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Maternal Environment and Fescue Cultivar Effects on Growth, Development, and Fertility of Beef Heifers

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MATERNAL ENVIRONMENT AND FESCUE CULTIVAR EFFECTS ON GROWTH, DEVELOPMENT, AND FERTILITY OF BEEF HEIFERS

Maternal Environment and Fescue Cultivar Effects on Growth, Development, and Fertility of Beef Heifers

A dissertation submitted in partial fulfillment
of the requirement for the degree of
Doctor of Philosophy in Animal Science

By

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Abstract

Two experiments were conducted to investigate maternal environment and fescue cultivar effects on growth and fertility of beef heifers. In experiment one, Brahman-influenced cows [n = 80; body condition score (BCS) = 5.6 ± 1.3] were assigned to graze common bermudagrass (CB) or toxic endophyte-infected tall fescue (E+) during a 60-d breeding season for 2 consecutive yr. Body condition (BC) was assessed at d 0, 30, and 60 of breeding season. Cows were managed to achieve marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8) BC during last trimester. Heifer (n = 80) weight was recorded at birth and weaning (WW; 7 to 8 mo). Data collected at 9 to 10 mo of age included: weight (PWW), hip height (HH), hip width (HW), pelvic height (PH), pelvic width (PW), and pelvic area (PA). In experiment two, Angus sired heifers (n = 80) from experiment one were weighed and randomly assigned to replicated pastures of E+ or non-toxic endophyte-infected (Novel) tall fescue at 9 to 10 mo of age for 190d. Data were collected at weaning, post-weaning (9 to 10 mo), yearling (11 to 12 mo), and prebreeding (13 to 14 mo), and included: BW, HH, HW, PH, PW, PA, and exit velocity (EV, s/m). Heifer estrus was monitored by radio-telemetry during first 30 d of breeding season. Yearling and prebreeding antral follicle count (AFC) was determined by ultrasound. A split-plot design was used for experiment one and two with pasture as experimental unit and heifer age as covariate. Main effects tested were cow conception forage (ConFor), cow conception BC (ConBC), cow BC during the last trimester (LateBC), and heifer fescue grazed during development (Hfes; experiment two). In experiment one, cows grazing E+ during conception had heifers that weighed less (*P* = 0.05) at birth compared to heifers from cows grazing CB (33.3 vs. 35.2 ± 0.5 kg). Cow breeding season forage x LateBC interaction (*P* = 0.05) affected heifer WW, PWW, and PA where heifers from cows grazing E+ ConFor in marginal-LateBC performed the poorest. In experiment two, heifers

developed on E+ from cows in marginal-ConBC, grazing E+ ConFor, and in marginal-LateBC had the lowest ($P < 0.0001$) average daily gain (ADG) compared to heifers developed on Novel from cows in good-ConBC, grazing E+ ConFor, and in good-LateBC (-0.30 vs. 0.58 ± 0.05 kg). Overall ADG was greater ($P < 0.001$) for heifers grazing Novel (0.6 ± 0.1 kg) compared to E+ (0.4 ± 0.1 kg) during development. Heifer AFC was affected ($P < 0.0001$) by a 4-way main effects interaction. Novel heifer AFC from cows in good-ConBC, grazing CB ConFor, and in marginal-LateBC was greater at yearling compared to E+ heifer AFC from cows in marginal-ConBC, grazing CB ConFor, and in good-LateBC (25.1 ± 0.8 vs. 3.8 ± 2.4 follicles). Heifer pregnancy rate was influenced by LateBC x Hfes (90.3, 69.6, 50.0, 43.8 % pregnant, respectively for Novel heifers from cows in good-LateBC, Novel heifers from cows in marginal-LateBC, E+ heifers from cows in good-LateBC, and E+ heifers from cows in marginal-LateBC). Cows consuming toxic endophyte-infected tall fescue during conception reduced birth weight of heifer calves. Cows in marginal-BC during conception and the last trimester reduced heifer weight, ADG, pelvic and hip growth. These heifer variables were further decreased by heifers grazing E+ during development. Ensuring adequate body condition of cows during conception and late-gestation, as well as developing heifers on Novel fescue will increase pelvic growth, number of antral follicles, and pregnancy rates of heifer offspring. Industry applicable tools such as monitoring cow BCS, using indicators of skeletal growth, and grazing Novel fescue could be beneficial in selecting breeding stock with consistent traits associated with successful reproduction.

This dissertation is approved for recommendation
to the Graduate Council.

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Dedication

This dissertation is dedicated to my daughter,

Sydney Cheyenne:

You are my light in the dark and every beat of my heart

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Review of Literature

INTRODUCTION

Reproductive efficiency is fundamentally important for sustainability of cattle production enterprises. Environmental and management factors can impact health, reproductive performance, and nutritional status (Funston et al., 2010). Animals consuming toxic endophyte-infected tall fescue (E+) have reduced productivity including decreased growth, development, and fertility (Paterson et al., 1995). Considering the impact of E+ on animal productivity, this review of the literature includes 1) the influence of maternal nutrition during gestation on subsequent offspring growth, development, and fertility; 2) history of tall fescue; 3) effects of E+ on animal production; and 4) non-toxic endophyte infected tall fescue (Novel) and impacts on animal production.

MATERNAL GESTATIONAL NUTRITION

Maternal nutrition is a critical factor in fetal growth and development. The quality of gestational nutrition can impact postnatal growth and development as well as subsequent reproductive performance (Funston et al., 2010). For the establishment of normal fetal development, adequate maternal nutrition in early pregnancy is critical (Long et al., 2012). Barker (1992) hypothesized environmental influences in early fetal development may impair development, increasing the risk for adult-hood diseases, which he later termed fetal programming (Barker et al., 1993). Nutritional insults during gestation can have profound effects on subsequent offspring growth and fertility (Ashworth et al., 2009; Funston et al., 2010).

Effects on Growth and Development. Cows maintaining a negative energy state pre-partum resulted in suboptimal body condition score (BCS) at parturition (Hess et al., 2005).

Nutrient restricted cows often lose body condition (BC) during pregnancy and postpartum, which can reduce offspring growth (Paputungan and Makarechian, 2000). Heifers born from nutritionally challenged dams had lower birth weights and reduced growth (Funston et al., 2010; Cushman et al., 2009). Continuously restricting cows 100 d pre-partum resulted in lower birth weights (Corah et al., 1975). The time in which cow BC loss or gain occurs may result in different outcomes on offspring growth and development. Therefore, BCS and BC during breeding and gestation effects on calf growth, development, and reproduction have been investigated (Morrison et al., 1999; Lake et al., 2005).

Studies on effects of BC and nutrition on growth performance of calves have given varying results. Calf birth weights were shown to be not affected by BC at calving or BCS change during the last trimester of pregnancy (DeRouen et al., 1994; Morrison et al., 1999; Lake et al., 2005). In contrast, other studies have noted lower birth weights were associated with loss of maternal BC during the last trimester of pregnancy (Freetly et al., 2000; Paputungan and Makarechian, 2000). Body condition score at calving did not affect WW of calves (DeRouen et al., 1994; Spitzer et al., 1995; Morrison et al., 1999). In contrast, Paputungan and Makarechian (2000) demonstrated BCS of the dam during late-gestation was positively associated with WW.

Effects on Offspring Reproduction. Maternal nutrition during gestation may impact fertility of subsequent offspring such as oocyte quality, folliculogenesis, and pregnancy rate (Cushman et al., 2009; Mossa et al., 2009). The peak number of follicles and oocytes within fetal ovaries occurs during gestation, and a positive association with ovarian reserve and antral follicle count (AFC; the total number of follicles > 3mm in diameter on both ovaries) has been reported (Erickson, 1966; Burns et al., 2005; Ireland et al., 2008, 2009; Cushman et al., 2009). Undernutrition of ewes during early gestation resulted in developmental retardation of fetal ovaries as measured by germ cell degeneration (Borwick et al., 1997). Maternal caloric restriction decreased ovarian granulosa cell proliferation and increased apoptosis in fetal ovaries, suggesting maternal nutrient restriction may delay or retard fetal ovarian maturation (Lea et al., 2006). Maternal nutrient restriction during early- to mid-gestation in sheep resulted in oocyte DNA damage in fetal ovaries (Murdoch et al., 2003) and prenatal undernutrition resulted in decreased ovulation rates in sheep (Rae et al., 2002). Nutrient restricted ewes during mid- to late-gestation decreased primordial follicle numbers in fetal ovaries, which could affect future follicular activity and possibly fertility (Grazul-Bilska et al., 2009). Mossa et al. (2009) demonstrated that heifers born to mothers nutritionally restricted during the first 110 d of gestation had 60% lower AFC compared to control heifers despite no difference observed in birth weight. Cushman et al. (2009) reported low birth weight heifers had fewer AFC and reduced pregnancy rates.

ENDOPHYTE-INFECTED TALL FESCUE

Wild-type tall fescue [E+; *Lolium arundinaceum* (Schreb.) Darbysh.] is an excellent forage species that is well adapted to the Midwestern and Southeastern United States due to its drought resistance and toxicity to insects (Bacon, 1995). This highly adaptive species was introduced into the United States in the 1940's (Bacon, 1995). The defensive mechanisms of tall fescue evolved as a symbiotic relationship between the plant and an endophytic fungus (*Neotyphodium coenophialum*; Bacon, 1995). Toxins produced by the endophyte which have been identified as ergot alkaloids provide mechanisms of defense (Lyons et al., 1986; Yates et al., 1985). Although the endophyte is beneficial to the plant, adverse symptoms were observed in animals grazing pastures of tall fescue following forage introduction (Cunningham, 1948).

Endophyte-infected fescue has been studied to analyze the specific aspects adversely affecting livestock.

Ergot Alkaloids. Defensive herbivory against insects is based on production of secondary metabolites, loline alkaloids (Bacon, 1995). Petroski et al. (1990) suggested E+ possesses the ability to compete with other grasses possibly as a result of the allelopathic behavior of loline alkaloids where plant species inhibit growth of competing species via chemical production. Concentration of loline alkaloids in forage vary with season, nitrogen fertilization amounts, grazing pressure, and amount of insect herbivory (Bush et al., 1982, 1993; Belesky et al., 1987; Eichenseer et al., 1991). The loline alkaloid peramine was reported to be the major insect deterrent in E+ (Rowan and Tapper, 1989; Tapper et al., 1989; Siegel et al., 1990).

Numerous ergot alkaloids were found in E+ including ergocryptine, ergotamine, ergonovine, and lysergic acid amide. Ergovaline has been identified as the most prevalent ergopeptide alkaloid in E+ suggesting it causes or contributes to fescue toxicosis due to its biological activity (Porter et al., 1979; Lyons et al., 1986; Porter, 1995; de Lorme et al., 2007; Dyer, 1993; Moubarak et al., 1993; Solomons et al., 1989). Lysergic acid amide was reported to exist in concentrations equal to ergovaline levels (Bacon, 1995). Hill et al. (2001) suggested lysergic acid crossed the ruminal epithelium at a greater rate than other alkaloids due to the chemical structure, or core ring, of the lysergic acid molecule. De Lorme et al. (2007) demonstrated upon consumption of an E+ diet, ergot alkaloids were liberated from the digestible fraction of the diet and ergovaline was degraded to lysergic acid via rumen microbial degradation.

Ergovaline concentrations in E+ seeds and forage were reported to range from 2 to 6 µg/g. Total ergot alkaloid concentration in E+ were noted to vary with season and amount of nitrogen fertilizer applied to fescue pastures (Lyons et al., 1986, 1990; Rottinghaus, 1991). Symptoms of fescue toxicosis exhibited by animals consuming E+ were reported to ensue at concentrations of 50 ng (0.05 μg) of ergovaline/ g of grass in heat stressed cattle (Cornell et al., 1990).

Fescue Toxicosis. Cattle grazing tall fescue in New Zealand demonstrated crippling which resembled the gangrenous symptoms of ergotism (Cunningham, 1948). The condition (fescue foot) was subsequently described in the U.S. during the 1950's (Goodman, 1957). In addition to fescue foot crippling effects, various other symptoms have been identified. Jacobson et al. (1963) described the clinical syndrome of fescue foot, later termed fescue toxicosis, included symptoms of weight loss, rough hair coat, varying amounts of dry gangrene in extremities (primarily tail and lower legs), elevated body temperature, increased respiration rates, and elevated heart rate. The tendency for animals to develop dry gangrene, due to ischemia, was more prevalent in colder environments (Jacobson et al., 1963). Research indicated cattle grazing E+ suffer fescue toxicosis characterized by elevated body temperature, reduced feed intake, decreased average daily gain (ADG), and reduced pregnancy rates exacerbated during periods of heat stress (Looper et al., 2006; Paterson et al., 1995; Schmidt and Osborn, 1993).

Toxic Tall Fescue Impact on Growth and Development. Cows grazing E+ reduced calf birth weight (Brown et al., 2000; Watson et al., 2004; Burke et al., 2010) and heifers grazing E+ had suppressed growth and development (Paterson et al., 1995; Schmidt and Osborn, 1993). Weaning weights were reduced for calves managed on E+ prior to weaning and ADG of steers grazing E+ was decreased (Gay et al., 1988; Brown et al., 1999; Watson et al., 2004). Cows grazing fescue-legume pastures weaned heavier calves compared to calves from cows grazing E+ (Holloway et al., 1979). The influence of E+ preweaning environment may not persist as calves reared for slaughter can exhibit compensatory gains following feedlot entry (Coffey et al., 1990; Long et al., 2012).

Toxic Tall Fescue Impact on Reproductive Performance. Toxic endophyte-infected tall fescue has been detrimental to reproductive processes including reduced pregnancy and calving rates (Looper et al., 2010; Paterson et al., 1995; Porter and Thompson, 1992; Schmidt and Osborn, 1993). Research has identified the time frame of pregnancy loss to less than 30 d of gestation suggesting early events such as folliculogenesis, oocyte maturation, or early embryonic development may be negatively affected by E+ (Waller et al., 2001). McKenzie and Erickson (1991) reported a decrease in follicle numbers in heifers consuming E+. Seals et al. (2005) did not observe differences in follicle numbers of heifers administered ergotamine tartrate to simulate fescue toxicosis. In that study, heifers were administered the diet and ovarian follicles scanned during a 30-d period, which may not been sufficient to simulate the effects of heifers grazing E+ on folliculogenesis to affect oocyte quality due to the length of folliculogenesis. Follicle growth from pre-antral to mature ovulatory size requires about 60 to 80 d in cattle (Britt, 1992). Investigating effects of E+ over a longer period may better represent potential effects of E+ on follicular dynamics and oocyte quality. Mean follicle numbers from heifers fed E+ seed diets for 100 d were not different from heifers fed a control diet (Rorie et al., 1998). The effects of E+ on folliculogenesis may become more apparent when considering environmental factors. Heat stress combined with E+ consumption reduced the number follicles and preovulatory follicle diameter (Burke et al., 2001; Burke and Rorie, 2002).

The addition of alkaloids to culture media negatively affected oocyte maturation and prevented development of subsequent embryos produced in vitro (Panter et al., 2002). Heifers fed E+ diet produced fewer oocytes and were of poorer quality (Jones and King, 2009). Oocyte zona pellucida width was thinner from E+ heifer oocytes compared to control heifers suggesting structural affects to the zona, which could potentially affect fertilization (Jones and King, 2009). Heifers receiving ergotamine tartrate to simulate the effects of grazing E+ produced embryos of reduced quality and development, where the percentage of embryos that developed to compacted morula or higher stage of development was lower in heifers fed ergotamine (56%) compared to control (88%; Schuenemann et al., 2005). Embryo recovery rate tended to be reduced in heifers fed ergotamine possibly due to increased rectal temperatures and lower plasma prolactin concentrations (Schuenemann et al., 2005). Reduced prolactin concentrations and increased rectal temperatures are prevalent symptoms of fescue toxicosis in cattle (Looper et al., 2010; Seals et al., 2005). Embryos collected from donors not consuming E+ diet transferred on d 7 into recipients consuming ergotamine tartrate resulted in no difference in pregnancy rates between treatment groups, suggesting E+ deleterious effects on pregnancy rates may occur before d 7 on the oocyte or during the early stages of embryonic development (Schuenemann et al., 2005).

NON-TOXIC ENDOPHYTE-INFECTED TALL FESCUE

The negative impacts of grazing E+ resulted in research dedicated to the development of endophyte-free (E-) tall fescue. Endophyte-free tall fescue had reduced drought tolerance and inefficient stand persistence compared to E+ (Malinowski et al., 2005; Lacefield et al., 1993). Endophyte-free tall fescue was deemed uneconomical and nonviable as an alternative to E+ due to an inability to persist (Bouton, 2000). The discovery of new endophytes with low alkaloid production resulted in development of non-toxic (Novel) endophyte-infected tall fescue (Bouton et al., 2002; Nihsen et al., 2004; West et al., 2001; Gunter and Beck, 2004). Novel combines the advantages of plant persistence of E+ and the animal performance of E- (Gunter and Beck, 2004;

Nihsen et al., 2004). Steers grazing Novel performed similar to steers grazing E- and better than steers grazing E+ (Nihsen et al., 2004). Watson et al. (2004) reported cows grazing Novel pastures had heavier calves and higher BCS at the end of the grazing period compared to cows grazing E+. Cows grazing Novel had calves with higher ADG and weaning weights than calves raised by cows grazing E+ pastures (Watson et al., 2004). Cattle grazing Novel demonstrated improved animal performance compared to cattle grazing E+, and stress related to E+ may be circumvented (Parish et al., 2003a, 2003b; Watson et al., 2002, 2004).

OBJECTIVES

Nutrition quality during conception and gestation can affect pre- and postnatal growth patterns and influence subsequent offspring reproductive performance. Transient events pre- or early postnatal may have profound effects on offspring physiology that may not become immediately apparent (Barker, 1992). Exposure to nutritional stress in utero could modify long-term stress reactivity after birth via fetal mechanisms shielding or buffering maternal stress and possibly affecting offspring metabolism (Entringer et al., 2009; Seckl and Holmes, 2007). Considering the potential impact of stress related to E+ on animal productivity, objectives of this dissertation were to:

1) Determine the effects of maternal body condition and maternal forage type grazed during breeding season on subsequent daughter post-natal development.

2) Determine effects of maternal forage type grazed during conception, cow body condition (BC) during conception, body condition during late-gestation, and fescue cultivar grazed during heifer development on growth and fertility of beef heifers.

LITERATURE CITED

Ashworth, C. J., L. M. Toma, and M. G. Hunter. 2009. Nutritional effects on oocyte and embryo development in mammals: implications for reproductive efficiency and environmental sustainability. Phil. Trans. R. Soc. B. 364: 3351-3361.

Bacon, C. W. 1995. Toxic endophyte-infected tall fescue and range grasses: Historical perspectives. J. Anim. Sci. 73:861-870.

Barker, D. J. 1992. The effect of nutrition of the fetus and neonate on cardiovascular disease in adult life. Proc. Nutr. Soc. 51: 135-144.

Barker, D. J., C. N. Martyn, C. Osmond, C. N. Hales, and C. H. D. Fall. 1993. Growth in utero and serum cholesterol concentrations in adult life. BMJ 307: 1524-1527.

Belesky, D. P., J. A. Stuedemann, R. D. Plattner, S. R. Wilkinson, and O. J. Devine. 1987. Fungal endophyte infection-loline derivative alkaloid concentration of grazed tall fescue. Agron. J. 79:217.

Borwick, S. C., S. M. Rhind, S. R. McMillen, and P. A. Racey. 1997. Effect of undernutrition of ewes from the time of mating on fetal ovarian development in mid-gestation. Reprod. Fertil. Dev. 9: 711-715.

Bouton, J. H., G. C. M Latch, N. S. Hill, C. S. Hoveland, M. A. McCann, R. H. Watson, J. A. Parish, L. C. Hawkins, and F. N. Thompson. 2002. Reinfection of tall fescue cultivars with nonergot alkaloid producing endophytes. Agron. J. 94:567-574.

Bouton, J. H. 2000. The use of endophytic fungi for pasture improvement in the USA. p. 163-168. *In* V. H. Paul and P. D. Dapprich (ed.) Proc.Int. *Neotyphodium*Grass Interactions Symp., 4^{th}, Soest, Germany. 27-29 Sept. 2000. Univ. Paderborn, Germany.

Britt, J. H. 1992. Impacts of early postpartum metabolism on follicular development and fertility. Bovine. Prac. 24:39-43.

Brown, M. A., A. H. Brown, Jr., W. G. Jackson, and J. R. Miesner. 2000. Genotype x environment interactions in Angus, Brahman, and reciprocal-cross cows and their calves grazing common bermudagrass, endophyte-infected tall fescue pastures, or both forages. J. Anim. Sci. 78:546-551.

Brown, M. A., W. A. Phillips, A. H. Brown, S. W. Coleman, W. G. Jackson, and J. R. Miesner. 1999. Postweaning performance of calves from Angus, Brahman, and reciprocal-cross cows grazing endophyte-infected tall fescue or common bermudagrass. J. Anim. Sci. 77:25-31.

Burns, D. S., F. Jimenez-Krassel, J. L. H. Ireland, P. G. Knight, and J. J. Ireland. 2005. Numbers of antral follicles during follicular waves in cattle: Evidence for high variation among individuals, very high repeatability in individuals, and an inverse association with serum follicle-stimulating hormone concentrations. Biol. Reprod. 73: 54-62.

Bush, L.P., P.L. Cornelius, R. C. Buckner, D. R. Varney, R. A. Chapman, P. B. Burrus, C. W. Kennedy, T. A. Jones, and M. J. Saunders. 1982. Association of N-actetylloline derivative and N-formylloline derivative with *Epichloe typhina* in tall fescue. Crop Sci. 22:941-.

Bush, L. P., F. F. Fannin, M. R. Siegel, D. L. Dahlman, H. R. Burton. 1993. Chemistry, occurrence and biological effects of saturated pyrrolizidine alkaloids associated with endophyte-grass interaction. Agric. Ecosyst. Environ. 44:81.

Burke, J. M., S. W. Coleman, C. C. Chase, Jr., D. G. Riley, M. L. Looper, and M. A. Brown. 2010. Interaction of breed type and endophyte-infected tall fescue on milk production and quality in beef cattle. J. Anim. Sci. 88:2802-2811.

Burke, J. M. and R. W. Rorie. 2002. Changes in ovarian function in mature beef cows grazing endophyte-infected tall fescue. Theriogenology 57:1733-1742.

Burke, J. M., D. E. Spiers, F. N. Kojima, G. A. Perry, B. E. Salfen, S. L. Wood, D. J. Patterson, M. F. Smith, M. C. Lucy, W. G. Jackson, and E. L. Piper. 2001. Interaction of endophyte-infected fescue and heat stress on ovarian function in the beef heifer. Biol. Reprod. 65:260-268.

Coffey, K. P., L. W. Lomas, and J. L. Moyer. 1990. Grazing and subsequent feedlot performance by steers that grazed different types of fescue pasture. J. Prod. Agric. 3:415-4.

Corah, L. R., T. G. Dunn, and C. C. Kaltenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819-824.

Cornell, C. N., J. V. Lueker, G. B. Garner, and J. L. Ellis. 1990. Establishing ergovaline levels for fescue toxicosis, with and without endoparasite, under controlled climate conditions. In: S. S. Quisenberry and R. E. Joost (ed.) Proc. Int. Symp. On *Acremonium*/ Grass Interactions. 75.

Cunningham, I. J. 1948. Tall fescue grass is poison for cattle. N. Z. J. Agric. 77:519.

Cushman, R. A., M. F. Allan, L. A. Kuehn, W. M. Snelling, A. S. Cupp, and H. C. Freetly. 2009. Evaluation of antral follicle count and ovarian morphology in crossbred beef cows: Investigation of influence of stage of estrous cycle, age, and birth weight. J. Anim. Sci. 87:1971-1980.

De Lorme, M. J. M., S. L. Lodge-Ivey, and A. M. Craig. 2007. Physiological and digestive effects of *Neotyphodium coenophialum*-infected tall fescue fed to lambs. J. Anim. Sci. 85:1199-1206.

DeRouen, S. M., D. E. Franke, D. G. Morrison, W. E. Wyatt, D. F. Coombs, T. W. White, P. E. Humes, and B. B. Greene. 1994. Prepartum body condition and weight influences on reproductive performance of first-calf beef cows. J. Anim. Sci. 72:1119-1125.

Dyer, D. C. 1993. Evidence that ergovaline act on serotonin receptor. Life Sci. 53:223.

Entringer, S., R. Kumsta, D. H. Hellhammer, P. D. Wadhwa, and S. Wust. 2009. Prenatal exposure to maternal psychosocial stress and HPA axis regulation in young adults. Horm. Behav. 55:292-298.

Erickson, B. H. 1966. Development and radio-response of the prenatal bovine ovary. J. Reprod. Fertil. 11: 97-105.

Freetly, H. C., C. L. Ferrell, and T. G. Jenkins. 2000. Timing of realimentation of mature cows that were feed-restricted during pregnancy influences calf birth weights and growth rates. J. Anim. Sci. 78:2790-2796.

Funston, R. N., D. M. Larson, and K. A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: implications for beef cattle production. J. Anim. Sci. 88(E-Suppl.):205-215.

Gay, N., J. A. Boling, R. Dew, and D. E. Miksch. 1988. Effects of endophyte-infected tall fescue on beef cow-calf performance. Appl. Agric. Res. 3:182.

Goodman, A. A. 1957. Fescue foot in cattle in Colorado. J. Am. Vet. Med. Assoc. 121:289.

Grazul-Bilska, A. T., J. S. Caton, W. Arndt, K. Burchill, C. Thorson, E. Boroczyk, J. J. Bilski, D. A. Redmer, L. P. Reynolds, and K. A. Vonnahme. 2009. Cellular proliferation and vascularization in ovine fetal ovaries: Effects of undernutrition and selenium in maternal diet. Reprod. 137:699-707.

Gunter, S. A. and P. A. Beck. 2004. Novel endophyte-infected tall fescue for growing beef cattle. J. Anim. Sci. 82:E75-E82.

Hess, B. W., S. L. Lake, E. J. Scholljegerdes, T. R. Weston, V. Nayigihugu, J. D. C. Molle, and G. E. Moss. 2005. Nutritional controls of beef cow reproduction. J. Anim. Sci. 83 (E. Suppl.):E90-E106.

Hill, N. S., F. N. Thompson, J. A. Stuedemann, G. W. Rottinghaus, H. J. Hu, D. L. Dawe, and E. E. Hiatt, III. 2001. Ergot alkaloids transport across ruminant gastric tissues. J. Anim. Sci. 79:542-549.

Holloway, J. W. W. T. Butts, Jr., J. D. Beaty, J. T. Hopper, and N. S. Hall. 1979. Forage intake and performance of lactating beef cows grazing high or low quality pastures. J. Anim. Sci. 48:692-700.

Ireland, J. J., A. E. Zielak-Steciwko, F. Jimenez-Krassel, J. Folger, A. Bettegowda, D. Sheetz, S. Walsh, F. Mossa, P. G. Knight, G. W. Smith, P. Lonergan, and A. C. O. Evans. 2009. Variation in the ovarian reserve is linked to alterations in intrafollicular estradiol production and ovarian biomarkers of follicular differentiation and oocyte quality in cattle. Biol. Reprod. 80:954-964.

Ireland, J. L. H., D. Scheetz, F. Jimenez-Krassel, A. P. N. Themmen, F. Ward, P. Lonergan, G. W. Smith, G. I. Perez, A. C. O. Evans, and J. J. Ireland. 2008. Antral follicle count reliability predicts number of morphologically healthy oocytes and follicles in ovaries of young adult cattle. Biol. Reprod.79:1219-1225.

Jacobson, D. B., W. M. Miller, and D. M. Seath. 1963. Nature of fescue toxicity and progress toward identification of the toxic entity. J. Dairy Sci. 46:416-422.

Jones, K. L. and S. S. King. 2009. Effect of domperidone supplementation of fescue-fed heifers on plasma and follicular fluid fatty acid composition and oocyte quality. J. Anim. Sci. 87:2227-2238.

Lacefield, G., D. Ball, and J. Henning. 1993. Results of two-state survey of county agents regarding status of endophyte-infected and endophyte-free tall fescue. p. 22-25. Proc. Southern Pasture and Forage Crop Improvement Conf., 49th, Longboat Key, FL. 14-16 June 1993.

Lake, S. L., E. J. Scholljegerdes, R. L. Atkinson, V. Nayigihugu, S. I. Paisley, D. C. Rule, G. E. Moss, T. J. Robinson, and B. W. Hess. 2005. Body condition score at parturition and postpartum supplemental fat effects on cow and calf performance. J. Anim. Sci. 83:2908-2917.

Lea, R. G., L. P. Andrade, M. T. Rae, L. T. Hannah, C. E. Kyle, J. F. Murray, S. M. Rhind, and D. W. Miller. 2006. Effects of maternal undernutrition during early pregnancy on apoptosis regulators in the ovine fetal ovary. Reprod. 131:113-124.

Long, N. M., C. B. Tousley, K. R. Underwood, S. I. Paisley, W. J. Means, B. W. Hess, M. Du, and S. P. Ford. 2012. Effects of early- to mid-gestational undernutrition with or without protein supplementation on offspring growth, carcass characteristics, and adipocyte size in beef cattle. J. Anim. Sci. 90:197-206.

Looper, M. L., S. T. Reier, B. C. Williamson, M. A. Sales, D. M. Hallford, and C. F. Rosenkrans, Jr. 2010. Effects of body condition on measure of intramuscular and rump fat, endocrine factors, and calving rate of beef cows grazing common bermudagrass or endophyte-infected tall fescue. J. Anim. Sci. 88:4133-4141.

Looper, M. L., T. S. Edrington, R. Flores, C. F. Rosenkrans, Jr., M. E. Nihsen, and G. E. Aiken. 2006. Prevalence of Escherichia coli O157:H7 and Salmonella in beef steers consuming different forage diets. Lett. Appl. Microbiol. 42:583-588.

Lyons, P. C., R. D. Plattner, and C. W. Bacon. 1986. Occurrence of peptide and clavinet ergot alkaloids in tall fescue. Science (Washington, DC). 232:487.

Malinowski, D. P., D. P. Belesky, and G. C. Lewis. 2005. Abiotic stresses in endophytic grasses. *In Neotyphodium* in Cool-Season Grasses. 1st ed. p. 187-199. Editors C. A. Roberts, C. P. West, and D. E. Spiers. Blackwell Publishing, Ames, IA.

McKenzie, P. P. and B. H. Erickson. 1991. Effects of fungal-infested fescue on gonadotropin secretion and follilculogenesis in beef heifers. J. Anim. Sci. (Suppl 1) 69:387 (Abstr.)

Morrison, D. G., J. C. Spitzer, and J. L. Perkins. 1999. Influence of prepartum body condition score change on reproduction in multiparous beef cows in moderate body condition. J. Anim. Sci. 77:1048-1054.

Mossa, F., D. Kenny, F. Jimenez-Krassel, G. W. Smith, D. Berry, S. Butler, T. Fair, P. Lonergan, J. J. Ireland, and A. C. O. Evans. 2009. Undernutrition of heifers during the first trimester of pregnancy diminishes size of the ovarian reserve in female offspring. Biol. Reprod. 81: Abstract 135.

Moubarak, A. S., E. L. Piper, C. P. West, and Z. B. Johnson. 1993. Interaction of purified ergovaline from endophyte-infected tall fescue with synaptosomal ATPase enzyme system. J. Agric. Food Chem. 41:407.

Murdoch, W. J., E. A. Van Kirk, K. A. Vonnahme, and S. P. Ford. 2003. Ovarian responses to undernutrition in pregnant ewes, USA. Reprod. Biol. Endocrinol. 1:6

Nihsen, M. E., E. L. Piper, C. P. West, R. J. Crawford, Jr., T. M. Denard, Z. B. Johnson, C. A. Roberts, D. A. Spiers, and C. F. Rosenkrans, Jr. 2004. Growth rate and physiology of steers grazing tall fescue inoculated with novel endophytes. J. Anim. Sci. 82:878-883.

Panter, K. E., L. F. James, D. R. Gardner, M. H. Ralphs, J. A. Pfister, B. L. Stegelmeier and S. T. Lee. 2002. Reproductive losses to poisonous plants: Influence of management strategies. J Range Manage. 55:301-308.

Paputungan, U. and M. Makarechian. 2000. The influence of dam weight, body condition and udder scores on calf birth weight and preweaning growth rates in beef cattle. Asian-Aus. J. Anim. Sci. 13:435-439.

Parish, J. A., M. A. McCann, R. H. Watson, C. S. Hoveland, L. L. Hawkins, N. S. Hill, and J. H. Bouton. 2003a. Use of nonergot alkaloid-producing endophytes for alleviating tall fescue toxicosis in sheep. J. Anim. Sci. 81:1316-1322.

Parish, J. A., M. A. McCann, R. H. Watson, C. S. Hoveland, L. L. Hawkins, N. S. Hill, and J. H. Bouton. 2003b. Use of nonergot alkaloid-producing endophytes for alleviating tall fescue toxicosis in stock cattle. J. Anim. Sci. 81:2856-2868.

Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73:889-898.

Petroski, R. J., C. L. Dornbos, Jr., and R. G. Powell. 1990. Germination and growth inhibition of annual ryegrass (*Lolium multiflorum* L.) and alfalfa (*Medicago sativa* L.) by loline alkaloids and synthetic N-acetylloine derivatives. J. Agric. Food Chem. 38:1716.

Porter, J. K., C. W. Bacon, and J. D. Robbins. 1979. Ergosine, ergosinine, chanoclavine I from Epichloe typhina. J. Agric. Food Chem. 27:595.

Porter, J. K. and F. N. Thompson. 1992. Effects of fescue toxicosis on reproduction in livestock. J. Anim. Sci. 70:1594-1603.

Porter, J. K. 1995. Analysis of endophyte toxins: Fescue and other grasses toxic to livestock. J. Anim. Sci. 73:871-880.

Rae, M. T., C. E. Kyle, D. W. Miller, A. J. Hammond, A. N. Brooks, and S. M. Rhind. 2002. The effects of undernutrition, in utero, on reproductive function in adult male and female sheep. Anim. Reprod. Sci. 72:63-71.

Rorie, R., D. Kreider, E. Piper, and D. Hazlett. 1998. Effect of fescue endophyte toxins on conception rate, embryo development, and reproductive tract function in beef cattle. AR Agric. Exp. Sta. Rep. 464:105-107.

Rottinghaus, G. E., G. B. Garner, C. N. Cornell, and J. L. Ellis. 1991. An HPLC method for quantitating ergovaline in endophyte-infected tall fescue: seasonal variation of ergovaline levels in stems with leaf sheaths, leaf blade and seed heads. J. Agric. Food Chem. 39:112.

Rowan, D. D. and B. A. Tapper. 1989. An efficient method for the isolation of peramine, an insect feeding deterrent produced by the fungus *Acremonium lolii*. J. Nat. Prod. 52:193.

Schmidt, S. P., and T. G. Osborn. 1993. Effects of endophyte-infected tall fescue on animal performances. Agric. Ecosyst. & Environ. 44:233.

Schuenemann, G. M., M. E. Hockett, J. L. Edwards, N. R. Rohrbach, K. BF. Breuel, F. N. Schrick. 2005. Embryo development and survival in beef cattle administered ergotamine tartrate to simulate fescue toxicosis. Reprod. Biol. 5:137-150.

Seals, R. C., G. M. Schuenemann, W. Lemaster, A. M. Saxton, J. C. Waller, and F. N. Schrick. 2005. Follicular dynamics in beef heifers consuming ergotamine tartrate as a model of endophyte-infected tall fescue consumption. J. Anim. Vet. Adv. 4:97-102.

Seckl, J. R. and M. C. Holmes. 2007. Mechanisms of disease: glucocorticoids, their placental metabolism and fetal ‘programming’ of adult pathophysiology. Nat. Clin. Pract. Endocrinol. Metab. 3:479-488.

Siegel, M. R., G. C. M. Latch, L. P. Bush, F. F. Fannin, D. D. Rowen, B. A. Tapper, C. W. Bacon, and M. C. Johnson. 1990. Fungal endophyte-infected grasses: alkaloid accumulation and aphid response. J. Chem. Ecol. 12:3301.

Solomons, R. N., J. W. Oliver, and R. D. Linnabary. 1989. Reactivity of dorsal pedal vein of cattle to selected alkaloids associated with Acremonium coenophialum-infected fescue grass. Am. J. Vet. Res. 50:235-238.

Spitzer, J. C., D. G. Morrison, R. P. Wettemann, and L. C. Faulkner. 1995. Reproductive responses and calf birth and weaning weights as affects by body condition at parturition and postpartum weight gain in primiparous beef cows. J. Anim. Sci. 73:1251-1257.

Tapper, B. A., D. D. Rowen, and G. C. M. Latch. 1989. Detection and measurement of the alkaloid peramine in endophyte-infected grasses. J. Chromatogr. 463:133.

Waller, J. C., F. N. Schrick, M. C. Dixon, A. E. Fisher, A. M. Saxton, and H. A. Fribourg. 2001. Tall fescue based forage systems for developing beef replacement heifers. J. Anim. Sci. 79:458 (Abstr.).

Watson, R. H., M. A. McCann, J. A. Parish, C. S. Hoveland, F. N. Thompson, and J. H. Bouton. 2004. Productivity of cow-calf pairs grazing tall fescue pastures infected with either the wild-type endophyte or a nonergot alkaloid-producing endophyte strain, AR542. J. Anim. Sci. 82:3388-3393.

Watson, R. H., M. A. McCann, J. A. Parish, C. S. Hoveland, N. S. Hill, and J. H. Bouton. 2002. Performance of cow-calf pairs on MaxQ tall fescue. *In* Proc. SERA-IEG/8 2002 Workshop.

West, C. P., E. L. Piper, M. E. Nihsen, S. A. Gunter, K. A. Cassida, D. A. Spiers, C. A. Roberts, and R. C. Crawford. 2001. Performance of cattle on “HiMag” tall fescue infected with novel endophytes. Page 262 in Proc. Amer. Forage Grassl. Coun. Vol. 10. Springdale, AR.

Yates, S. G., R. D. Plattner, and G. B. Garner. 1985. Detection of ergopeptide alkaloids in endophyte infected toxic Ky-31 tall fescue by mass spectometry/ spectometry. J.Agric. Food Chem. 33:719.

Maternal Body Condition and Forage Grazed during Conception Effects on Post-Natal Development of Crossbred Beef Heifers

ABSTRACT

Gestational nutrition of the dam can affect postnatal growth of offspring. Our objective was to determine effects of forage type grazed during conception, and body condition (BC) of cows during conception and the last trimester of pregnancy on growth of heifer calves. Brahman-influenced cows (body condition score, BCS = 5.6 ± 1.3) were assigned to graze either common bermudagrass (CB) or toxic tall fescue (E+) for a 60-d breeding season during 2 yr. Cow BC was assessed at d 0, 30, and 60 of the breeding season. Cows were managed to achieve marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8) BC during the last trimester of gestation. Weight of heifers (n = 80) was recorded at birth, weaning (WW; 7 to 8 mo) and at 9 to 10 mo of age (post-weaning weight, PWW). Indicators of heifer size included: hip height (HH), hip width (HW), pelvic height (PH), pelvic width (PW), and pelvic area (PA). Data were analyzed using mixed procedure with pasture as experimental unit, heifer age as a covariate, and heifer within year as a repeated measure. Model main effects were maternal breeding season forage (ConFor), conception BC (ConBC = BC at d 0 of breeding season) and BC during the last trimester of gestation (LateBC). Cows grazing E+ during conception had heifers that weighed less ($P = 0.05$) at birth compared with heifers from cows grazing CB (33.3 ± 0.6 kg vs. 35.2 ± 0.5 kg). Heifer adjusted 205-d WW tended ($P = 0.06$) to be affected by an interaction between ConFor x ConBC. Interaction ($P = 0.05$) between ConFor and LateBC affected heifer WW (240.1 ± 6.0 kg, 233.5 ± 4.8 kg, 245.9 ± 5.1 kg, and 211.7 ± 6.7 kg; respectively for CB ConFor x good-LateBC, CB ConFor x marginal-LateBC, E+ ConFor x good-LateBC, and E+ ConFor x marginal-LateBC). Conception forage x LateBC interaction affected ($P = 0.05$) PWW where heifers from

cows grazing E+ ConFor in marginal-LateBC had the lowest PWW than any other forage LateBC combination (241, 270, 259, and 260 kg, respectively E+ ConFor in marginal-LateBC, E+ ConFor in good-LateBC, CB ConFor in marginal-LateBC, and CB ConFor in good-LateBC). Interaction between ConFor and LateBC affected (P = 0.04) heifer PA where heifers from cows grazing E+ ConFor in good-LateBC had the largest PA compared to heifers from cows grazing E+ ConFor in marginal-LateBC, cows grazing CB ConFor in good-LateBC, and CB ConFor in marginal-LateBC (132 ± 4, 112 ± 5, 114 ± 5, and 116 ± 5 cm^2, respectively). Consumption of toxic tall fescue during conception reduced birth weight of heifer calves. Cows in marginal-BC during the last trimester of pregnancy reduced heifer weaning weight, pelvic and hip growth. Ensuring cows are in good-BC during conception and the last trimester will circumvent reduced growth in heifer progeny.

INTRODUCTION

The quality of maternal nutrition during conception and gestation has been shown to impact postnatal growth, development, and subsequent reproductive performance of offspring (Funston et al., 2010). Heifers born from nutritionally challenged dams had lower birth weights and reduced growth (Greenwood et al., 1998, 2000; Freetly et al., 2000; Wu et al., 2006; Funston et al., 2010).

Fetal development during early pregnancy can be affected by maternal diet (Greenwood and Cafe, 2007). Nutrient restriction and body condition (BC) loss during the last trimester of pregnancy resulted in lighter birth weight calves (Corah et al., 19775; Paputungan and Makarechian, 2000). Other studies reported calf birth weight was not affected by body condition score (BCS) during the last trimester (DeRouen et al., 1994; Lake et al., 2005). Long et al.

(2012) demonstrated nutrient restriction early (45 d post breeding) to mid-gestation did not influence steer or heifer weaning weight. In contrast, Paputungan and Makarechian, 2000 reported BC at calving affected weaning weight of calves.

Wild-type tall fescue [E+; *Lolium arundinaceum* (Schreb.) Darbysh.] is an excellent forage species that is well adapted to the Midwestern and Southeastern United States of America due to its drought resistance, and toxicity to insects (Bacon, 1995). Consumption of E+ can negatively affect cattle productivity due to fescue toxicosis (Paterson et al., 1995). Fescue toxicosis is characterized by elevated body temperature, reduced feed intake and decreased average daily gain (ADG; Paterson et al., 1995). Looper et al. (2010) reported cows with marginal BC grazing E+ had reduced calving rates. Watson et al. (2004) demonstrated BCS of cows grazing E+ was lower, cow ADG was reduced, and cows birthed lighter calves. Studies have shown cows grazing E+ reared calves with reduced weaning weight (Gay et al., 1988; Brown et al., 1999). The objective of this study was to determine effects of forage type grazed by dam during conception, maternal BC at conception, and maternal BC during the last trimester of pregnancy on subsequent heifer growth.

MATERIALS AND METHODS

The committee for animal welfare at the USDA-ARS, Dale Bumpers Small Farms Research Center, Booneville, Arkansas, and the University of Arkansas Institutional Animal Care and Use Committee (No. 040200) approved animal procedures used in this study.

Cow Management. Brahman-influenced cows (n = 80; BCS = 5.6 ± 1.3) were assigned, during a 60-d breeding season, to graze (1 cow/ 0.7 ha) either common bermudagrass [CB; *Cynodon dactylon* (L.) Pers.; n = 3 (16 ha) pastures/ yr] or toxic tall fescue [E+; *Lolium* *arundinaceum* (Schreb.) Darbysh.; n = 3 (16 ha) pastures/ yr]. Cow body condition was assessed at d 0 (ConBC = cow BC during conception), 30, and 60 of the breeding season. From May 8 to July 11 (yr 1) and from May 8 to July 9 (yr 2), cows were exposed to Angus bulls (1 bull/ 20 cows) previously evaluated for breeding soundness. All cows grazed CB for 145 d following the 60-d breeding season, after which, all cows grazed stockpiled and spring-growth E+. Cows were managed to achieve marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8) BC (LateBC = cow BC during last trimester of pregnancy). Stocking rate during the last trimester was 1 cow/ 0.3 ha (marginal BC; BW = 462.3 ± 81 kg; BCS = 4.2 ± 0.8, where 1 = emaciated to 9 = obese; Wagner et al., 1988) or 1 cow/ 0.8 ha (good BC; BW = 585.2 ± 44 kg; BCS = 6.3 ± 0.8). Calving dates of cows ranged from February 11 to April 9 (yr 1) and from February 2 to April 9 (yr 2).

Forage Management. Pastures of both forage types were established > 20 yr and E+ pastures were > 85% endophyte-infected. Pastures were characterized three times (d 0, 30, and 60) during the breeding season to determine forage mass, nutritive value, and concentration of ergovaline. Forage mass was determined using a disk meter (Bransby et al., 1977) and forage height was recorded at 100 random locations in each pasture. Forage was clipped to ground level beneath the disk meter at each location per pasture to calibrate the disk meter. Samples were dried (60°C) in a forced-air oven for 72 h and weighed to calculate regression equations of DM/ha and disk meter height. Nutritional analysis of forage was carried out on random samples (20 samples/16 ha) collected at each sampling date. Dried forage samples were ground to pass through a 0.85-mm screen and analyzed for CP by rapid combustion (AOAC, 1990; Elementar Americas Inc., Mt. Laurel, NJ) and NDF using Ankom Technology (Macedon, NY) by the Agricultural Diagnostic Service Laboratory, University of Arkansas, Fayetteville. High-performance liquid chromatography was utilized to determine ergovaline concentrations

(Rottinghaus et al., 1991) on pooled samples taken from E+ pastures (20 samples/16 ha of pasture) cut into 5.1-cm pieces, and was stored at -4°C until determination.

Heifer Growth Characteristics. Weight of heifer calves (n = 80) was recorded at birth and adjusted for cow age. At weaning, heifers were weighed (WW; 7 to 8 mo) and managed as a single herd for 64 ± 2 d post-weaning at which time they were weighed (post-weaning weight, PWW; 9 to 10 mo of age) and measured for hip height (HH), hip width (HW), pelvic height (PH), pelvic width (PW), and pelvic area (PA). Hip height was measured using a sliding caliper (Altitude Stick, NASCO, Fort Atkinson, WI). Hip width was measured by firmly closing a clamp over the edge of the hook bones and measuring the distance between the clamp ends. Measurements for PH and PW were obtained per rectum using a Rice Pelvimeter (Lane Manufacturing, Denver, CO). Pelvic height was determined as the vertical distance between the pubis symphysis and the sacral vertebrae. Pelvic width was determined as the horizontal distance between the shafts of the ilia. Pelvic area was calculated as the product of PH x PW.

Statistical Analyses. Heifer growth measurements were analyzed by ANOVA within a split-plot design and a 2 x 2 x 2 treatment structure. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary, NC) with pasture as the experimental unit, heifer age as a covariate, and heifer within year as a repeated measure. Main effects were maternal breeding season forage (ConFor; E+ vs. CB), conception BC (ConBC; marginal vs. good), and BC during the last trimester of pregnancy (LateBC; marginal vs. good). All main effects and interactions were tested using Kenward-Rogers approximation for calculation of the df of the pooled error term and when F-tests were significant least squared means were separated using Tukey’s procedures. When interactions were not significant, the model was reduced.

RESULTS

Forage Characteristics. The interaction between ConFor and collection date influenced ($P < 0.01$) forage DM mass (Table 1), but did not influence NDF ($P = 0.73$) or CP ($P = 0.95$). The overall CP between forage type did not differ ($P > 0.60$). The CP percentage on d 0 was greater than d 30 and 60 of the study (day effect; $P < 0.01$; Table 1). Throughout the study, CB NDF percentage was greater ($P < 0.01$) than E+ pastures (Table 1) and d 60 NDF was greater ($P < 0.01$) than other collection dates (Table 1). Ergovaline concentrations ranged from 0.28 to 0.83 mg/ kg of DM (pooled SE = 0.058) for E+ pastures from May to July throughout the 2-yr study and the overall mean ergovaline concentration was 0.51 ± 0.034 mg/ kg of DM (Table 1).

Heifer Weights. Maternal conception forage influenced ($P = 0.05$) adjusted birth weight of heifers (Table 2). Cows grazing E+ during conception had heifers weighing less at birth compared with heifers from cows grazing CB (33.3 ± 0.6 kg vs. 35.2 ± 0.5 kg). Heifer WW tended ($P = 0.06$) to be affected by ConFor x ConBC interaction. The ConFor x LateBC interaction influenced ($P = 0.05$) heifer WW (242, 234, 244, and 212 ± 6 kg, respectively for heifers from cows grazing CB ConFor in good-LateBC, grazing CB in marginal-LateBC, grazing E+ in good-LateBC, and grazing E+ in marginal-LateBC). Interaction ($P = 0.05$) between ConFor and LateBC affected heifer PWW. At 9 to 10 mo of age, heifers from cows grazing E+ ConFor in marginal-LateBC weighed less than any other forage LateBC combination (241, 270, 259, and 260 kg, respectively E+ ConFor in marginal-LateBC, E+ ConFor in good-LateBC, CB ConFor in marginal-LateBC, and CB ConFor in good-LateBC). Interaction ($P = 0.08$) between ConFor and ConBC tended to affect PWW of heifers. All other interactions did not ($P > 0.20$) affect heifer birth weight, WW, or PWW (Table 3).

Heifer Body Measurements. Interaction between ConFor and LateBC affected ($P = 0.04$) heifer PA. Heifers from cows grazing E+ ConFor in good-LateBC had the largest PA compared to heifers from cows grazing E+ ConFor in marginal-LateBC, cows grazing CB ConFor in good-LateBC, and CB ConFor in marginal-LateBC (132, 112, 114, and 116 ± 5 cm^2, respectively). Heifer PH tended ($P = 0.07$) to be affected by the interaction between ConFor and LateBC (11.7, 11.9, 12.8, and 11.4 ± 0.3 cm, respectively for cows grazing CB ConFor in good-LateBC, CB ConFor in marginal-LateBC, E+ ConFor in good-LateBC, and E+ ConFor in marginal-LateBC). All other main effects interactions did not ($P > 0.10$) influence heifer HH, HW, or PW.

DISCUSSION

Maternal plane of nutrition during gestation has been associated with developmental programming of subsequent offspring which can impact pre- and postnatal growth (Wu et al., 2006; Greenwood and Cafe, 2007). Maternal undernutrition has been shown to negatively impact growth (Greenwood et al., 1998, 2000; Wu et al., 2006). Continuously restricting cows and heifers 100 d prepartum resulted in calves with lighter birth weights (Corah et al., 1975; Roberts et al., 2007).

As a consequence of cows grazing E+ during conception, heifer birth weights were lighter than heifers from cows grazing CB during the breeding season. Other studies have noted cows grazing E+ had calves with lighter birth weights (Brown et al., 2000; Watson et al., 2004; Burke et al., 2010). Nutrient restriction, by limit feeding hay or high stocking rates on E+, resulted in cows losing BW 90 d prepartum and lower calf birth weights (Morrison et al., 1999).

Cows grazing fescue-legume pastures weaned heavier calves compared to calves from cows grazing E+ (Holloway et al., 1979). Furthermore, WW were reduced for calves managed on E+ prior to weaning (Brown et al., 1999; Watson et al., 2004). Some studies have reported that feedlot performance was not affected by the influence of E+ during preweaning despite lower birth and/or weaning weights (Coffey et al., 1990).

Long et al. (2012) reported nutrient restriction to 70% of NRC recommendations during early- to mid-gestation did not affect WW. Differences in heifer WW observed in the current study were affected by nutrient restriction of cows during late gestation, which has been reported in previous studies (Corah et al., 1975). The long-term effects of cows grazing E+ during conception as well as nutrient restriction during late gestation may become more apparent in subsequent offspring selected as replacement heifers.

Body condition during late gestation tended to influence HW. Hip width measurements have been reported to be highly correlated with PA (Johnson et al., 1988). Heifer pelvic measurements were influenced by cow nutrient restriction during late gestation. Disproportionate calf birth weight relative to the pelvic dimensions of the dam was reported to be the major cause of dystocia (Bellows et al., 1971; Naazie et al., 1989). Utilizing heifer pelvic measurements could identify heifers with less calving difficulty (Johnson et al., 1988; Colburn et al., 1997).

Body condition score is an indicator of energy reserves that may be utilized to support physiological processes in situations of elevated metabolic demands (Lake et al., 2005; Funston et al., 2008). The priority of nutrient utilization can vary under different conditions during breeding and pregnancy (Funston et al., 2010). Cows in marginal-BC during the last trimester resulted in heifer offspring with reduced pelvic and hip growth. Ensuring cows are in good-BC during the last trimester of gestation may circumvent reduced post-natal growth and development of heifer progeny to be utilized as replacement breeding stock.

LITERATURE CITED

Bacon, C. W. 1995. Toxic endophyte-infected tall fescue and range grasses: Historical perspectives. J. Anim. Sci. 73:861-870.

Bellows, R. A., R. B. Gibson, D. C. Anderson, and R. E. Short. 1971. Precalving body size and pelvic area relationships in Hereford heifers. J. Anim. Sci. 33:455-457.

Bransby, D. I., A. G. Matches, and G. F. Krause. 1977. Disk meter for rapid estimation of herbage yield in grazing trials. Agron. J. 69:393-396.

Brown, M. A., A. H. Brown, Jr., W. G. Jackson, and J. R. Miesner. 2000. Genotype x environment interactions in Angus, Brahman, and reciprocal-cross cows and their calves grazing common bermudagrass, endophyte-infected tall fescue pastures, or both forages. J. Anim. Sci. 78:546-551.

Brown, M. A., W. A. Phillips, A. H. Brown, S. W. Coleman, W. G. Jackson, and J. R. Miesner. 1999. Postweaning performance of calves from Angus, Brahman, and reciprocal-cross cows grazing endophyte-infected tall fescue or common bermudagrass. J. Anim. Sci. 77:25-31.

Burke, J. M., S. W. Coleman, C. C. Chase, Jr., D. G. Riley, M. L. Looper, and M. A. Brown. 2010. Interaction of breed type and endophyte-infected tall fescue on milk production and quality in beef cattle. J. Anim. Sci. 88:2802-2811.

Coffey, K. P., L. W. Lomas, and J. L. Moyer. 1990. Grazing and subsequent feedlot performance by steers that grazed different types of fescue pasture. J. Prod. Agric. 3:415-4.

Colburn, D. J., G. H. Deutscher, M. K. Nielsen, and D. C. Adams. 1997. Effects of sire, dam traits, calf traits, and environments on dystocia and subsequent reproduction of two-year-old heifers. J. Anim. Sci. 75:1452-1460.

Corah, L. R., T. G. Dunn, and C. C. Kaltenbach. 1975. Influence of prepartum nutrition on the reproductive performance of beef females and the performance of their progeny. J. Anim. Sci. 41:819-824.

DeRouen, S. M., D. E. Franke, D. G. Morrison, W. E. Wyatt, D. F. Coombs, T. W. White, P. E. Humes, and B. B. Greene. 1994. Prepartum body condition and weight influences on reproductive performance of first-calf beef cows. J. Anim. Sci. 72:1119-1125.

Freetly, H. C., C. L. Ferrell, and T. G. Jenkins. 2000. Timing of realimentation of mature cows that were feed-restricted during pregnancy influences calf birth weights and growth rates. J. Anim. Sci. 78:2790-2796.

Funston, R. N., D. M. Larson, and K. A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: implications for beef cattle production. J. Anim. Sci. 88(E-Suppl.):205-215.

Funston, R. N., J. L. Martin, D. C. Adams, and D. M. Larson. 2008. Effects of winter grazing system and supplementation during late gestation on performance of beef cows and progeny. Proc. West. Sec. Am. Soc. Anim. Sci. 59:102-105.

Gay, N., J. A. Boling, R. Dew, and D. E. Miksch. 1988. Effects of endophyte-infected tall fescue on beef cow-calf performance. Appl. Agric. Res. 3:182.

Green, R. D., J. S. Brinks, and D. G. LeFever. 1988. Genetic characterization of pelvic measures in beef cattle: Heritabilities, genetic correlations and breed differences. J. Anim. Sci. 66:2842-2850.

Greenwood, P. L. and L. M. Cafe. 2007. Prenatal and pre-weaning growth and nutrition of cattle: long-term consequences for beef production. Animal 1(9):1283-1296.

Greenwood, P. L., A. S. Hunt, J. W. Hermanson, and A. W. Bell. 2000. Effects of birth weight and postnatal nutrition on neonatal sheep: II. Skeletal muscle growth and development. J. Anim. Sci. 78:50-61.

Greenwood, P. L., A. S. Hunt, J. W. Hermanson, and A. W. Bell. 1998. Effects of birth weight and postnatal nutrition on neonatal sheep: I. Body growth and composition, and some aspects of energetic efficiency. J. Anim. Sci. 76:2354-2367.

Holloway, J. W. W. T. Butts, Jr., J. D. Beaty, J. T. Hopper, and N. S. Hall. 1979. Forage intake and performance of lactating beef cows grazing high or low quality pastures. J. Anim. Sci. 48:692-700.

Johnson, S. K., G. H. Deutscher, and A. Parkhurst. 1988. Relationships of pelvic structure, body measurements, pelvic area and calving difficulty. J. Anim. Sci. 66:1081-1088.

Lake, S. L., E. J. Scholljegerdes, R. L. Atkinson, V. Nayigihugu, S. I. Paisley, D. C. Rule, G. E. Moss, T. J. Robinson, and B. W. Hess. 2005. Body condition score at parturition and postpartum supplemental fat effects on cow and calf performance. J. Anim. Sci. 83:2908-2917.

Long, N. M., C. B. Tousley, K. R. Underwood, S. I. Paisley, W. J. Means, B. W. Hess, M. Du, and S. P. Ford. 2012. Effects of early- to mid-gestational undernutrition with or without protein supplementation on offspring growth, carcass characteristics, and adipocyte size in beef cattle. J. Anim. Sci. 90:197-206.

Looper, M. L., S. T. Reiter, B. C. Williamson, M. A. Sales, D. M. Hallford, and C. F. Rosenkrans, Jr. 2010. Effects of body condition on measure of intramuscular and rump fat, endocrine factors, and calving rate of beef cows grazing common bermudagrass or endophyte-infected tall fescue. J. Anim. Sci. 88:4133-4141.

Morrison, D. G., J. C. Spitzer, and J. L. Perkins. 1999. Influence of prepartum body condition score change on reproduction in multiparous beef cows in moderate body condition. J. Anim. Sci. 77:1048-1054.

Naazie, A., M. M. Makarechian, and R. T. Berg. 1989. Factors influencing calving difficulty in beef heifers. J. Anim. Sci. 67:3243-3249.

Paputungan, U. and M. Makarechian. 2000. The influence of dam weight, body condition and udder scores on calf birth weight and preweaning growth rates in beef cattle. Asian-Aus. J. Anim. Sci. 13:435-439.

Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci. 73:889-898.

Roberts, A. J., S. I. Paisely, T. W. Geary, E. E. Grings, R. C. Waterman, and M. D. MacNeil. 2007. Effects of restricted feeding of beef heifers during the postweaning period on growth, efficiency, and ultrasound carcass characteristics. J. Anim. Sci. 85:2740-2745.

Rottinghaus, G. E., G. B. Garner, C. N. Cornell, and J. L. Ellis. 1991. An HPLC method for quantitating ergovaline in endophyte-infected tall fescue: seasonal variation of ergovaline levels in stems with leaf sheaths, leaf blade and seed heads. J. Agric. Food Chem. 39:112.

Wagner, J. J., K. S. Lusby, J. W. Oltjen, J. Rakestraw, R. P. Wettemann, and L. E. Walters. 1988. Carcass composition in mature Hereford cows: Estimation and effect on daily metabolizable energy requirement during winter. J. Anim. Sci. 66:603-612.

Watson, R. H., M. A. McCann, J. A. Parish, C. S. Hoveland, F. N. Thompson, and J. H. Bouton. 2004. Productivity of cow-calf pairs grazing tall fescue pastures infected with either wild-type endophyte or a nonergot alkaloid-producing endophyte strain, AR542. J. Anim. Sci. 82:3388-3393.

Wu, G., F. W. Bazer, J. M. Wallace, and T. E. Spencer. 2006. Board-invited review: Intrauterine growth retardation: Implications for the animal sciences. J. Anim. Sci. 84:2316-2337.

TABLES AND FIGURES

Table 1. Dry matter mass and nutrient content (DM basis) of common bermudagrass (CB) and toxic endophyte-infected tall fescue (E+) pastures grazed by beef cows during a 60-d breeding season.

	Forage environment			Day of breeding season				*P*-value		
Item	CB	E+	SE	0	30	60	SE	Forage	Day	Forage x day
DM, kg/ ha	3,130	6,166	219.3	4,548	4,465	4,932	185.7	< 0.01	0.04	< 0.01
CP, %	12.0^{a}	12.4^{a}	1.16	14.7^{a}	11.7^{b}	10.3^{b}	1.16	0.60	< 0.01	0.95
NDF, %	66.7^{a}	60.8^{b}	0.48	62.2^{a}	62.2^{a}	66.9^{b}	0.76	< 0.01	< 0.01	0.73
Ergovaline, mg/kg		0.51	0.034	0.48	0.48	0.57	0.058			

^{a,b}Means without common superscripts within row differ ($P < 0.01$).

Table 2. Effects of cow grazing common bermudagrass or toxic endophyte-infected tall fescue during conception, cow body condition during conception, and cow body condition during the last trimester of pregnancy on indicators of growth in beef heifers.

Item[5]	ConFor[1]		ConBC[2]		LateBC[3]		Pooled	Effects *P*-value[4]			
	CB	E+	Good	Marginal	Good	Marginal	SEM	Age	ConFor	ConBC	LateBC
Weight											
Birth, kg	35.2	33.2	34.7	33.7	34.6	33.8	± 0.5		0.03	0.21	0.28
Weaning, kg	238	230	236	232	243	225	± 4.0	0.004	0.22	0.59	0.02
Post-wean, kg	261	257	260	258	265	252	± 4.0	0.006	0.47	0.73	0.05
Hip											
Height, cm	117	115	116	115	116	115	± 0.7	0.11	0.10	0.28	0.21
Width, cm	34.3	33.9	34.1	34.1	34.6	33.6	± 0.3	0.02	0.47	0.90	0.07
Pelvic											
Height, cm	11.8	12.4	12.1	12.2	12.3	11.9	± 0.3	0.47	0.16	0.78	0.34
Width, cm	9.9	9.9	9.9	9.9	10.0	9.7	± 0.1	0.01	0.90	0.62	0.05
Area, cm^2	117	122	120	120	123.9	115.9	± 3.2	0.12	0.27	0.99	0.12

[1]ConFor = cow forage grazed during conception [common bermudagrass (CB) or toxic endophyte-infected tall fescue (E+)]
[2]ConBC = cow body condition (BC) during conception [marginal body condition score (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8)].
[3]LateBC = cow BC during the last trimester of pregnancy [marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8)].
[4]Main effects of ConFor, ConBC, and LateBC as well as Covariate (Age) *P*-values.
[5]Item = heifer growth indicators.

Influence of Maternal Environment during Conception and Late-Gestation, and Fescue Cultivar during Heifer Development on Growth and Fertility of Crossbred Beef Heifers

ABSTRACT

Objective was to determine effects of maternal forage type grazed during conception, cow body condition during conception and late-gestation, and heifer fescue cultivar grazed during development on heifer growth and fertility. Brahman-influenced cows (body condition score; BCS = 5.6 ± 1.3) were assigned to graze common bermudagrass (CB) or toxic endophyte-infected tall fescue (E+) for a 60-d breeding season (ConFor = cow conception forage) during 2 yr. Cow body condition (BC) was assessed at d 0, 30, and 60 of breeding season (ConBC = cow BC during conception). Cows were managed to achieve marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8) BC during the last trimester (LateBC = cow BC during late-gestation). At 9 to 10 mo of age, Angus-sired (1/8 to 1/4 Brahman) heifers (n = 80) were weighed and randomly assigned to replicated pastures of E+ or non-toxic (Novel) endophyte-infected tall fescue (Hfes = heifer fescue cultivar grazed during development) for 190 d during 2 yr. Heifer body weight and growth data were collected at initiation of grazing study (9 to 10 mo), yearling (11 to 12 mo), and prebreeding (13 to 14 mo). Heifer antral follicle count (AFC) was determined by ultrasound at yearling and prebreeding. Data were analyzed using mixed procedure with pasture as experimental unit, heifer age as a covariate, and heifer within year as a repeated measure. Main effects tested were ConFor, ConBC, LateBC, and Hfes. Heifers developed on E+ from cows in marginal-ConBC, grazing E+ ConFor, and in marginal-LateBC had the lowest ($P < 0.0001$) ADG compared to Novel heifers from cows in good-ConBC, grazing E+ ConFor, and in good-LateBC(-0.30 vs. 0.58 ± 0.03 kg). Pelvic height ($P < 0.0001$) was influenced by ConBC x ConFor x LateBC x Hfes interaction where heifers developed on E+ from cows in marginal-

ConBC, grazing CB ConFor, and in good-LateBC had the smallest PH. Heifer AFC was affected (*P* < 0.0001) by ConBC x ConFor x LateBC x Hfes interaction. Novel heifer AFC from cows in good-ConBC, grazing CB ConFor and in marginal-LateBC was greater at yearling compared to E+ heifer AFC (25.1 ± 0.8 vs. 3.8 ± 2.4 follicles) from cows in marginal-ConBC, grazing CB ConFor and in good-LateBC. Heifer pregnancy rate was influenced (*P* < 0.05) by LateBC x Hfes (90.3, 69.6, 50.0, 43.8 %, respectively Novel Hfes from cows in good-LateBC, Novel Hfes from cows in marginal-LateBC, E+ Hfes from cows in good-LateBC, and E+ Hfes from cows in marginal-LateBC). Ensuring cows are in adequate BC during conception and late-gestation will result in increased pelvic growth, more antral follicles, and improved pregnancy rates of heifer offspring.

INTRODUCTION

Nutrient restricted cows often lose body condition (BC) during pregnancy and postpartum, which can impact offspring growth, development, and subsequent reproductive performance (Freetly et al., 2000; Funston et al., 2010). Wild-type tall fescue [E+; *Lolium arundinaceum* (Schreb.) Darbysh.] is an excellent forage species that is well adapted to the Midwestern and Southeastern United States of America due to its drought resistance, and toxicity to insects (Bacon, 1995). Cattle grazing toxic endophyte-infected tall fescue (E+) can suffer fescue toxicosis which is characterized by elevated body temperature, reduced feed intake, and decreased ADG (Goetsch et al., 1987; Looper et al., 2006; Paterson et al., 1995; Schmidt and Osborn, 1993). Looper et al. (2010) reported cows with marginal-BC grazing E+ had reduced calving rates. Watson et al. (2004) demonstrated body condition score (BCS) of cows grazing E+ was lower, cow ADG was reduced, and cows birthed lighter calves. Heifers grazing E+ have suppressed growth which could be detrimental to reproductive processes including pregnancy rates (Paterson et al., 1995; Porter and Thompson, 1992; Schmidt and Osborn, 1993).

Heifers fed diets containing ergot alkaloids resulted in reduced follicle numbers and preovulatory follicle diameter, which was exacerbated during heat stress (McKenzie and Erickson, 1991; Burke et al., 2001). Fewer antral follicles during estrous cycles could impact fertility as antral follicle count has been positively associated with fertility in cattle (Burns et al., 2005; Ireland et al., 2008; Cushman et al., 2009).

The negative effects of cattle grazing E+ led to the development of non-toxic endophyte-infected tall fescue (Novel; Bouton et al., 2002; Nihsen et al., 2004; West et al., 2001). Research has demonstrated cattle grazing Novel do not exhibit signs of fescue toxicosis and show improved performance compared to cattle grazing E+ (Nihsen et al., 2004; Parish et al., 2003; Watson et al., 2004). Objective of this study was to determine effects of maternal forage type grazed during conception, cow body condition (BC) during conception, BC during late-gestation, and fescue cultivar during heifer development on growth and fertility of beef heifers.

MATERIALS AND METHODS

The committee for animal welfare at the USDA-ARS, Dale Bumpers Small Farms Research Center, Booneville, Arkansas, and the University of Arkansas Institutional Animal Care and Use Committee (No. 040200) approved animal procedures used in this study.

Cow Management. Brahman-influenced cows [n = 80; body condition score (BCS) = 5.6 ± 1.3] were assigned, during a 60-d breeding season, to graze (1 cow/ 0.7 ha) either common bermudagrass [CB; *Cynodon dactylon* (L.) Pers.; n = 3 (16 ha) pastures/ yr] or toxic tall fescue [E+; *Lolium arundinaceum* (Schreb.) Darbysh.; n = 3 (16 ha) pastures/ yr]. Cow body condition was assessed at d 0 (ConBC = cow BC during conception), 30, and 60 of the breeding season. From May 8 to July 11 (yr 1) and from May 8 to July 9 (yr 2), cows were exposed to Angus bulls (1 bull/ 20 cows) previously evaluated for breeding soundness. All cows grazed CB for 145 d following the 60-d breeding season, after which all cows grazed stockpiled and spring-growth E+. Cows were managed to achieve marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8) BC during last trimester of pregnancy (LateBC = cow BC). Stocking rate during the last trimester was 1 cow/ 0.3 ha [marginal BC; body weight (BW) = 462.3 ± 81 kg; BCS = 4.2 ± 0.8, where 1 = emaciated to 9 = obese; Wagner et al., 1988] or 1 cow/ 0.8 ha (good BC; BW = 585.2 ± 44 kg; BCS = 6.3 ± 0.8). Calving dates of cows ranged from February 11 to April 9 (yr 1) and from February 2 to April 9 (yr 2).

Forage Management. Pastures of both forage types were established > 20 yr and E+ pastures were > 85% endophyte-infected. Pastures were characterized three times (d 0, 30, and 60) during the breeding season to determine forage mass, nutritive value, and concentration of ergovaline. Forage mass was determined using a disk meter (Bransby et al., 1977) and forage height was recorded at 100 random locations in each pasture. Forage was clipped to ground level beneath the disk meter at each location per pasture to calibrate the disk meter. Samples were dried (60°C) in a forced-air oven for 72 h and weighed to calculate regression equations of DM/ha and disk meter height. Nutritional analysis of forage was carried out on random samples (20 samples/16 ha) collected at each sampling date. Dried forage samples were ground to pass through a 0.85-mm screen and analyzed for CP by rapid combustion (AOAC, 1990; Elementar Americas Inc., Mt. Laurel, NJ) and NDF using Ankom Technology (Macedon, NY) by the Agricultural Diagnostic Service Laboratory, University of Arkansas, Fayetteville. High-performance liquid chromatography was utilized to determine ergovaline concentrations

(Rottinghaus et al., 1991) on pooled samples taken from E+ pastures (20 samples/16 ha of pasture) cut into 5.1-cm pieces, and was stored at -4°C until determination.

Heifer Forage Management. In two subsequent years, Angus-sired (1/8 to 1/4 Brahman) heifers (n = 80) were weighed at weaning (240 ± 30 kg) and managed on CB pasture (16 ha) for 64 ± 2 d. Heifers (9 to 10 mo of age) were blocked by weight and randomly assigned (4 head/ pasture) to replicated pastures (1 ha) of E+(n = 3 pastures) or non-toxic endophyte-infected tall fescue [four HiMag (Novel) tall fescue with strain 4 endophyte (HiMag4; Nihsen et al., 2004), and four (three pastures in yr 2; Novel) Jesup tall fescue with the AR542 endophyte strain (MaxQ™; Bouton et al., 2002)].

Heifer Weight and Growth Measurements. Heifer weights and body dimensions were determined at weaning (7 to 8 mo), post-weaning (9 to 10 mo), yearling (10 to 11 mo), and prebreeding (13 to 14 mo). Body dimensions were: hip height (HH), hip width (HW), pelvic height (PH), pelvic width (PW), and pelvic area (PA). Hip height was measured using a sliding caliper. (Altitude Stick, NASCO, Fort Atkinson, WI). Hip width was measured by firmly closing a clamp over the edge of the hook bones and measuring the distance between the clamp ends. Measurements for PH and PW were obtained per rectum using a Rice Pelvimeter (Lane Manufacturing, Denver, CO). Pelvic height was determined as the vertical distance between the pubis symphysis and the sacral vertebrae. Pelvic width was determined as the horizontal distance between the shafts of the ilia. Pelvic area was calculated as the product of PH x PW. Exit velocity (EV; rate at which the heifers exited the squeeze chute and traversed 1.83 m) was determined using two infrared sensors (FarmTek, Inc., North Wiley, TX) and recorded as time (s)/distance (m).

Heifer Reproductive Traits. Antral follicle count (AFC; total number of follicles >3mm in diameter on both ovaries, Burns et al., 2005) was determined by an individual technician using real-time ultrasonography (Aloka 500 V®; Corometrics, Wallingford, CT, equipped with a 7.5-MHz transducer). Those counts were determined twice at yearling (d 73 ± 2 and 85 ± 2) and prebreeding (d 175 ± 2 and d 187). Heifers received 100 mg GnRH (Cystorelin, Merial LLC, Duluth, GA) on d 187 along with a controlled internal drug-releasing device (CIDR; Pfizer Animal Health, New York, NY) for 7 d and administered 25 mg $PGF_2\alpha$ at removal of CIDR. On d 194, all heifers were fitted with a radio-telemetry transmitter (HeatWatch, Cow Chips LLC, Denver, CO). Estrous activities were recorded for each heifer during the first 30 d of breeding season and included date and time of the onset of estrus, number of mounts received, duration (h) of estrus, as well as the quiescent (no estrus activity between two individual mounts) period. During the 60 d breeding season, all heifers were removed from fescue pastures and maintained as a single herd on a CB pasture (16 ha) to avoid the potential effects of fescue on bull fertility. Three Angus bulls, previously evaluated for breeding soundness were used during the 60 d breeding season. Pregnancy was determined 60 d after the breeding season.

Statistical Analyses. Heifer growth measurements were analyzed by ANOVA within a split-plot design. Growth measurements, estrous behavior and AFC were analyzed using the mixed procedure of SAS (SAS Inst., Cary, NC) with pasture within year as the experimental unit, heifer age as a covariate, and heifer within year as a repeated measure. The main effects tested were maternal forage grazed during conception (ConFor = cow forage grazed during conception; E+ or CB), conception BC (ConBC; marginal vs. good), BC during the last trimester of pregnancy (LateBC; marginal vs. good), and heifer fescue cultivar grazed during development (Hfes = E+ or Novel). In addition, interactions of main effects were included in the model. When interactions were not significant, the model was reduced. All main effects and interactions were tested using Kenward-Rogers approximation for calculation of the df of the pooled error term and when F-tests were significant least squared means were separated using Tukey's procedures. Percentage of heifers exhibiting estrus during the first 30 d of the breeding season and pregnancy rate were analyzed by Chi-square analysis.

RESULTS

The covariate of heifer age was significant ($P < 0.05$) for post-weaning body weight (BW), yearling BW, average daily gain (ADG), HW, and pre-breeding AFC. Heifer BW increased ($P < 0.0001$) as heifers got older and was influenced by a 4-way interaction of main effects (Figure 1). As with BW heifer ADG was ($P < 0.0001$) affected by ConBC x ConFor x LateBC x Hfes interaction (Figure 2). That interaction, in part, can be attributed to heifers developed on Novel compared to heifers grazing E+ during development (0.54 ± 0.01 vs. 0.35 ± 0.02 kg/d).

Hip height and HW increased ($P < 0.0001$) over time. Heifer HH was influenced ($P = 0.002$) by the interaction between ConBC and ConFor where heifers from cows grazing E+ in good-ConBC had the smallest HH compared to heifers from cows grazing CB in good-ConBC, cows grazing E+ in marginal-ConBC, and cows grazing CB in marginal-ConBC (119.2, 123.0, 121.5, and 121.2 ± 0.7 cm, respectively). Interaction between ConFor and LateBC influenced ($P = 0.0002$) heifer HH. Heifers from grazing E+ during conception in marginal-LateBC had the smallest HH compared to heifers from cows grazing E+ ConFor in good-LateBC, cows grazing CB in marginal-LateBC, and cows grazing CB in good-LateBC (117.9, 122.7, 122.4, 121.8 ± 0.7 cm, respectively). Heifer HH was affected by the main effect of ConFor (Table 1). Hip Width was affected (*P* = 0.04) by the LateBC by Hfes interaction. Heifers from cows in marginal-LateBC developed on E+ had the smallest HW compared to HW of heifers from cows in marginal-LateBC developed on Novel, cows in good-LateBC developed on E+, and cows in good-LateBC developed on E+ (36.0, 37.7, 37.7, 37.7 ± 0.4 cm, respectively). Heifer HW was influenced (*P* = 0.01) by the main effect of Hfes (Table 1), but was not affected (*P* > 0.13) by other main effects or their interactions.

Heifer PH (*P* < 0.0001) increased over time. Interaction between ConBC x ConFor x LateBC x Hfes affected (*P* < 0.0001) heifer PH. Pelvic height of E+ heifers from cows in marginal-ConBC, grazing E+ ConFor, and in good-LateBC was greater compared to PH of E+ heifers from cows in marginal-ConBC, grazing CB ConFor, and in good-LateBC (14.56 ± 0.76 cm vs. 10.28 ± 0.6 cm). Heifer PW and PA increased (*P* < 0.0001) over time but were not altered by the interaction between ConBC x ConFor x LateBC x Hfes. Pelvic width was affected (*P* = 0.004) by LateBC where PW of heifers from cows in good-LateBC was greater compared to PW of heifers from cows in marginal LateBC (11.4 ± 0.1 cm vs. 11.0 ± 0.1 cm, respectively; Table 1). Heifer PW was not (*P* > 0.13) influenced by other main effects or their interactions.

Yearling heifer EV was (*P* = 0.002) affected by the ConBC x ConFor x Hfes 3-way interaction. Heifers developed on E+ from cows in good-ConBC, grazing CB during conception exited the chute faster compared to E+ heifers from cows in marginal-ConBC, grazing CB during conception (23.4 ± 11.9 s/m vs.105.3 ± 13.6 s/m, respectively). Post-weaning and prebreeding heifer EV was not (*P* > 0.32) affected by main effects or their interactions.

Antral follicle count was influenced by scan date (*P* < 0.0001). Yearling heifer AFC was (*P* < 0.0001) affected by the ConBC x ConFor x LateBC x Hfes interaction (Table 2). Novel heifers from cows in good-ConBC, grazing CB ConFor and in marginal-LateBC had the most antral follicles at yearling compared to E+ heifers from cows in marginal-ConBC, grazing CB ConFor and in good-LateBC (25.1 ± 0.8 follicles vs. 3.8 ± 2.4 follicles, respectively). Prebreeding heifer AFC was ($P = 0.002$) affected by the ConBC x ConFor x LateBC x Hfes interaction (Table 2). Heifers developed on E+ from cows in good-ConBC, grazing E+ ConFor and in good-LateBC had the most antral follicles at prebreeding compared to Novel heifers from cows in good-ConBC, grazing E+ ConFor and in marginal-LateBC (24.4 ± 1.3 follicles vs. 12.8 ± 1.3 follicles, respectively).

Interaction between ConFor and Hfes affected ($P = 0.02$) the percentage of Novel heifers exhibiting estrus as recorded by HeatWatch during the first 30 d of the breeding season (Table 3). More heifers exhibited estrus that were developed on Novel from cows grazing E+ during conception compared to Novel heifers from cows grazing CB during conception (83% vs. 54%, respectively). Interaction between ConBC and Hfes did not ($P > 0.13$) affect the percentage of E+ heifers exhibiting estrus. Interaction between LateBC and Hfes did not ($P > 0.74$) affect the percentage of Novel or E+ heifers exhibiting estrus. Number of mounts during estrus was ($P < 0.0001$) affected by the ConBC x ConFor x LateBC x Hfes interaction (Table 3). Novel heifers from cows in good-ConBC, grazing E+ ConFor and in marginal-LateBC had the most mounts during estrus compared to E+ heifers from cows in good-ConBC, grazing E+ ConFor and in marginal-LateBC (24.9 ± 1.7 mounts vs. 7.6 ± 2.0 mounts, respectively). Duration of estrus was ($P = 0.02$) affected by the ConBC x ConFor x LateBC x Hfes interaction (Table 3). Novel heifers from cows in marginal-ConBC, grazing CB ConFor and in good-LateBC had the longest duration of estrus compared to E+ heifers from cows in marginal-ConBC, grazing E+ ConFor and in good-LateBC (9.0 ± 0.6 hr vs. 2.6 ± 1.4 hr, respectively). Heifer quiescence was ($P < 0.0001$) affected by the ConBC x ConFor x LateBC x Hfes interaction (Table 3). Heifers developed on E+ from cows in marginal-ConBC, grazing E+ ConFor and in good-LateBC had the shortest quiescence, while E+ heifers from cows in good-ConBC, grazing CB ConFor and in marginal-LateBC had the longest (16.8 ± 8.4 min vs. 62.4 ± 4.2 min, respectively) quiescence.

Heifer pregnancy rate was influenced ($P = 0.05$) by LateBC x Hfes (90.3, 69.6, 50.0, 43.8 % pregnant: Novel heifers from cows in good-LateBC, Novel heifers from cows in marginal-LateBC, E+ heifers from cows in good-LateBC, and E+ heifers from cows in marginal-LateBC, respectively). All other interactions did not ($P > 0.20$) affect heifer pregnancy rate.

DISCUSSION

The quality of maternal nutrition during conception and late-gestation could impact postnatal growth, development, and subsequent reproductive performance of offspring (Martin et al., 2007; Funston et al., 2010). Since the discovery of toxins in tall fescue, research has focused on production implications of livestock grazing E+ and the effects of this endophyte infected grass on different aspects of animal agriculture. Overall ADG of heifers developed on Novel was greater compared to heifers developed on E+, which is consistent with previous research (Watson et al., 2004). Heifers developed on E+ from cows in marginal-BC during conception and from cows in marginal-BC during late gestation had lower ADG. Heifers born from thin cows and then developed on E+ suffered a double insult, which likely contributed to reduced ADG.

Antral follicle count has been positively associated with fertility in cattle and has consequently been used as a predictor of fertility (Burns et al., 2005; Ireland et al., 2007; Cushman et al., 2009). Maternal environment has an important role in the regulation of and or variation in ovarian reserve as measured by AFC (Ireland et al., 2011). In fact, maternal nutrient restriction during conception and the first trimester of pregnancy (the period encompassing the peak in fetal oocyte numbers) resulted in 60% lower AFC in heifers born to nutrient restricted cows (Mossa et al., 2009). Mean AFC in the current study was lower in heifers from cows in marginal-BC during conception compared to heifers from cows in good-BC during conception substantiating the importance of maternal BC during conception and early pregnancy on subsequent heifer AFC.

Jones et al. (2003) reported differences in estrous cycles of heifers consuming an E+ seed diet. No differences in estrous activity were noted in cows grazing E+ compared to cows grazing CB (Looper et al., 2008). Problems associated with reduced estrus activity may manifest in heifers grazing E+ if heifers were born from nutrient restricted cows. Furthermore, nutrient restriction and BW loss in heifers resulted in cessation of estrous cycles (Wettemann and Bossis, 1999).

Heifers receiving ergotamine to simulate cattle grazing E+ produced embryos of reduced quality and development, and embryo recovery rate tended to be lower compared to control heifers (Schuenemann et al., 2005). Embryos collected from donors not consuming ergotamine and transferred on d 7 into recipients consuming ergotamine tartrate revealed no differences in pregnancy rates. Those results suggest the deleterious effects of ergot alkaloids on pregnancy rates occur before d 7 during oocyte maturation or early stages of embryonic development (Schuenemann et al., 2005). Our data are consistent with previous research in that cattle consuming E+ forage have reduced pregnancy rates (Paterson et al., 1995; Schmidt and Osborn, 1993; Stricker et al., 1979; Tucker et al., 1989).

Nutrition has been shown to affect growth as indicated by weight at puberty and skeletal body measurements (Ferrell, 1982; Gombe and Hansel, 1973; Nelsen et al., 1982). Using growth indicators revealed heifers from thin cows, developed on E+ had reduced overall growth compared to heifers developed on Novel. Reduced heifer growth affects critical events such as first calving, and increased incidences of dystocia in heifers with smaller pelvic dimensions (Bellows et al., 1971; Johnson et al., 1988; Stevenson and Call, 1988).

Consistent with previous research, heifers developed on toxic tall fescue had reduced growth compared to heifers grazing Novel fescue during development (Watson et al., 2004). Growth of E+ heifers was further decreased by a marginal-maternal-BC during conception and maternal nutrient restriction during late-gestation. Variations in maternal environment negatively impacted ovarian reserve, specifically noted by the significant effect of cow body condition during conception on AFC of heifer offspring. Overall pregnancy rates were lower for heifers developed on E+ compared to Novel and was further impacted by maternal BC during late-gestation. Utilizing growth indicators such as skeletal body measurements in combination with Novel fescue for development of replacement beef heifers will result in increased ADG. Ensuring cows are in adequate BC during conception and late-gestation will result in increased pelvic growth, more antral follicles, and improved pregnancy rates of their heifer offspring.

LITERATURE CITED

Bacon, C. W. 1995. Toxic endophyte-infected tall fescue and range grasses: Historical perspectives. J. Anim. Sci. 73:861-870.

Bellows, R. A., R. B. Gibson, D. C. Anderson, and R. E. Short. 1971. Precalving body size and pelvic area relationships in Hereford heifers. J. Anim. Sci. 33:455-457.

Bransby, D. I., A. G. Matches, and G. F. Krause. 1977. Disk meter for rapid estimation of herbage yield in grazing trials. Agron. J. 69:393-396.

Bouton, J. H., G. C. M Latch, N. S. Hill, C. S. Hoveland, M. A. McCann, R. H. Watson, J. A. Parish, L. C. Hawkins, and F. N. Thompson. 2002. Reinfection of tall fescue cultivars with nonergot alkaloid producing endophytes. Agron. J. 94:567-574.

Burke, J. M., D. E. Spiers, F. N. Kojima, G. A. Perry, B. E. Salfen, S. L. Wood, D. J. Patterson, M. F. Smith, M. C. Lucy, W. G. Jackson, and E. L. Piper. 2001. Interaction of endophyte-infected fescue and heat stress on ovarian function in the beef heifer. Biol. Reprod.65:260-268.

Burns, D. S., F. Jimenez-Krassel, J. L. H. Ireland, P. G. Knight, and J. J. Ireland. 2005. Numbers of antral follicles during follicular waves in cattle: Evidence for high variation among individuals, very high repeatability in individuals, and an inverse association with serum follicle-stimulating hormone concentrations. Biol. Reprod. 73: 54-62.

Cushman, R. A., M. F. Allan, L. A. Kuehn, W. M. Snelling, A. S. Cupp, and H. C. Freetly. 2009. Evaluation of antral follicle count and ovarian morphology in crossbred beef cows: Investigation of influence of stage of estrous cycle, age, and birth weight. J. Anim. Sci. 87:1971-1980.

Ferrell, C. L. 1982. Effects of postweaning rate of gain on onset of puberty and productive performance of heifers of different breeds. J. Anim. Sci. 55:1272-1283.

Freetly, H. C., C. L. Ferrell, and T. G. Jenkins. 2000. Timing of realimentation of mature cows that were feed-restricted during pregnancy influences calf birth weights and growth rates. J. Anim. Sci. 78:2790-2796.

Funston, R. N., D. M. Larson, and K. A. Vonnahme. 2010. Effects of maternal nutrition on conceptus growth and offspring performance: implications for beef cattle production. J. Anim. Sci. 88(E-Suppl.):205-215.

Goetsch, A. L., A. L. Jones, S. R. Stokes, K. W. Beers, and E. L. Piper. 1987. Intake, digestion, passage rate, and serum prolactin in growing dairy steers fed endophyte-infected fescue with noninfected fescue, clover or wheat straw. J. Anim. Sci. 64:1759-1768.

Gombe, S. and W. Hansel. 1973. Plasma luteinizing hormone (LH) and progesterone levels in heifers on restricted energy intakes. J. Anim. Sci. 37:728-733.

Ireland, J. J., G. W. Smith, D. Scheetz, F. Jimenez-Krassel, J. K. Folger, J. L. H. Ireland, F. Mossa, P. Lonergan, and A. C. O. Evans. 2011. Does size matter in females? An overview of the impact of high variation in the ovarian reserve on ovarian function and fertility, utility of anti-Mullerian hormone as a diagnostic marker for fertility and causes of variation in the ovarian reserve in cattle. Reprod. Fertil. Dev. 23:1-14.

Ireland, J. L. H., D. Scheetz, F. Jimenez-Krassel, A. P. N. Themmen, F. Ward, P. Longeran, G. W. Smith, G. I. Perez, A. C. O. Evans, and J. J. Ireland. 2008. Antral follicle count reliability predicts number of morphologically healthy oocytes and follicles in ovaries of young adult cattle. Biol. Reprod.79:1219-1225.

Ireland, J. J., F. Ward, F. Jimenez-Krassel, J. L. H. Ireland, G. W. Smith, P. Lonergan, and A. C. O. Evans. 2007. Follicle numbers are highly repeatable within individual animals but are inversely correlated with FSH concentrations and the proportion of good-quality embryos after ovarian stimulation in cattle. Human Reprod. 22:1687-1695.

Johnson, S. K., G. H. Deutscher, and A. Parkhurst. 1988. Relationships of pelvic structure, body measurements, pelvic area and calving difficulty. J. Anim. Sci. 66:1081-1088.

Jones, K. L., S. S. King, K. E. Griswold, D. Cazac, and C. L. Cross. 2003. Domperidone can ameliorate deleterious reproductive effects and reduced weight gain associated with fescue toxicosis in heifers. J. Anim. Sci. 81:2568-2574.

Looper, M. L., T. S. Edrington, R. Flores, C. F. Rosenkrans, Jr., M. E. Nihsen, and G. E. Aiken. 2006. Prevalence of Escherichia coli O157:H7 and Salmonella in beef steers consuming different forage diets. Lett. Appl. Microbiol. 42:583-588.

Looper, M. L., S. T. Reiter, S. Nabhan, R. Flores, C. R. Bailey, A. H. Brown, Jr., and C. F. Rosenkrans, Jr. 2008. Body condition and forage type influence intramuscular and rump fat, and reproductive performance of postpartum Brahman-influenced cows. AAES Research Series 563:50-52.

Looper, M. L., S. T. Reiter, B. C. Williamson, M. A. Sales, D. M. Hallford, and C. F. Rosenkrans, Jr. 2010. Effects of body condition on measure of intramuscular and rump fat, endocrine factors, and calving rate of beef cows grazing common bermudagrass or endophyte-infected tall fescue. J. Anim. Sci. 88:4133-4141.

Martin, J. L., K. A. Vonnahme, D. C. Adams, G. P. Lardy, and R. N. Funston. 2007. Effects of dam nutrition on growth and reproductive performance of heifer calves. J. Anim. Sci. 85:841-847.

McKenzie, P. P. and B. H. Erickson. 1991. Effects of fungal-infested fescue on gonadotropin secretion and folliculogenesis in beef heifers. J. Anim. Sci. (Suppl 1) 69:387 (Abstr.)

Mossa, F., D. Kenny, F. Jimenez-Krassel, G. W. Smith, D. Berry, S. Butler, T. Fair, P. Lonergan, J. J. Ireland, and A. C. O. Evans. 2009. Undernutrition of heifers during the first trimester of pregnancy diminishes size of the ovarian reserve in female offspring. Biol. Reprod. 81: Abstract 135.

Nelsen, T. C., C. R. Long, and T. C. Cartwright. 1982. Postinflection growth in straightbred and crossbred cattle. II. Relationships among weight, height and pubertal characters. J. Anim. Sci. 55:293-304.

Nihsen, M. E., E. L. Piper, C. P. West, R. J. Crawford, Jr., T. M. Denard, Z. B. Johnson, C. A. Roberts, D. A. Spiers, and C. F. Rosenkrans, Jr. 2004. Growth rate and physiology of steers grazing tall fescue inoculated with novel endophytes. J. Anim. Sci. 82:878-883.

Parish, J. A., M. A. McCann, R. H. Watson, N. N. Paiva, C. S. Hoveland, A. H. Parks, B. L. Upchurch, N. S. Hill, and J. H. Bouton. 2003. Use of non-ergot alkaloid-producing endophytes for alleviating tall fescue toxicosis in stocker cattle. J. Anim. Sci. 81:2856-2868.

Paterson, J., C. Forcherio, B. Larson, M. Samford, and M. Kerley. 1995. The effects of fescue toxicosis on beef cattle productivity. J. Anim. Sci.73:889-898.

Porter, J. K. and F. N. Thompson. 1992. Effects of fescue toxicosis on reproduction in livestock. J. Anim. Sci. 70:1594-1603.

Rottinghaus, G. E., G. B. Garner, C. N. Cornell, and J. L. Ellis. 1991. An HPLC method for quantitating ergovaline in endophyte-infected tall fescue: seasonal variation of ergovaline levels in stems with leaf sheaths, leaf blade and seed heads. J. Agric. Food Chem. 39:112.

Schmidt, S. P., and T. G. Osborn. 1993. Effects of endophyte-infected tall fescue on animal performances. Agric. Ecosyst. & Environ. 44:233.

Schuenemann, G. M., M. E. Hockett, J. L. Edwards, N. R. Rohrbach, K. BF. Breuel, F. N. Schrick. 2005. Embryo development and survival in beef cattle administered ergotamine tartrate to simulate fescue toxicosis. Reprod. Biol. 5:137-150.

Stevenson, J. S. and E. P. Call. 1988. Reproductive disorders in the periparturient dairy cow. J. Dairy Sci. 71:2572-2583.

Stricker, J. A., a. G. Matches, G. B. Thompson, V. E. Jacobs, F. A. Martz, H. N. Wheaton, H. D. Currence, and G. F. Krause. 1979. Cow-calf production on tall fescue-ladino clover pastures with and without nitrogen fertilization or creep feeding: spring calves. J. Anim. Sci. 48:13-25.

Tucker, C. A., R. E. Morrow, J. R. Gerrish, C. J. Nelson, G. B. Garner, V. E. Jacobs, W. G. Hires, J. J. Shinkle, and J. R. Forwood. 1989. Forage systems for beef cattle: Effect of winter supplementation and forage system on reproductive performance of cows. J. Prod. Agric. 2:217-221.

Watson, R. H., M. A. McCann, J. A. Parish, C. S. Hoveland, F. N. Thompson, and J. H. Bouton. 2004. Productivity of cow-calf pairs grazing tall fescue pastures infected with either the wild-type endophyte or a nonergot alkaloid-producing endophyte strain, AR542. J. Anim. Sci. 82:3388-3393.

West, C. P., E. L. Piper, M. E. Nihsen, S. A. Gunter, K. A. Cassida, D. A. Spiers, C. A. Roberts, and R. C. Crawford. 2001. Performance of cattle on “HiMag” tall fescue infected with novel endophytes. Page 262 in Proc. Amer. Forage Grassl. Coun. Vol. 10. Springdale, AR.

Wettemann, R. P. and I. Bossis. 1999. Energy intake regulates ovarian function in beef cattle. Proc. Amer. Soc. An. Sci. 1-10.

TABLES AND FIGURES

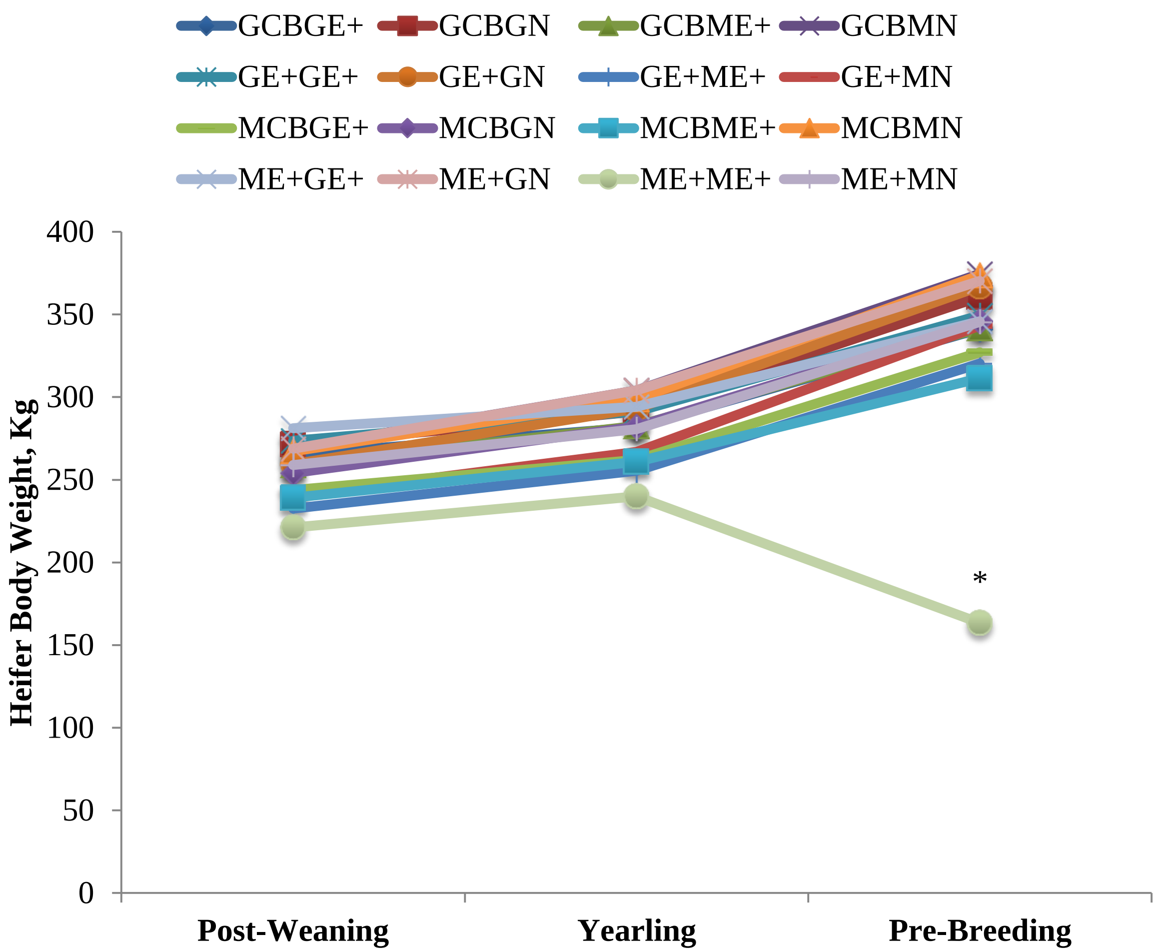

Figure 1. Heifer body weight during development effected by the interaction between conception body condition (BC) of cow (ConBC[1]) x cow forage grazed during conception (ConFor[2]) x cow body condition during late gestation (LateBC[3]) x heifer fescue[4] cultivar grazed during development ($P < 0.0001$; pooled SEM = 42).

[1]ConBC = Good (BCS = 6.3 ± 0.8) or Marginal (BCS = 4.2 ± 0.8)
[2]Confor = common bermudagrass (CB) or toxic endophyte-infected tall fescue grazed (E+)
[3]LateBC = Good or Marginal
[4]Heifer fescue cultivar = toxic (E+) or non-toxic (Novel) endophyte-infected tall fescue

Abbreviations: **GCBG** = good-ConBC, CB, good-LateBC; **GCBM** = good-ConBC, CB, marginal-LateBC; **GE+G** = good-ConBC, E+, good-LateBC; **GE+M** = good-ConBC, E+, marginal-LateBC; **MCBG** = marginal-ConBC, CB, good-LateBC; **MCBM** = marginal-ConBC, CB, marginal-LateBC; **ME+G** = marginal-ConBC, E+, good-LateBC; **ME+M** = marginal-ConBC, E+, marginal-LateBC

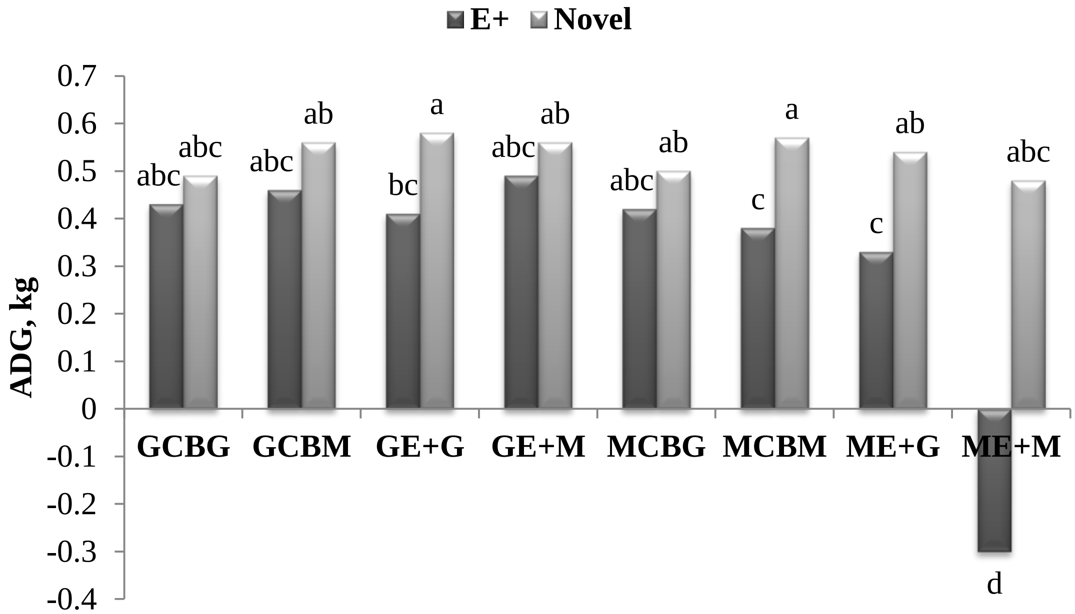

Figure 2. Heifer ADG during development effected by the interaction between conception body condition (BC) of cow (ConBC[1]) x cow forage grazed during conception (ConFor[2]) x cow body condition during late gestation (LateBC[3]) x heifer fescue[4] cultivar grazed during development (*P* < 0.0001; SEM = 0.03 kg).

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[1]ConBC = Good (BCS = 6.3 ± 0.8) or Marginal (BCS = 4.2 ± 0.8)
[2]Confor = common bermudagrass (CB) or toxic endophyte-infected tall fescue grazed (E+)
[3]LateBC = Good or Marginal
[4]Heifer fescue cultivar = toxic (E+) or non-toxic (Novel) endophyte-infected tall fescue

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Table 1. Effects of cow grazing common bermudagrass or toxic endophyte-infected tall fescue during conception, cow body condition during conception, and cow body condition during the last trimester of pregnancy on indicators of growth in beef heifers.

	ConFor[1]		ConBC[2]		LateBC[3]		Hfes[4]		Pooled	Effects *P*-value[5]			
Item	CB	E+	Good	Marg	Good	Marg	E+	Novel	SEM	ConFor	ConBC	LateBC	Hfes
Weight													
Postwean, kg	260	254	259	256	264	251	245	261	± 4.0	0.35	0.64	0.05	0.22
Yearling, kg	284	280	284	280	586	278	273	291	± 4.0	0.40	0.44	0.15	0.007
Prebreed, kg	345	333	347	331	345	333	319	359	± 4.0	0.20	0.11	0.19	0.003
Hip													
Height, cm	123	121	121	121	122	121	121	122	± 0.5	0.004	0.60	0.08	0.21
Width, cm	37.5	37.0	37.2	37.2	37.4	37.0	36.8	37.7	± 0.3	0.15	0.98	0.30	0.01
Pelvic													
Height, cm	13.7	13.8	13.8	13.7	13.8	13.7	13.7	13.8	± 0.1	0.60	0.75	0.48	0.47
Width, cm	11.3	11.2	11.3	11.4	11.4	11.0	11.1	11.3	± 0.1	0.51	0.34	0.02	0.15
Area, cm^2	156	155	157	154	159	152	153	158	± 2.7	0.95	0.52	0.09	0.21

[1]ConFor = cow forage grazed during conception [common bermudagrass (CB) or toxic endophyte-infected tall fescue (E+)].
[2]ConBC = cow body condition (BC) during conception [marginal body condition score (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8)].
[3]LateBC = cow BC during the last trimester of pregnancy [marginal (BCS = 4.2 ± 0.8) or good (BCS = 6.3 ± 0.8)].
[4]Hfes = heifer fescue cultivar grazed during development [E+ or non-toxic endophyte-infected tall fescue (Novel)].
[5]Main effects of ConFor, ConBC, and LateBC *P*-values; covariate of heifer age was significant ($P < 0.05$) for postweaning weight, yearling weight, and hip width.

Table 2. Heifer yearling and prebreeding antral follicle count affected by the interaction between maternal conception body condition x maternal forage grazed during conception x maternal body condition during late gestation x heifer fescue grazed during development.

	Marginal-ConBC[1]								Good-ConBC[1]							
	CB[2]				E+[2]				CB				E+			
	Good-LateBC[3]		Marginal-LateBC[3]		Good-LateBC		Marginal-LateBC		Good-LateBC		Marginal-LateBC		Good-LateBC		Marginal-LateBC	
AFC[5]	E+[4]	Novel[4]	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel
Yr[5]	4^{d}	18^{c}	24^{ab}	19^{bc}	18^{bc}	19^{bc}	22^{ab}	18^{c}	25^{ab}	22^{ab}	25^{ab}	25^{ab}	23^{ab}	25^{ab}	20^{abc}	16^{c}
PBr[5]	N/A	15^{yz}	20^{xy}	17^{yz}	19^{xy}	16^{yz}	18^{yz}	16^{yz}	20^{xy}	18^{yz}	20^{yz}	19^{xy}	24^{x}	18^{yz}	14^{yz}	13^{z}

[1]ConBC = Cow body condition [BC; good (BCS = 6.3 ± 0.8) or marginal (BCS = 4.2 ± 0.8)] during conception.
[2]Cow conception forage type grazed [common bermudagrass (CB) or toxic endophyte-infected tall fescue (E+)].
[3]LateBC = Cow BC during last trimester of gestation.
[4]Heifer fescue cultivar grazed during development [E+ or non-toxic endophyte-infected tall fescue (Novel)].
[5]AFC = antral follicle count of heifers at yearling (Yr) and prebreeding (PBr).
N/A = no data.
[a,b,c,d]Means without common superscripts differ ($P < 0.05$; pooled SE = 1.2).
[x,y,z] Means without common superscripts differ ($P < 0.05$; pooled SE = 1.2).

Table 3. Estrous activity and pregnancy rate of crossbred beef heifers affected by the maternal conception body condition x maternal forage grazed during conception x maternal body condition during late gestation x heifer fescue cultivar grazed during development interaction.

ConBC[1]:	Marginal								Good							
ConFor[2]:	CB[2]				E+[2]				CB				E+			
LateBC[3]	Good		Marginal		Good		Marginal		Good		Marginal		Good		Marginal	
Hfes[4]:	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel	E+	Novel
Item[5]																
n	3	8	5	9	3	10	2	3	1	5	5	5	2	6	2	4
Est,%	67	100	80	100	100	90	100	100	N/A	100	80	100	50	83	0	50
Mnts	N/A	17[b]	11[bc]	12[bc]	10[bc]	15[bc]	N/A	10[bc]	16[bc]	24[a]	15[bc]	21[a]	9[c]	14[bc]	8[c]	25[a]
Dur, h	N/A	9[j]	6[j]	7[j]	3[k]	6[j]	N/A	6[j]	7[j]	8[j]	8[j]	9[j]	7[j]	5[k]	3[k]	7[j]
Quies, m	N/A	34[yz]	37[yz]	34[yz]	17[z]	29[yz]	N/A	59[x]	27[yz]	22[z]	60[x]	32[yz]	52[xy]	26[yz]	28[yz]	20[yz]
Preg,%	33	89	40	44	33	91	50	100	100	100	57	80	67	83	0	80

[1]ConBC = Cow body condition [BC; good (BCS = 6.3 ± 0.8) or marginal (BCS = 4.2 ± 0.8)] during conception.

[2]Cow conception forage type grazed [common bermudagrass (CB) or toxic endophyte-infected tall fescue (E+)].

[3]LateBC = Cow BC during last trimester of gestation.

[4]Hfes = heifer fescue cultivar grazed during development [E+ or non-toxic endophyte-infected tall fescue (Novel)].

[5]Item = Est (percentage of heifers exhibiting estrus); Mnts (number of mounts during estrus); Dur (length of estrus); Quies (period of no activity between mounts); and Preg (percentage of heifers pregnant).

[a,b,c,d]Means without common superscripts differ (*P* < 0.05; pooled SE = 1.6).

[j, k]Means without common superscripts differ (*P* < 0.05; pooled SE = 1.0).

[x,y,z] Means without common superscripts differ (*P* < 0.05; pooled SE = 4.6).

Dissertation Conclusion

Maternal environment during conception and late gestation can impact growth, development, and fertility of female offspring. Cow body condition (BC), forage grazed during conception, and the availability of nutrients during the last trimester of pregnancy are related to post-natal growth and fertility of heifers. Cows in marginal BC during conception and late gestation resulted in reduced growth, fewer antral follicles, and reduced pregnancy rates of heifer offspring. Grazing toxic endophyte-infected tall fescue (E+) during conception resulted in cows having lower birth weight heifer calves compared to heifers from cows grazing common bermudagrass during conception. Heifers grazing E+ during development had decreased average daily gain (ADG), antral follicle count, estrous activity, and reduced pregnancy rates compared to heifers grazing non-toxic endophyte-infected tall fescue (Novel) during development. Ensuring cows are in good-BC during conception and have adequate nutrients to maintain good body condition throughout pregnancy will circumvent reduced growth and fertility of heifer progeny. Utilizing skeletal body measurements as indicators of growth and Novel fescue for replacement beef heifer development will result in improved heifer ADG, estrous activity, and increased pregnancy rates.