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To the Graduate Council:

I am submitting herewith a thesis written by Luther Edward Smith, Jr. entitled "Estrus and Ovulation Relationships in Beef Cattle." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

John D. Smalling
Major Professor

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ESTRUS AND OVULATION RELATIONSHIPS IN BEEF CATTLE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Luther Edward Smith, Jr.

June 1969

To

My wife, Karen, and my son, Randy, whose love and patience made this study possible.

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ABSTRACT

A study involving 80 cows and heifers of the Angus and Hereford breeds was conducted in two separate years at the Knoxville Experiment Station of the University of Tennessee.

This study was conducted to determine the length of estrus and the time of ovulation in relationship to estrus and the effects certain environmental and genetic factors had on these phenomena.

The mean duration of 136 estrous periods was $9.51 \pm .83$ hours. Although parous females had a longer estrus than non-parous cattle, the difference was not significant. It was also found that breed had no significant effect on the length of estrus. When both estrous periods of each trial were considered together, trial had no significant effect on length of estrus; but the length of the second estrous period was significantly ($P < .05$) shorter in Trial III than in Trial I or II.

The mean interval from beginning of estrus to time of ovulation was 24.8 ± 1.35 hours and the mean interval from end of estrus to time of ovulation was 15.5 ± 1.3 hours. Trial had a significant ($P < .05$) effect on time of ovulation. Trial represents the combined effects of differences in cattle, observers, season, and the effects of estrus synchronization in Trial III. The effect of breed and parity were confounded by an interaction between the two factors. Angus heifers had a significantly ($P < .05$) shorter interval from the end of estrus to time of ovulation than Hereford heifers or Angus cows, while Hereford cows had a significantly ($P < .05$) shorter interval than Angus cows or Hereford heifers.

Estrus occurred most frequently during the early morning and early afternoon hours, while ovulation occurred most frequently during the early afternoon and evening hours.

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CHAPTER I

INTRODUCTION

The introduction and use of artificial insemination in cattle today has created new problems and accented some old problems involved in breeding. One of the most obvious and important problems created by artificial insemination is determining the optimum time of insemination. In order for fertilization to occur, the time of insemination must be such that viable sperm will be present in the upper region of the female reproductive tract at the time of ovulation.

The only visible evidence available to the breeder, or inseminator, of approximate time of ovulation is the estrous, or "heat," period of the cow or heifer. In order for a breeder to determine the time of ovulation in a cow, he must be able to define the time of ovulation in terms of its relationship to estrus. For this to be done, the interval from the beginning of estrus to time of ovulation and the interval from the end of estrus to ovulation must be determined. Once the time of ovulation is accurately defined in relationship to estrus, the inseminator will be able to breed the cow when the probability of viable sperm being present in the oviduct at ovulation is greatest.

The purpose of this study was to determine the length of estrus in beef cattle, the relationship of ovulation to estrus, and the effect certain genetic and environmental factors have on these phenomena.

CHAPTER II

REVIEW OF LITERATURE

I. LENGTH OF ESTRUS

Weber (1911) tabulated the opinions of various authorities as to the average length of estrus in cows and concluded that in those that exhibited strong signs, estrus varied from 12 to 36 hours in length; while in cows showing an average intensity, estrus lasted 6 to 36 hours; and in cows exhibiting feeble symptoms, estrus lasted from 3 to 36 hours.

Asdell (1946), from data available at the time on cattle of all ages, found a mean duration of estrus of 13.6 ± 0.16 hours. The modal length was 14 hours, and 82% of the estrous periods were between 10 and 18 hours in length.

Masuda _et al._ (1951) collected data on 1,134 estrous periods in a group of Holstein cows and reported an average duration of estrus of 21.6 hours. They found also that the frequency of beginning of estrus was greater from 4:00 p.m. to 10:00 p.m. than at any other time of day.

Perkins _et al._ (1959) collected data for 97 estrous periods of 17 "repeat-breeding" dairy heifers. The heifers were observed at eight-hour intervals for beginning of heat and at four-hour intervals for end of heat. The results showed an average duration of estrus of 19.0 ± 4.0 hours.

Wiltbank et al. (1957) reported the mean duration of estrus for 45 estrous periods in Angus heifers that were checked at two-hour intervals to be 21.1 hours. Hafez (1962) reported an average duration of estrus of 17 hours with a range from 4 to 30 hours.

Effect Of Parity.

Most evidence suggests that the estrous period in parous cattle is somewhat longer than in non-parous cattle. Hammond (1927) reported the duration of estrus in dairy animals as 19.3 hours in cows and 16.1 hours in heifers. He reported a range of 6 to 30 hours with an overall average of 17 hours.

Trimberger and VanDemark (1948) checked 86 cows and 46 heifers representing the Ayrshire, Guernsey, Holstein, and Jersey breeds at two-hour intervals for the beginning and end of estrus. They reported a significantly longer mean duration of estrus for the cows (17.8 hours) than for the heifers (15.3 hours).

Effect Of Climate.

Gerasimova (1938) found in 125 cows of various breeds and crosses in a subtropical climate the mean duration of estrus to be 12.5 hours with a range of 6 to 20 hours. In 94.9% of the observations, the range was from 6.2 to 16.0 hours.

Anderson (1944), in the country of Kenya, from observations made on 1,130 estrous periods in Zebu cattle and 678 estrous periods in grade cattle, primarily of Shorthorn breeding, found a mean duration of estrus of 4.78 hours in Zebu cattle and 7.40 hours in grade cows. He also found little seasonal variation in estrus length in the grade cattle. Ivankov (1956) reported the mean duration of estrus in cattle in subtropical regions to be 14 hours with a range of 7.0 to 27.7 hours.

Branton et al. (1957) at Louisiana State University checked 131 Holstein and 103 Jersey cows and heifers at six-hour intervals except during four, ten-day seasonal periods, when observations were made at two-hour intervals. Preliminary results on 245 heat periods gave an average duration of estrus of 13.24 ± 0.44 hours for the observations made at six-hour intervals; average duration of estrus in 30 animals observed at two-hour intervals was 11.90 ± 0.68 hours. Hall et al. (1958) collected data on 1,055 estrous periods of 242 cows. The mean duration of estrus was 12.37 and the range was 2 to 40 hours. Approximately ten per cent of the cattle failed to show standing heat during the study. Hall et al. (1959) at Louisiana State University, in an experiment involving a total of 270 dairy cattle, collected data on 1,460 estrous periods which showed a mean duration of estrus of 11.9 hours. They found the range to be 2 to 46 hours, a modal value of 12.2 hours and a median of 12.0 hours.

In Wisconsin, Aschbacher et al. (1956), in an experiment designed to determine fertility at different stages of estrus, checked grade Holstein cows at eight-hour intervals for beginning of heat and at four-hour intervals for end of heat and found a mean duration of estrus of 17.1 hours.

The above data show that the estrous period of cattle in the subtropical regions of the world appears to be from 5 to 6 hours shorter than that reported for cattle in the more temperate climates.

Effect Of Sterile Copulation.

Marion et al. (1950) in an experiment in Wisconsin used 25 dairy heifers of four breeds to determine the effect of sterile copulation on time of ovulation and estrous phenomena in the bovine. The heifers were observed for four estrous periods, two periods serving as controls and two as experimental. The experimental period differed only in that the heifers were served by a vasectomized bull. They reported an average length of estrus in non-serviced animals of 21.1 hours and of 18.2 hours for serviced animals. Since this difference was not significant, they concluded that sterile copulation did not shorten length of estrus in cattle.

Effect Of Exogenous Hormone.

Marion et al. (1952) undertook a study to determine the effect of administration of an unfractionated gonadotrophic pituitary extract[1] on the time of ovulation and length of estrus in 14 dairy heifers. They first recorded normal periods on the heifers and then in successive estrous cycles treated them with the unfractionated pituitary extract at various stages of the estrous cycle and measured the length of estrus. They found that hormone treatment had no effect on the average duration of estrus, the treated and control periods being 23.06 and 23.50 hours, respectively.

Hansel et al. (1952) found that the injection of estradiol benzoate at the beginning of estrus did not affect the length of estrus.

[1]Vetrophin, a commercial product prepared by Abbott Laboratories, was the extract used in these studies.

Hansel and Trimberger (1952) used 11 dairy heifers in a study to determine the effect of progesterone, administered at the start of estrus, on ovulation time. Data were collected on several control periods and then on several treated periods. The mean reduction in duration of estrus in the treated periods was 3.6 hours ($P < .05$). Trimberger and Hansel (1955), however, injected 30 dairy cows with progesterone at various days of the estrous cycle to control estrus and ovulation and found that this treatment had no effect on duration of estrus.

Wiltbank et al. (1967) fed 500 mg. of 16 α 17-dehydroxyprogesterone (DHPA) daily for 20 days to synchronize estrus in heifers and observed that the treatment shortened the mean duration of estrus from 21.0 hours in untreated heifers to 16.5 hours in treated animals. Casida et al. (1945) observed in sheep that the estrous periods of 30 ewes were shortened 0.3 to 0.4 days by injections of unfractionated anterior pituitary extracts and purified follicle-stimulating extract.

Ulberg and Lindley (1960) in trials using grade females of three different breeds found that three different combinations of progesterone-estradiol benzoate treatments (50 mg. progesterone followed with 5 mg. estradiol benzoate, 50 mg. progesterone, and 12.5 mg. progesterone followed with 1.25 mg. estradiol benzoate produced no significant differences in duration of estrus between treated animals or between treated animals and controls.

Donaldson et al. (1968) in experiments in Australia involving the feeding of different levels of 6 chloro- Δ -6 17 acetoxyprogesterone (CAP) to dairy heifers, Herefords, Shorthorns, and Brahman crossbreds, found a mean duration of estrus of 13.9 $\pm$ 0.5 hours with no significant difference between controls and CAP-fed animals.

Although some conflict exists in the data reported, most work has shown that hormone treatment given at various days throughout the estrous cycle will not affect duration of estrus; but hormone treatment at the beginning of the estrous period will shorten estrus.

II. TIME OF OVULATION

Hammond (1927) reported that ovulation occurred between 24 and 48 hours after the beginning of estrus. Krillov (1937) found the time of ovulation to be 18 to 24 hours after the onset of estrus, and Andreev (1937) reported that the interval from the onset of estrus to the time of ovulation was 30 to 40 hours. Werner _et al._ (1939), from a study involving 35 estrous periods in dairy heifers, reported the average interval from the end of estrus to the time of ovulation to be 11.5 hours with a range from 2.5 hours to 22.0 hours.

Nalbandov and Casida (1939) examined cattle at two-hour intervals and found a mean interval from end of estrus to time of ovulation of 11.5 hours with a range of 2.3 to 2.8 hours. In a study involving 72 estrous periods in 22 grade dairy cows, Nalbandov _et al._ (1942) reported that ovulation occurred approximately 14 hours after the end of estrus. They found that ovulation occurred most frequently at 11:00 a.m. They also observed that the later the time of day that ovulation occurred, the longer the interval from the end of estrus to ovulation; and the later the time of day that estrus ended, the shorter the interval from the end of estrus to ovulation.

Asdell (1946) concluded from available data that ovulation usually occurs from 13.5 to 15.5 hours after the end of estrus with a range of from two hours before the end of heat to 26 hours after the end of heat. Masuda _et al._ (1950) found the average interval from end of estrus to time of ovulation to be 29 hours.

Aschbacher _et al._ (1956) checked grade Holstein cows at four-hour intervals for ovulation in an experiment designed to determine fertility at different stages of estrus and found a mean interval from end of estrus to time of ovulation of 11.1 hours.

Wiltbank _et al._ (1957), reporting on 45 estrous periods of Angus heifers that were palpated _per rectum_ at two-hour intervals, found a mean time of ovulation from the end of estrus of 9.2 hours. The range was 2 to 22 hours.

Perkins _et al._ (1959), from observations made on 97 estrous periods of 17 repeat-breeding dairy heifers that were rectally palpated at two-hour intervals while in estrus and until ovulation occurred, found the mean time of ovulation to be 12.3 hours after the end of estrus.

Effect Of Parity.

Current data show that parous animals have a longer interval from end of estrus to time of ovulation than do non-parous animals. On observations made on 73 estrous periods of 47 cattle of beef and dairy breeds in which the ovaries were palpated _per rectum_ at two-hour intervals. Brewster *et al.* (1941) reported the mean interval from end of estrus to time of ovulation to be 13.75 ± 0.68 hours with 67% of the ovulations occurring between 8 and 16 hours after the end of estrus. They also found that the interval from end of estrus to time of ovulation was shorter in heifers (11.9 ± 0.99 hours) than in parous cattle (14.48 ± 0.84 hours).

Trimberger and VanDemark (1948), in a study of 46 heifers and 86 cows of Ayrshire, Holstein, Guernsey, and Jersey breeding that were palpated *per rectum* at two-hour intervals to determine time of ovulation, found the mean interval from end of estrus to ovulation to be 10.2 hours in heifers and 10.7 hours in cows. This difference, however, was not statistically significant. The overall average of cows and heifers from end of estrus to ovulation was 10.5 hours with 81.8% of the ovulations occurring from 7 to 14 hours after the end of estrus.

Hall *et al.* (1959), from data collected on 1,460 estrous periods of 270 cattle, found that heifers ovulated sooner (10.8 hours) after the end of estrus than did cows (12.9 hours).

Effect Of Climate.

From available data it appears that climate has little, if any, effect on the length of the interval from end of estrus to time of ovulation in cattle. Gerasimova (1938), in an experiment in a subtropical climate, collected data from a group of 125 cows of various breeds and crosses and found that ovulation occurred 16 to 38 hours after the onset of estrus with a mean interval of 27.8 hours.

Hall et al. (1958) at Louisiana State University, from data collected on 1,055 estrous periods of 242 cows, found a mean interval from the end of estrus to ovulation of 12.8 hours.

Hall et al. (1959), also in Louisiana, reported a mean interval from end of estrus to time of ovulation of 12.9 hours for cows and 10.8 hours for heifers. This compares favorably with data from more temperate regions of mean intervals of 10.5 hours by Trimberger and VanDemark (1948), of 12.3 hours by Perkins et al. (1959), and of 11.5 hours by Nalbandov and Casida (1939).

Effect Of Exogenous Hormone.

Hansel et al. (1951) studied time of ovulation in ten dairy heifers during estrous cycles in which no treatment was given and during estrous cycles in which small doses of progesterone in corn oil were administered subcutaneously at the beginning of estrus. Examinations were made at two-hour intervals to determine the time of ovulation. The responses were variable, but the mean interval from the end of estrus to time of ovulation was only half as great in the progesterone-treated periods as it was in the control periods.

Hansel and Trimberger (1952), in a study designed to determine the effects of ovarian hormones on ovulation time, first determined ovulation time in 11 heifers in control estrus cycles. Then they injected subcutaneously 5 to 50 mg. doses of progesterone dissolved in corn oil. They found that the injection of progesterone within two hours after the start of estrus significantly shortened the interval from beginning of estrus to time of ovulation. They found no significant dose effect.

Marion *et al.* (1952) undertook a study to determine the effect of the administration of an unfractionated gonadotrophic pituitary extract during estrus on the time of ovulation in 14 dairy heifers. Ovulation times were first recorded on the heifers without any treatment. The heifers were then treated with the extract, and observations were made at successive estrous periods with the ovaries being examined at two-hour intervals by palpation *per rectum*. The mean interval from the end of estrus to time of ovulation of the estrous periods in which the heifers were treated with the hormone preparation was 1.01 hours, while in the untreated periods it was 11.74 hours.

Hansel *et al.* (1952) in an experiment in which they injected estradiol into dairy heifers at the beginning of estrus, found that this treatment had no significant effect on the time of ovulation. Hough *et al.* (1955) studied the effects of the administration of epinephrine, atropine, and atropine plus progesterone at the beginning of estrus on time of ovulation in dairy heifers. Epinephrine did not significantly affect ovulation time. The atropine and atropine plus progesterone treatments blocked ovulation.

Trimberger and Hansel (1955) started daily injections of 30 dairy cows with progesterone (50 mg., 75 mg., or 100 mg.) at various days of the estrous cycle to control estrus and ovulation. They found that treatment had no effect, however, on the interval from beginning of estrus to time of ovulation.

Ulberg and Lindley (1960) used three different combinations of progesterone-estrogen treatments (50 mg. progesterone followed by 5 mg. estrogen, 50 mg. progesterone only, and 12.5 mg. progesterone followed by 1.25 mg. estrogen) in trials using grade females of three different beef breeds. They found no significant difference in time of ovulation between treatments or between treated and control animals.

Wiltbank _et al_. (1967) found no effect on the interval from onset of estrus to time of ovulation when heifers were fed 500 mg. of DHPA daily for 20 days to synchronize estrus. Donaldson _et al_. (1968) found that feeding different levels of CAP to dairy heifers, Herefords, Shorthorns, and Brahman crossbreds had no effect on the interval from onset of estrus to time of ovulation. They found an interval of 26.9 $\pm$ 0.6 hours.

Although some conflict exists in available data, the majority of the work supports the hypothesis that treatment with an exogenous hormone at the start or during estrus will affect ovulation time; but periodic, or even daily, treatment with an exogeneus hormone during the estrous cycle does not affect the interval from end of estrus to time of ovulation.

III. USE OF MELENGESTEROL ACETATE (MGA)

Recently, researchers have used an artificial progestogen, 6α-methyl-6-dehydro-16-methylene-17-acetoxy-progesterone (MGA), also called melengesterol acetate, in the feedlot rations of heifers to suppress estrus and increase feedlot performance. The manufacturer reported that a dosage range of 0.35 to 0.50 mg. per heifer per day almost totally suppressed estrus and that, generally, no evidence of estrus was found during the first 48 hours following withdrawal of the hormone from the feed.

Zimbelman and Smith (1966) fed MGA to heifers to synchronize estrus and found that, when orally administered, MGA was 300 to 900 times as potent as 6-α-methyl-17-acetoxy-progesterone (MAP) and by injection was 10 to 15 times as potent in estrus synchronization. They found the optimal oral dose of MGA to be 0.4 mg. per head per day.

Young et al. (1969) fed 80 good and choice grade Angus feeder heifers 0.2, 0.4, and 0.6 mg. of MGA per head per day in a ration of ground corn and corn silage with soybean oil meal as the carrying agent. They found that 0.4 mg. of MGA was the minimal effective dose to suppress estrus. The average daily gain and feed efficiency were not affected over the 154-day feeding period.

O'Brien et al. (1968) fed MGA to 32 Angus-Hereford crossbred heifers and used 32 head as controls. Each treated heifer received 0.3 mg. MGA in the feed daily. The MGA group gained significantly faster. Seven heifers on MGA came into heat while on treatment. MGA-treated heifers had heavier ovaries, but the total number of Graafian follicles was not significantly increased. Follicles 12 mm. in diameter and larger were more numerous ($P < .01$) in the MGA groups.

CHAPTER III

EXPERIMENTAL PROCEDURE

I. SOURCE OF DATA

This study was conducted at the University of Tennessee, Alcoa Research Unit, Knoxville Experiment Station. Data were collected in two separate years (1964 and 1968) on a total of 80 cows and heifers of both the Angus and Hereford breeds to determine estrus and ovulation relationships in beef cattle.

II. EXPERIMENTAL ANIMALS AND METHODS OF OBSERVATION

Experimental Animals.

The cattle were selected out of the breeding herd at the Alcoa farm. The animals included lactating cows, each of which had calved at least 30 days prior to the experimental period, non-lactating cows, and heifers which were at least fifteen months of age (Table I). All animals were rectally palpated before the start of each trial to determine the presence of any gross abnormalities. Any animals exhibiting abnormalities were eliminated from the study.

Observation Methods And Records.

The experiment was divided into three trials (Winter, 1964; Summer, 1964; and late Fall, 1968). The length of each trial was designed to include two estrous periods of each animal. Observations on estrus and ovulation were recorded only on estrous cycles that

TABLE I. EXPERIMENTAL ANIMALS IN ALL TRIALS

Breed	Number of non-lactating cows	Number of lactating cows	Number of heifers	Total
Angus	13	0	19	32
Hereford	19	5	24	48
All animals	32	5	43	80

were 21 ± 3 days in length. The criterion used for estrus was standing for mounting by other animals. Estrus and ovulation each were recorded as having occurred midway between the observation time when first observed and the previous observation time.

III. TRIAL I

Trial I began at 11:00 a.m., January 6, 1964, and continued until 11:00 a.m., February 26, 1964 (51 days). Data were collected on 17 animals, all of the Hereford breed, including 6 non-lactating cows, 5 lactating cows, and 6 heifers.

The animals were placed together in a lot at the beginning of the trial and were fed corn silage at the rate of approximately 45 lbs. per head per day along with one pound of cottonseed oil meal per head daily for the duration of the experimental period. Animals were observed for estrus for at least thirty minutes at six-hour intervals (11:00 a.m., 5:00 p.m., 11:00 p.m., and 5:00 a.m.). A vasectomized bull, turned in with the cows during each observation period, was used to aid in the detection of heat. When estrus was exhibited the animal was rectally palpated by one of two technicians at six-hour intervals to determine time of ovulation. When several animals were examined at one time, incidental observation of the herd was made for as long as two hours because of the close proximity of the working corrals to the examining chute.

The animals were allowed to re-cycle, and observations were made on the second estrous period.

IV. TRIAL II

Trial II extended from 5:00 a.m., July 1, 1964, through 5:00 p.m., August 19, 1964 (50 days). Data were collected on 20 animals (Table II).

TABLE II. EXPERIMENTAL ANIMALS IN TRIAL II

Breed	Number of non-lactating cows	Number of lactating cows	Number of heifers	Total
Angus	2	0	0	2
Hereford	7	0	11	18
All animals	9	0	11	20

At the beginning of the experimental period the animals were placed on an orchardgrass-ladino clover pasture. All cows and calves were kept together and the calves were allowed access to creep feed. A vasectomized bull was used in the detection of estrus and was kept in a separate lot, usually adjoining that of the test animals, when not being used. The cattle were observed for estrus for at least thirty minutes at six-hour intervals. When estrus was observed, the animal was palpated at six-hour intervals until ovulation occurred.

The animals were allowed to re-cycle, and a second series of observations was made.

V. TRIAL III

Data were collected on 43 animals in Trial III. In addition to preliminary examinations at the start of the trial, weights were recorded on each animal at the beginning and the end of the trial period.

The cattle were divided into cows and heifers and then further subdivided into pens of five or six animals. The cattle were then fed MGA/100[1] premixed in a protein supplement and fed with corn silage daily. The heifers received .48 mg. of MGA/100 per head daily (.40 mg. per pound of protein supplement), and the cows received .60 mg. per head daily. The hormone was fed for 16 days (beginning November 5, 1968, and ending November 20, 1968). The purpose of the feeding of the MGA/100 was to synchronize estrus to facilitate observations and record keeping. After the hormone was withdrawn, the cattle were fed a grass silage ration *ad lib.* for the duration of the trial.

Following the withdrawal of the hormone, the cattle were divided into two groups, with the parous and non-parous animals

[1]MGA/100 is the trademark of the Upjohn Company, Kalamazoo, Michigan for melengesterol acetate.

being divided as equally as possible. Group I was placed in a small lot with a vasectomized bull and Group II was placed in a small lot without a bull. Each group was further divided into two subgroups with each animal in one subgroup wearing a Kamar heat-detection pad and the other subgroup having none[2] (Table III).

The cattle were observed at six-hour intervals until estrus occurred at which time the animal exhibiting estrus was moved to a small pen which contained animals from both groups that were currently exhibiting estrus. These cattle were palpated per rectum at three-hour intervals (11:00 a.m., 2:00 p.m., 5:00 p.m., 8:00 p.m., 11:00 p.m., 2:00 a.m., 5:00 a.m., and 8:00 a.m.) until ovulation occurred to determine follicular activity and time of ovulation. Palpations were made by three technicians working nine-hour shifts. Each shift overlapped the other by one hour so that the technicians would be able to confer and relate pertinent observations. Once ovulation was recorded, the animal was placed in the original pen to which it was assigned.

The cattle were then allowed to re-cycle and observations were recorded on the second set of estrous periods.

The cattle were artificially inseminated during the second series of examinations in accordance with the procedure of the previously mentioned heat-detection experiment.

[2]The subgrouping of animals was for data collection in another concurrent experiment on heat-detection methods.

TABLE III. ANIMAL ALLOTMENT DESIGN OF TRIAL III

Breed	Parity	Group I: No. of cattle with pads*	Group I: No. of cattle without pads*	Group II: No. of cattle with pads*	Group II: No. of cattle without pads*	Total
Angus	Cow	3	2	3	3	11
	Heifer	$\frac{5}{8}$	$\frac{5}{7}$	$\frac{4}{7}$	$\frac{5}{8}$	$\frac{19}{30}$
Hereford	Cow	2	1	2	1	6
	Heifer	$\frac{2}{4}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{3}{4}$	$\frac{7}{13}$
All animals		12	9	10	12	43

*Kamar heat-detection pads

VI. STATISTICAL ANALYSES

The purpose of this study was to determine the effects of five independent variables on length of estrus, the interval from beginning of estrus to time of ovulation, and the interval from the end of estrus to time of ovulation. The independent variables involved were trial, breed of animal, parity of animal, parity-trial interaction, and parity-breed interaction. In this study lactating and non-lactating cows were considered two different parities in order to determine any effects lactation might have had on the dependent variables.

Estimates of the effects of trial, breed, parity, parity-breed interaction, and parity-trial interaction on length of estrus and the relationship of ovulation to estrus were made by least-squares analysis of data with disproportionate and unequal subclass numbers (Harvey, 1960).

The mathematical model used as the basis for the analysis of length of estrus was:

$$Y_{ijkl} = m + t_i + b_j + p_k + (tp)_{ik} + (bp)_{jk} + e_{ijkl}$$

$i = 1, 2, 3$ $\qquad$ $j = 1, 2$

$k = 1, 2, 3$ $\qquad$ $l = 1, 2, \ldots, 80$

Where:

Y_{ijkl} is the observed length of estrus for the ijkl-th individual.

m is the effect common to all observations and is the mean of the population when equal numbers exist in the subclasses.

t_i is the effect of the i-th trial.

b_j is the effect of the j-th breed.

p_k is the effect of the k-th parity.

$(tp)_{ik}$ is the effect of the ik-th interaction of trial and parity.

$(bp)_{jk}$ is the effect of the jk-th interaction of parity and breed.

e_{ijkl} is the random error associated with the ijkl-th individual.

The same model and analysis was also used to determine the effects of the independent variables on the interval from beginning of estrus to time of ovulation and on the interval from the end of estrus to the time of ovulation.

The data were divided into first and second estrous periods within each trial in an effort to determine any effect the synchronization of estrus in Trial III by the feeding of MGA/100 might have had on duration of estrus and the relationship of ovulation to estrus.

Duncan's multiple range tests (1955) as modified by Kramer (1957) were used for mean separation.

CHAPTER IV

RESULTS AND DISCUSSION

Data were collected on 136 estrous periods of 80 cows and heifers of the Angus and Hereford breeds at the Alcoa Research Unit of the University of Tennessee, at Knoxville, in two separate years to determine the length of estrus and the relationship of ovulation to estrus and the effects certain genetic and environmental factors had on these phenomena.

The cattle were regularly observed for estrus and once estrus occurred, were palpated per rectum to determine ovulation time. Data were collected on two estrous periods of normal cycles (21 ± 3 days) in each trial.

I. LENGTH OF ESTRUS

The mean duration of estrus for the 136 observed estrous periods was 9.51 ± .83 hours. This agrees with the reports of Branton (1957), Hall (1958), and Gerasimova (1938) which suggested that the length of estrus is shorter in cattle in the more southern latitudes than it is in dairy breeds in the more northern regions as reported by Trimberger and VanDemark (1948), Aschbacher (1956), Perkins (1959), and Wiltbank (1957).

Parity.

A difference in length of estrus between parities did exist with a mean figure of 10.9 hours in lactating cows, 9.7 hours in non-lactating cows, and 8.0 hours in heifers. Analysis of variance as shown in Table IV, however, shows that the differences between these means were not significant ($P > .05$). Trimberger and VanDemark (1948) and Hammond (1927) reported the duration of estrus of parous cattle to be longer than the duration of estrus in non-parous cattle.

<u>Breed</u>.

Although the length of estrus in Hereford cattle (10.1 hours) was almost two hours longer than in Angus cattle (8.6 hours), analysis of variance (Table IV) indicates the effect of breed on duration of estrus was non-significant.

<u>Trial</u>.

Analysis of variance (Table IV) shows that in the second estrous period, trial had a significant effect on the length of estrus with length of estrus in Trial III (8.0 hours) being significantly ($P < .05$) shorter than in Trials I (9.5 hours) and II (10.0 hours). However, no significance was found in the differences between mean lengths of estrus of the first estrous periods of all three trials. Trial had no significant effect on the length of estrus when both first and second estrous periods were considered together. No significant difference in length of estrus existed between first and second estrous periods. Although trial represents the combined effects of differences in cattle, observers, season, and the effects of synchronization in Trial III, the effects of differences in cattle observed would appear to represent the major effects. This would seem to be true because of the following factors: (1) the observers were the same in Trials I and II and of those observers, one was also an observer in Trial III, (2) seasonal

TABLE IV

ANALYSIS OF VARIANCE OF DURATION OF ESTRUS

Source of variation	Degrees of freedom	First estrous period	Second estrous period
		Mean square	Mean square
Total	74	——	——
Trial	2	74181.1	1069968.3*
Breed	1	1532777.8	3788308.6
Parity	2	244333.3	11904.7
Trial-Parity interaction	2	24314.7	34660.6
Breed-Parity interaction	2	97519.6	34660.6
Error	65	183456.0	181470.0

*$P < .05$

conditions were similar in Trials I and III, and (3) estrus synchronization was conducted only on the first estrous period of Trial III. Furthermore, the same critera for estrus and method of detection were used in all three trials.

II. TIME OF OVULATION

For 136 estrous cycles the mean interval from beginning of estrus to time of ovulation was 24.80 ± 1.35 hours, and the mean interval from end of estrus to time of ovulation was 15.45 ± 1.25 hours. This agrees with the figures reported by Hammond (1927), Werner (1939), Nalbandov and Casida (1939), Asdell (1946), Aschbacher (1956), and Perkins (1959).

<u>Trial</u>.

Analyses of variance (Tables V and VI) show that trial had a significant effect on the interval from end of estrus to time of ovulation in both estrous periods. The interval from beginning of estrus to time of ovulation was significantly longer in Trial III (28.8 hours) than in either Trial I (24.4 hours) or Trial II (21.5 hours), while no significant difference was observed between Trials I and II. Trial also had an effect on interval from beginning of estrus to time of ovulation in the first estrous period. The interval from end of estrus to time of ovulation was significantly longer in Trial III (21.0 hours) than in either Trial I (12.5 hours) or Trial II (13.1 hours), but no significant difference was found between Trials I and II. With differences in observers and seasons partially minimized as previously explained, the data would suggest the feeding

TABLE V

ANALYSIS OF VARIANCE OF INTERVAL FROM BEGINNING OF ESTRUS TO TIME OF OVULATION

Source of variation	Degrees of freedom	First estrous period	Second estrous period
		Mean square	Mean square
Total	74	—	—
Trial	2	831936.5*	266838.2
Breed	1	113050.9	387363.3
Parity	2	201951.2	34198.3
Trial-Parity interaction	2	61013.2	165845.8
Breed-Parity interaction	2	124618.3	2585642.3*
Error	65	288697.0	874206.0

*$P < .05$

TABLE VI

ANALYSIS OF VARIANCE OF INTERVAL FROM END OF ESTRUS TO OVULATION

Source of variation	Degrees of freedom	First estrous period	Second estrous period
		Mean square	Mean square
Total	74	——	——
Trial	2	671494.3*	1350186.0*
Breed	1	40877.2	1415.9
Parity	2	645597.4*	35533.6
Trial-Parity interaction	2	45819.4	351647.8
Breed-Parity interaction	2	421701.7	1894738.6*
Error	65	243667.0	582712.0

*$P < .05$

of MGA/100 to synchronize estrus did delay the time of ovulation. This conclusion, however, conflicts somewhat with the work of Wiltbank (1967) and Donaldson (1968) which showed that the feeding of an artificial progestogen did not significantly affect the time of ovulation.

Breed-Parity.

The effects of both breed and parity were confounded by an interaction between the two that had a significant effect on the time of ovulation in the second estrous period. Parous Herefords had a significantly shorter interval from the beginning of estrus to ovulation (16.65 hours) than did Hereford heifers (30.50 hours).

Angus heifers had a significantly shorter interval from the end of estrus to the time of ovulation (8.7 hours) than either Hereford heifers (22.4 hours) or Angus cows (21.9 hours). It was found also that Hereford cows had a shorter interval (9.8 hours) than either Hereford heifers (22.4 hours) or Angus cows (21.9 hours). The fact that the Angus heifers had the shortest interval agrees with the work of Hall (1959), Brewster (1941), and Trimberger and VanDemark (1948) who reported the interval from end of estrus to time of ovulation to be shorter in non-parous cattle than in parous cattle. The fact that the Hereford heifers had the longest interval conflicts with the results obtained by these workers. No work was found, however, that showed any breed or breed-parity effect on ovulation time.

III. TIME OF DAY OF OCCURRENCE OF ESTRUS AND OVULATION

It was found that estrus was initiated most frequently during the early morning (4:00-8:00 a.m.) and early afternoon hours (12:00 noon-4:00 p.m.) and occurred less often during the late afternoon and early evening hours (4:00-12:00 p.m.) (Figure 1).

It was observed also that ovulation occurred most frequently during the early afternoon and evening hours (12:00 noon-8:00 p.m.) (Figure 2). This tends to agree with work done by Nalbandov (1942) who found the most frequent time of ovulation to be during the middle of the day.

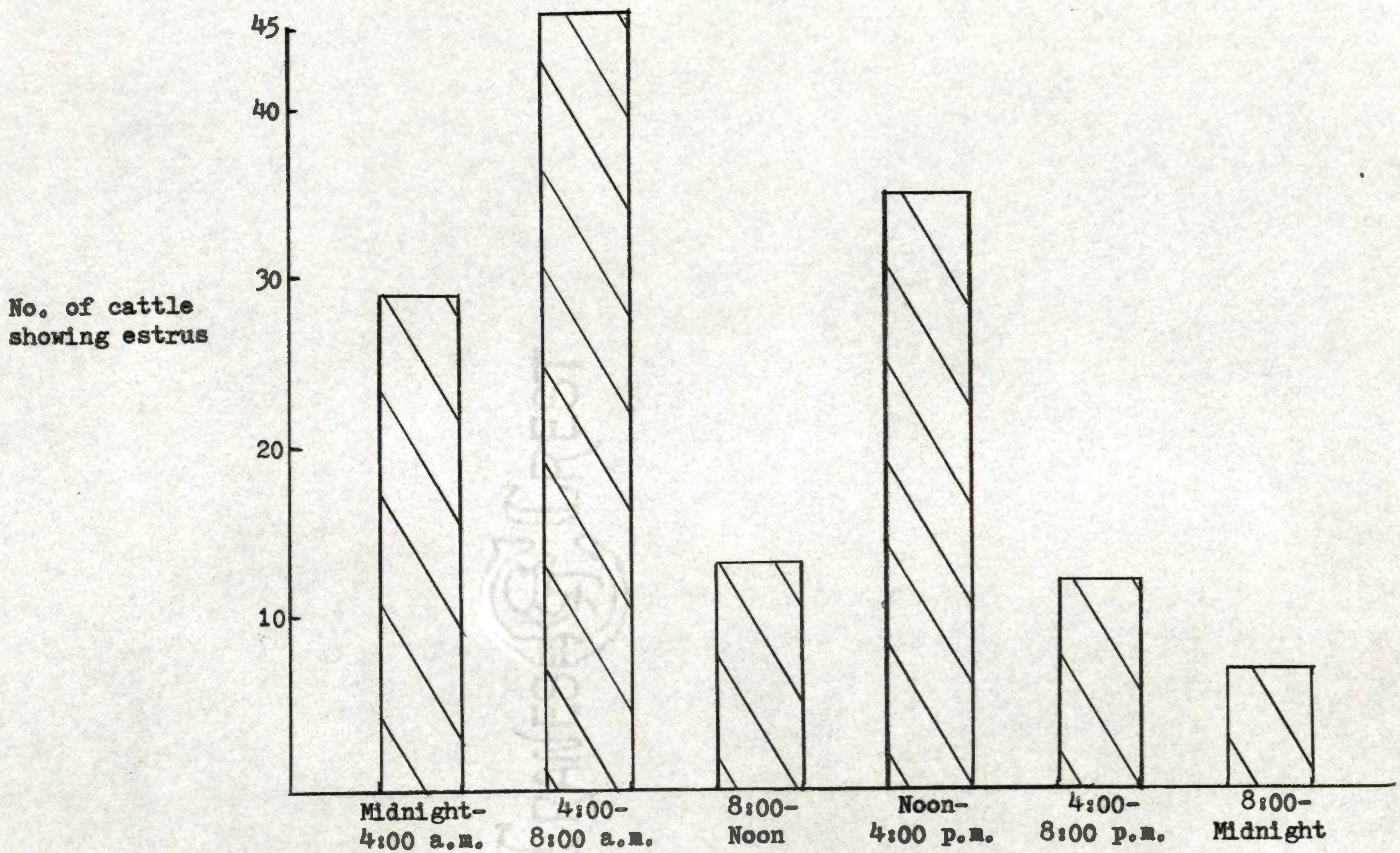

Figure 1. Frequency of occurrence of estrus during different time periods.

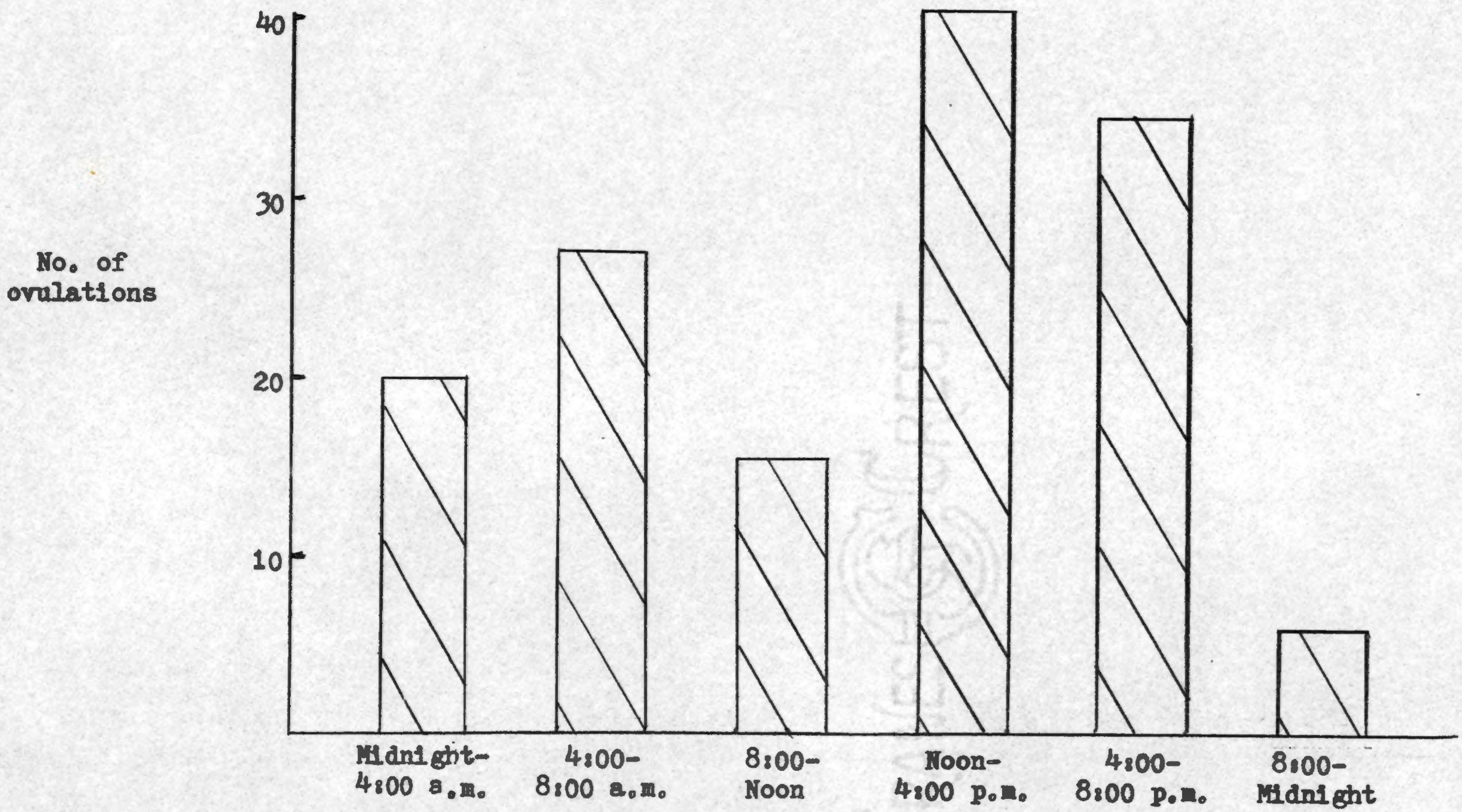

Figure 2. Frequency of ovulation during different time periods

CHAPTER V

SUMMARY AND CONCLUSIONS

Data were collected on 136 estrous periods of 80 cows and heifers of the Angus and Hereford breeds at the Knoxville Experiment Station in two separate years to determine the length of estrus and time of ovulation and the effects certain genetic and environmental factors had on these phenomena. Least-squares methods were used to analyze the data. Effects included in the least-squares models were trial, breed, parity, and interactions between trial and parity and between breed and parity.

The mean duration of estrus of the 136 estrous periods was $9.51 \pm .83$ hours. Although parous cattle had a longer mean estrus duration than non-parous cattle, the difference was not significant at the 0.05 probability level. It was also found that breed had no significant effect on the length of estrus. When both estrous periods were considered together, trial had no significant ($P > .05$) effect on length of estrus; but the length of estrus of the second estrous period was significantly ($P < .05$) shorter in Trial III than in Trials I or II.

The mean interval from beginning of estrus to time of ovulation was 24.8 ± 1.35 hours, and the mean interval from end of estrus to time of ovulation was 15.5 ± 1.25 hours. Trial had a significant ($P < .05$) effect on time of ovulation. Trial represents the combined effects of differences in cattle, observers, season, and the effects of estrus synchronization in Trial III. The effect of breed and parity were confounded by an interaction between the two factors. Angus heifers had a significantly ($P < .05$) shorter interval from the end of estrus to time of ovulation than Hereford heifers or Angus cows, while Hereford cows had a significantly ($P < .05$) shorter interval than Hereford heifers or Angus cows.

Estrus occurred most frequently during the early morning and early afternoon hours while ovulation occurred most frequently during the early afternoon and evening hours.

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LITERATURE CITED

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APPENDIX

TABLE VII

LEAST-SQUARES CONSTANTS FOR THE EFFECTS OF
TRIAL, BREED, AND PARITY ON
LENGTH OF ESTRUS

	Length of Estrus	
	First estrous period	Second estrous period
Trial		
Trial I	55.5	298.6[a]
Trial II	-84.3	-335.9[b]
Trial III	28.8	97.7[ab]
Breed		
Angus	-22.4	111.3
Hereford	22.4	-111.3
Parity		
Heifer	-150.3	-23.2
Non-lactating cow	140.5	-31.2
Lactating cow	-224.7	54.4

[a,b] Least-squares constants within column and effect do differ significantly ($P < .05$). All others do not differ significantly.

TABLE VIII

MEANS AND STANDARD ERRORS FOR
LENGTH OF ESTRUS

	Length of Estrus (in hours)			
	First estrous period		Second estrous period	
	Mean	Standard error	Mean	Standard error
Trial				
Trial I	11.2	1.7	13.5	1.8
Trial II	8.8	1.7	8.0	1.7
Trial III	10.7	1.8	4.3	1.8
Breed				
Angus	9.8	1.2	10.5	1.3
Hereford	10.6	1.2	6.8	1.2
Parity				
Heifer	7.7	1.7	8.3	1.9
Non-lactating cow	10.9	1.9	8.1	2.0
Lactating cow	12.3	2.5	9.5	2.5

TABLE IX

LEAST-SQUARES CONSTANTS FOR THE EFFECTS OF TRIAL AND BREED-PARITY ON THE INTERVAL FROM BEGINNING OF ESTRUS TO TIME OF OVULATION

	Interval from Beginning of Estrus to Ovulation	
	First estrous period	Second estrous period
Trial		
Trial I	-88.3[a]	39.1
Trial II	-231.2[b]	-170.6
Trial III	319.6[ab]	131.5
Breed-Parity		
Angus heifer	80.0	-500.5
Non-lactating Angus cow	64.9	240.1
Lactating Angus cow	-144.9	260.4
Hereford heifer	-80.0[ab]	500.5[ab]
Non-lactating Hereford cow	-64.9[a]	240.1[a]
Lactating Hereford cow	144.9[b]	260.4[b]

[a,b] Least-squares constants within column and effect do differ significantly ($P < .05$). All others do not differ significantly.

TABLE X

MEANS AND STANDARD ERRORS FOR INTERVAL FROM BEGINNING OF ESTRUS TO TIME OF OVULATION

	Interval from Beginning of Estrus to Ovulation (in hours)			
	First estrous period		Second estrous period	
	Mean	Standard error	Mean	Standard error
Trial				
Trial I	24.7	2.1	24.1	3.9
Trial II	22.3	2.1	20.6	3.7
Trial III	31.4	2.3	25.5	3.9
Breed-Parity				
Angus heifer	27.4	2.7	17.6	3.1
Non-lactating Angus cow	27.2	2.2	28.4	3.0
Lactating Angus cow	23.7	2.2	29.9	3.3
Hereford heifer	24.8	2.0	30.5	2.9
Non-lactating Hereford cow	25.0	2.5	16.7	3.8
Lactating Hereford cow	28.2	2.8	17.6	3.9

TABLE XI

LEAST-SQUARES CONSTANTS FOR THE EFFECTS OF TRIAL AND BREED-PARITY ON THE INTERVAL FROM END OF ESTRUS TO TIME OF OVULATION

	Interval from End of Estrus to Ovulation	
	First estrous period	Second estrous period
Trial		
Trial I	-143.9[a]	-260.5[a]
Trial II	-146.9[b]	-133.9[b]
Trial III	290.8[ab]	393.5[ab]
Breed-Parity		
Angus heifer	181.3[abc]	-402.0[abc]
Non-lactating Angus cow	65.6[afi]	280.3[afi]
Lactating Angus cow	-246.3[beh]	121.7[beh]
Hereford heifer	-181.3[cdg]	402.0[cdg]
Non-lactating Hereford cow	-65.6[def]	-280.3[def]
Lactating Hereford cow	246.3[ghi]	-121.7[ghi]

a,b,c,d,e,f,g,h,i Least-squares constants within column and effect do differ significantly ($P < .05$). All others do not differ significantly.

TABLE XII

MEANS AND STANDARD ERRORS FOR INTERVAL FROM END OF ESTRUS TO TIME OF OVULATION

	Interval from End of Estrus to Ovulation (in hours)			
	First estrous period		Second estrous period	
	Mean	Standard error	Mean	Standard error
Trial				
Trial I	13.5	1.9	10.5	2.4
Trial II	13.5	1.9	12.6	3.0
Trial III	20.8	2.1	21.4	3.2
Breed-Parity				
Angus heifer	23.5	2.0	9.2	3.2
Non-lactating Angus cow	18.1	2.5	19.4	3.1
Lactating Angus cow	5.7	1.4	16.3	2.7
Hereford heifer	17.7	2.0	22.4	3.8
Non-lactating Hereford cow	17.1	2.2	9.8	2.9
Lactating Hereford cow	15.2	2.1	12.0	3.0

VITA

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After graduating from Donelson High School in June, 1963, he entered Vanderbilt University, Nashville, Tennessee. After two years he transferred to the University of Tennessee, Knoxville, Tennessee, where he received his Bachelor of Science degree in Animal Husbandry in March, 1968. He then entered the University of Tennessee Graduate School to obtain a Master of Science degree in Animal Husbandry.