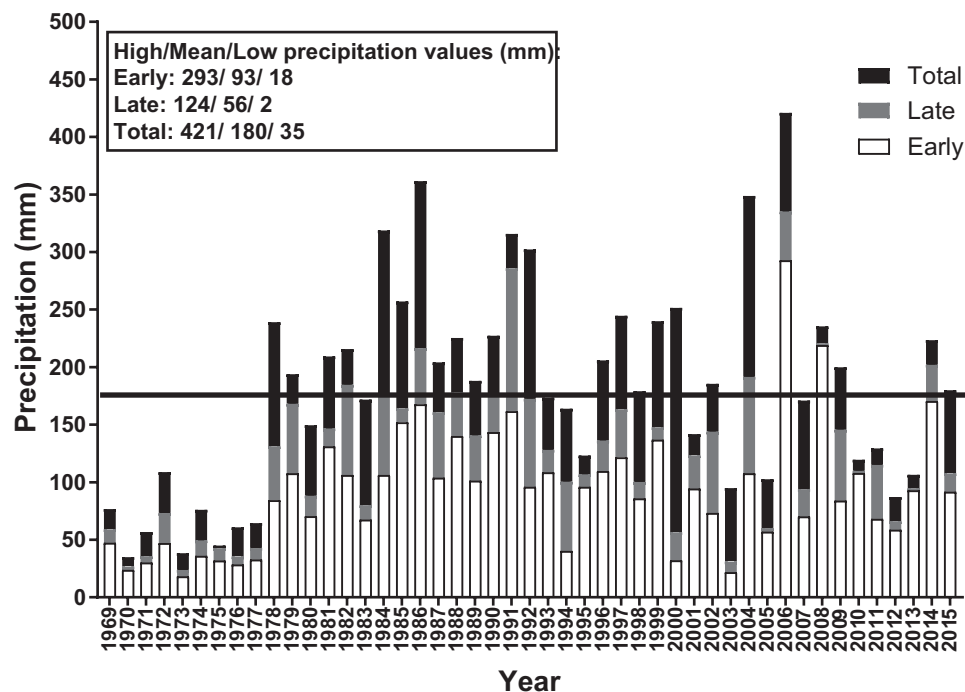


Figure 2. Annual precipitation reported on the Chihuahuan Desert Rangeland and Research Center from 1969 to 2015 in millimeter. Precipitation recorded during early gestation (open bar) represents 53% of precipitation received throughout the total period (black bar). Precipitation received during the late period (gray bar) represents approximately 17% of precipitation received. Average precipitation level indicated as dark horizontal bar (180 mm).

Table 1. Brangus calf growth performance based on precipitation received in utero

Item	Treatments*			SEM	P value
	Low	Avg	High		
Birth weight, kg					
Early gestation†	32	35	35	1.7	0.05
Late gestation‡	34	35	—	0.9	0.89
Total	31 ^a	35 ^b	37 ^b	1.6	0.05
Weaning weight, kg					
Early gestation	218 ^a	236 ^{ab}	259 ^b	14.4	0.04
Late gestation	227	244	—	7.6	0.12
Total	218 ^a	238 ^{ab}	258 ^b	15.8	0.05
Adj 205-d weight, kg					
Early gestation	211 ^a	230 ^{ab}	249 ^b	13.2	0.03
Late gestation	221	236	—	7.0	0.13
Total	210	233	247	14.6	0.08

*Treatments are low (Low) = z value less than or equal to -0.99 , average (Avg) = z value -0.99 to $+0.99$ of the mean, and high (High) = z value more than or equal to 0.99 .

†Late gestation = summation of monthly average rainfall received during the last trimester December–March.

‡Early gestation = summation of monthly average rainfall received the first trimester from July to September.

||Total = summation of monthly average rainfall from average conception date to average parturition date.

^{a,b}Within a row means with different superscripts are different ($P < 0.05$).

cattle resulting in increased BW entering the feedlot. Similarly, Sullivan et al. (2009) reported differences in birth BW in a stair-step supplementation study with a 2×2 factorial arrangement of treatments in pregnant beef heifers. Heifers were assigned a high (250% crude protein [CP] and 243% metabolizable energy [ME], expressed as a percentage of National Research Council [NRC; 1996] requirements) or low (75% CP and 199% ME) protein and dietary energy diet during the first or second 90 d of gestation. Heifers fed high levels of CP in either the first or the second trimester displayed greater concentrations of insulin-like growth factor (IGF)-I and leptin, which coincided with increased birth BW of their progeny when compared to calves from heifers fed the restricted diet (Sullivan et al., 2009).

In contrast to the current data, Long et al. (2010) allotted 20 crossbred heifers to one of two diets, low 55% of NRC nutrient requirements or moderate 100% of NRC nutrient requirements at day 32 of gestation until day 83. Authors reported no differences in calf birth BW or postnatal growth. This may suggest that the short duration of nutrient deprivation was not sufficient to elicit a developmental programming effect. Meyer et al. (2016) reported that Iowa calves classified as being born following a wet year had greater BW at feedlot entry and reduced number of days on feed when compared to calves born following a dry year. In addition, Meyer et al. (2016) also reported a decrease in 12th rib fat and marbling scores for calves in the high compared with low precipitation class.

During prolonged drought, reduction in forage yield and quality (Oelberg, 1956; Chaves et al., 2002; Anjum et al., 2003; Jaleel et al., 2008) are common. This combined with limitations of natural forage availability in semiarid environments have the potential to result in unfavorable progeny growth and development (Wu et al., 2006; Ford et al., 2007; Long et al., 2009). However, favorable forage quality can often overcome performance challenges with slightly limited forage availability. Desert plants have evolved to withstand prolonged drought by becoming more efficient in utilization of resources, preserving nutrient content. Pnueli et al. (2002) investigated the physiological mechanism of plant dormancy in a desert legume as a defense against such harsh environmental conditions. Plant DNA was extracted revealing a combination of avoidance and resistance strategies as the plant decreased protein denaturation and upregulated transcription factors for a pathogenesis-related protein. This suggests that native desert plant species have the ability to withstand harsh drought conditions with decreasing nutrient content before drought exposure. This mechanism may explain, in part, why there were no differences in birth BW, weaning BW, and adjusted 205-d BW among treatments during the late gestation period.

Female Progeny Reproductive Performance Data

Female progeny reproductive performance data are reported in Table 2. Though there were no

Table 2. Brangus female progeny performance based on precipitation received in utero

Item	Treatments*			SEM	P value
	Low	Avg	High		
Age at first calving					
Early gestation†	2.27	2.20	2.33	0.10	0.17
Late gestation‡	2.24	2.25	—	0.05	0.90
Total	2.22	2.26	2.20	0.09	0.82
Calved at 2 yr of age, %					
Early gestation	77	87	81	5	0.06
Late gestation	85	84	—	2	0.81
Total	82	85	86	5	0.77
Calved after 8 yr, %					
Early gestation	48	18	9	5	<0.0001
Late gestation	18	19	—	3	0.66
Total	38	15	16	5	<0.0001
Number of calves					
Early gestation	5.90 ^a	3.78 ^b	3.11 ^b	0.40	<0.0001
Late gestation	3.63	3.95	—	0.19	0.22
Total	5.23 ^a	3.52 ^b	3.88 ^b	0.36	<0.0001

*Treatments are low (Low) = *z* value less than or equal to -0.99, average (Avg) = *z* value -0.99 to +0.99 of the mean, and high (High) = *z* value more than or equal to 0.99.

†Early gestation = summation of monthly average rainfall received the first trimester from July to September.

‡Late gestation = summation of monthly average rainfall received during the last trimester December–March.

||Total = summation of monthly average rainfall from average conception date to average parturition date.

^{a,b}Within a row means with different superscripts are different ($P < 0.05$).

differences ($P \geq 0.17$) between treatment groups for age at first calf, females exposed to low precipitation levels in utero produced a greater ($P < 0.0001$) number of calves compared with animals experiencing average or high precipitation throughout gestation. In addition, there tended to be a greater ($P = 0.06$) proportion of heifers calving by 2 yr of age when exposed to average precipitation during early gestation when compared to their counterparts. [Funston et al. \(2010\)](#) reported dams in late gestation grazing winter range or corn residue, with or without protein supplementation had similar pregnancy rates in female offspring. Low-treatment females from the same periods also had a greater percentage calve after 8 yr of age ($P < 0.0001$). One potential factor for this would be the influence of maternal nutrition on the development of the HPG-axis. In response to maternal nutrient stress, the fetal HPG-axis upregulates circulating corticotropin binding globulin and downregulates hypothalamic glucocorticoid receptors, which essentially protects the fetus ([Challis et al., 2001](#)). This phenomenon may suggest that calves experiencing below average precipitation in utero are adapted to the intended environment. [Vonnahme et al. \(2006\)](#) investigated pregnant ewes from two systems, farm and range flocks, consuming either 50% or 100% of the NRC requirements during early to mid-gestation on fetal development. [Vonnahme et al. \(2006\)](#) reported

that range ewes consuming a limited diet had similar fetal blood glucose concentrations and weight compared with their range counterparts consuming an adequate plane of nutrition. Moreover, nutrient restricted and control fed range ewes displayed similar placental efficiency, whereas the farm ewes on a nutrient restricted diet had reduced placental efficiency compared to farm ewes consuming the control diet. On the basis of these data, researchers suggested that ewes managed in a harsh environment are adapted to nutrient insults and can compensate to maintain normal nutrient allocation to developing fetuses while consuming a lower plane of nutrition.

During early gestation, factors such as maximal placental growth, cellular differentiation, vascularization, and fetal organogenesis are occurring. These processes are vital in constructing basic fundamental necessities of fetal development and survival success ([Funston et al., 2010](#)). Female herd longevity and fertility are closely related to ovarian development that can be altered based on maternal diet (Da Silva et al., 2001; [Sullivan et al., 2009](#)). Thus, improved longevity in cows gestated during low precipitation periods may be related to the fact that cows were supplemented. The supplement would improve not only nutrient supply but supplements may be of greater quality (e.g., complimentary amino acid profiles), thereby improving fetal

development. Conversely, a lower plane of nutrition during the third trimester may negatively influence the development and growth of the endometrial tissue in progeny, by affecting the regulating hormones and their respective receptors (Gray et al., 2001). Martin et al. (2007) evaluated two groups of gestating dams offered the equivalent of 0.45 kg/d of protein supplement or no supplement while grazing low quality range, and reported heifers born to supplemented dams had greater pregnancy rates compared with heifers born to non-supplemented dams. Suggesting a higher plane of nutrition during the last trimester in dams may increase reproductive function in subsequent progeny. However, further research is warranted to identify the mechanisms that alter reproductive factors of female progeny in utero during the last trimester of gestation.

Drought has affected cattle production for years, which, from a management perspective, causes selection pressure for more adaptable cattle to better cope with difficult environments. By selecting for the more durable female, this may contribute to increased reproductive efficiency in the herd (Adams et al., 1996; Scasta et al., 2015). These results suggest animal reproductive performance may be programmed in utero and correlate to precipitation level. Further research is warranted investigating physiological or mechanistic differences within female progeny from the various precipitation levels experienced to elucidate the effect of precipitation level during key gestational time points.

Conflict of interest statement. None declared.

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