Beef Heifer Development

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INTRODUCTION

Replacement heifer management has a large influence on the reproductive success of beef herds. Overall herd productivity increases when a high percentage of heifers become pregnant early in the first breeding season and a high percentage of first-calf heifers (primiparous cows) conceive early in the breeding season for a second pregnancy.1–4 In order to become pregnant early in the breeding season as a heifer (nulliparous), deliver a live calf, and become pregnant early in the breeding season as a first-calf (primiparous) cow, management of heifer development must optimize nutrition, heifer maturity at the onset of breeding, bull fertility, and overall reproductive success.

Data used in the evaluation of breeding soundness of replacement heifers include body weight, days of age, reproductive tract maturity, and potentially pelvic area; the optimum timing of a reproductive soundness examination will depend on the nutrition, breeding, and marketing plans for specific herds.

Using the Kansas State University 3-point system (R, I, and P), veterinarians classify pre-breeding heifers as ready, intermediate, and problem.

KEYWORDS

- Beef heifer
- Puberty
- Reproductive soundness examination of heifers
- Estrous synchronization
- Artificial insemination

KEY POINTS

- In order to become pregnant early in the breeding season as a heifer, deliver a live calf, and become pregnant early in the breeding season as a first-calf (primiparous) cow, management of heifer development must optimize nutrition, heifer maturity at the onset of breeding, bull fertility, and overall reproductive success.
- Examination of yearling heifers before breeding can provide information on the current pubertal status of the group and allow better predictions regarding success of the breeding season.
- Data used in the evaluation of breeding soundness of replacement heifers include body weight, days of age, reproductive tract maturity, and potentially pelvic area; the optimum timing of a reproductive soundness examination will depend on the nutrition, breeding, and marketing plans for specific herds.
- Using the Kansas State University 3-point system (R, I, and P), veterinarians classify pre-breeding heifers as ready, intermediate, and problem.
PUBERTY

- Puberty is reached when a beef heifer is able to express estrous behavior and ovulate a fertile oocyte.
- Maturing of the neuroendocrine system induces the maturation and ovulation of the first oocyte as well as the hormonal changes that induce the first expression of behavioral estrus.
  - A gradual increase in gonadotropic (luteinizing hormone and follicle-stimulating hormone) activity causes the neuroendocrine system to mature.\textsuperscript{5,6}
- The first ovulation is usually not accompanied by external indications of estrus.\textsuperscript{7} It is generally thought that a certain amount of progesterone is needed for a period of time preceding ovulation in order to induce estrus behavior and for the following cycle to be of normal length.
  - Fertility to a mating associated with the pubertal estrus is reduced compared with the fertility of subsequent estrous cycles\textsuperscript{8}; therefore, heifers should reach puberty at least 21 days before the first day of the breeding season.
- Once the heifer has gone through a cycle with corpora luteal (CL) development or has been exposed to sufficient progesterone levels from other sources (eg, progesterone-impregnated intravaginal insert or feed-grade progestogen), the following cycles are normal.\textsuperscript{9}

PUBERTY: INFLUENCE OF AGE

- The onset of puberty is primarily influenced by age and weight within the breed.\textsuperscript{10–12}
- The average age at which cohorts of beef heifers reach puberty has been reported to range from 292 days to 678 days (9.6–22.0 months); with the average age at puberty for cohorts of the \textit{Bos taurus} breed and \textit{Bos taurus}–crossbred heifers commonly used in North America reported to be from 303 days to 429 days (10–14 months) (Table 1).
- Although reporting average age at puberty provides valuable information, this value represents a level at which approximately 50% of the heifers have reached puberty. Usually a percentage of the replacement heifer cohort reaching puberty much higher than 50% is desired by the time of the start of the breeding season.
- In order for primiparous cows (first-calf heifers) to give birth to their first calf at about 22 to 23 months of age so that they have 90 to 100 days between calving and the start of the breeding season, they must become pregnant by 388 to 418 days (12.7–13.7 months) of age and should reach puberty at least 21 days before the first day of the breeding season, that is, by 367 to 397 days (12.0–13.0 months) of age.
  - Crossbred heifers will reach puberty at a younger age than heifers that lack heterosis.\textsuperscript{21}
  - Because of differences in nutritional management and genetic selection, replacement heifers from different herds are expected to vary around the age-at-puberty estimate reported by Freely and Cundiff\textsuperscript{19} (1997), so that in many herds, the expected date to reach puberty is close to or after the desired onset of breeding for herd replacements.
- Knowing information such as the age when you expect 90% (or an appropriate target percentage based on overall herd goals) of a herd’s heifers to reach puberty and the length of time required for 90% of primiparous cows to resume fertile cycles after calving allows you to determine how much pressure to place on age when selecting replacement heifer candidates (Table 2).
<table>
<thead>
<tr>
<th>Heifer Description</th>
<th>Criterion for Puberty</th>
<th>Age at Puberty (Mean or Median)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angus-Simmental (n = 33) Gunn et al, 2015</td>
<td>Plasma P₄ concentration (q 7 d) Puberty = 7 d before P₄ &gt;2 ng/mL</td>
<td>Mean Control: 303 ± 10 d (SEM) DDG Tx: 330 ± 10 d (SEM)</td>
</tr>
<tr>
<td><strong>Bos indicus × Bos taurus</strong> (n = 120) Waters et al, 2015</td>
<td>Plasma P₄ concentration (q 7 d) Puberty = d P₄ &gt;0.5 ng/mL (followed by P₄ concentrations consistent with normal estrous cycle)</td>
<td>Mean Hay only Tx: 446 d CornSBM Tx: 423 d Perennial peanut Tx: 439 d</td>
</tr>
<tr>
<td>Hereford × Angus × Brahman (n = 40) Cardoso et al, 2014</td>
<td>Serum P₄ concentration (q 3–4 d) Puberty = 3 consecutive samples ≥1 ng/mL P₄</td>
<td>Median (estimated from Fig. 1) Low control: not calculable High control: 305 d Tx 1: 315 d Tx 2: 349 d</td>
</tr>
<tr>
<td>Brahman × British (n = 78) Moriel et al, 2014</td>
<td>Serum P₄ concentration (q 10 d) Puberty = first day of 2 consecutive samples ≥1.5 ng/mL P₄</td>
<td>Control: 397 d Tx 1: 292 d Tx 2: 347 d Tx 3: 379 d</td>
</tr>
<tr>
<td>Brahman (n = 6) and shorthorn (n = 6) Rodrigues et al, 2002</td>
<td>CL detection by transrectal ultrasound examination and serum P₄ concentration (q 7 d) Puberty = first day CL detected and confirmed by ≥1 ng/mL P₄ and CL maintained for at least 2 successive examinations</td>
<td>Brahman: 678 d Shorthorn: 507 d</td>
</tr>
</tbody>
</table>

(continued on next page)
<table>
<thead>
<tr>
<th>Heifer Description</th>
<th>Criterion for Puberty</th>
<th>Age at Puberty (Mean or Median)</th>
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</thead>
<tbody>
<tr>
<td>Various breeds</td>
<td>Visual observation for estrous behavior twice daily</td>
<td>Angus (n = 76): 410 d</td>
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<td></td>
<td>Puberty = first detected behavioral estrus</td>
<td>Hereford (n = 84): 429 d</td>
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<td>Ferrell, 1982</td>
<td></td>
<td>Red poll (n = 61): 355 d</td>
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<td></td>
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<td>Brown Swiss (n = 47): 317 d</td>
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<td></td>
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<td>Charolais (n = 36): 388 d</td>
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<tr>
<td></td>
<td></td>
<td>Simmental (n = 91): 348 d</td>
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<tr>
<td></td>
<td></td>
<td>Low postweaning gain: 387 d</td>
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<tr>
<td></td>
<td></td>
<td>Medium postweaning gain: 365 d</td>
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<td></td>
<td></td>
<td>High postweaning gain: 372 d</td>
</tr>
</tbody>
</table>

Abbreviations: CornSBM, corn-soybean meal; DDG, dried distillers grain; P₄, progesterone; SEM, standard error of the mean; Tx, treatment.

Fig. 1. Calculator to determine date to start the breeding season for replacement (nulliparous) heifers and the expected age at the start of breeding for heifers born early in the preceding calving season.
Table 2
Maximum day of the calving season for birth of replacement heifer candidates based on herd-specific expectations for age at 21 days after puberty and length of postpartum anestrus following first calving

<table>
<thead>
<tr>
<th>Age at Puberty (d)</th>
<th>Length of Postpartum Anestrus Following First Calving</th>
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<tr>
<td></td>
<td>90 d</td>
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<tr>
<td>350</td>
<td>67th</td>
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<td>370</td>
<td>47th</td>
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<td>390</td>
<td>27th</td>
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<td>410</td>
<td>7th</td>
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<tr>
<td>430</td>
<td>—</td>
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<tr>
<td>450</td>
<td>—</td>
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</table>

- Table 2’s calculations should be interpreted as follows:
  - If you have data to support that 90% of the heifers from a ranch will reach puberty by 390 days of age and you expect that 90% of first-calf heifers (primiparous cows) will have resumed fertile cycles by 100 days’ post partum, then you would only keep as replacement candidates heifers that were born by the 17th day of the mature cow calving season.
  - If you have data to support that 90% of the heifers from a ranch will reach puberty by 370 days of age and you expect that 90% of primiparous cows (first-calf heifers) will have resumed fertile cycles by 90 days’ post partum, then you would only keep as replacement candidates heifers that were born by the 47th day of the mature cow calving season.
- In order to select for young age at puberty (or at least avoid selecting for older age at puberty), crossbred heifers should be selected when possible and selection of sires for herd replacements should be influenced by expected progeny differences (EPDs) for scrotal circumference and heifer pregnancy.21,22
  - Scrotal circumference is measured in centimeters and is used as an indication of the age of puberty onset. Larger scrotal circumference at yearling age is associated with a younger age at puberty for that bull as well as for his bull and heifer offspring. In theory, the larger a bull’s scrotal circumference, the earlier his daughters will reach puberty and the higher probability that they will become pregnant early enough to calve at 2 years of age.
  - Heifer pregnancy is an economically relevant trait EPD that reports the probability that a bull’s daughters will conceive to calve at 2 years of age. This EPD is reported as a percentage whereby a higher value indicates the progeny with a higher probability of calving at 2 years of age.
- If herd replacements are known or suspected to reach puberty at a relatively older age (due to breed, lack of heterosis, or management decisions to have a low rate of weight gain from weaning to breeding), then a greater number of heifers must be developed and exposed to breeding so that even if a relatively small percentage of heifers become pregnant in a short breeding season, the number of replacements is sufficient to meet herd goals.
- In order to meet the management goal to breed replacement heifers at about 388 to 418 days (12.7–13.7 months) of age while recognizing that the biological constraint of age at puberty in many cohorts approaches the target breeding...
age, the heifer breeding season must be restricted to 30 to 45 days or less in many herds.
  ○ Depending on the length of the breeding season and whether or not estrous synchronization is used, heifers will have 1 to 3 mating opportunities and subsequently an expectation of approximately 60% to 95% of the cohort becoming pregnant.
  ○ An accurate estimation of pregnancy success for heifers is necessary in order to determine the appropriate number of heifers to enter the breeding season (and previously the number selected to enter the replacement heifer cohort at weaning).

CONSTRAINTS THAT DICTATE SELECTION CRITERIA FOR REPLACEMENT HEIFER CANDIDATES AT WEANING

- Primiparous cows (first-calf heifers) have a longer period of postpartum anestrus following the birth of their first calf compared with the length of anestrus following subsequent pregnancies; this period is expected to average about 80 to 100 days for primiparous cows in good body condition.23,24
- The nulliparous (replacement) heifer breeding season must end approximately 20 days before the start of the multiparous (mature) cow breeding season to ensure sufficient days post partum for most of the cohort to resume fertile estrous cycles by the start of the breeding season for their second pregnancy (Fig. 1).
  ○ If the last day of the breeding season for replacement heifers is scheduled so that the last heifer is expected to calve 20 days before the start of the mature cow calving season, all primiparous cows (first-calf heifers) will have at least 100 days between calving and the start of breeding.
- Heifer calves born in the first 3 weeks of the mature cow calving season will be 379 to 399 days of age at the start of a 30-day heifer breeding season that is scheduled to allow 100 days between the end of calving and the start of the next breeding season or 364 to 384 days of age for a 45-day heifer breeding season (Document S1, Table 3).

<table>
<thead>
<tr>
<th>Length of Heifer Breeding Season (d)</th>
<th>Age of Heifers Born in First 3 wk of Mature Cow Calving Season at the Start of the Heifer Breeding Season (d)</th>
<th>Age of Heifers Born in Second 3 wk of Mature Cow Calving Season at the Start of the Heifer Breeding Season (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>389–409</td>
<td>368–388</td>
</tr>
<tr>
<td>45</td>
<td>374–394</td>
<td>353–373</td>
</tr>
<tr>
<td>60</td>
<td>359–379</td>
<td>338–358</td>
</tr>
</tbody>
</table>
| Breeding season management: The start of the heifer breeding season is scheduled so that there are 90 d between end of calving as heifers and start of breeding as mature cows
| 30                                   | 379–399                                                                                                           | 358–378                                                                                           |
| 45                                   | 364–384                                                                                                           | 343–363                                                                                           |
| 60                                   | 349–369                                                                                                           | 328–348                                                                                           |
Heifers that are born in the first 21 to 42 days of the calving season are more likely than later-born heifers to reach puberty before a controlled 30- to 45-day breeding season scheduled to allow 90 to 100 days between the last calf being born and the start of the breeding season for the cohort’s second pregnancy (see Table 3).

Heifers that reach puberty later than 399 days of age will not be cycling at the start of a 30-day breeding season scheduled to provide 100 days between calving and the start of the breeding season for a second pregnancy, even if born on the first day of the mature cow breeding season.

**PUBERTY: INFLUENCE OF WEIGHT**

- Weight is an important factor determining the onset of puberty.
- Ensuring that the nutritional program is meeting average daily gain requirements for the period from weaning to breeding is critical for a successful heifer development program.
  - Differences between actual weights and target weights at critical midpoints between weaning and breeding can be used to influence the recommendation to increase or decrease the energy content of the diet so that target weight will be met by the start of breeding.
  - The use of ionophores, anthelmintics, and progestogen-based synchronization protocols will help ensure that heifers reach target weights and puberty before the start of the breeding season.
- The target weight to reach puberty is based on research that calculates the ratio between the average weight of heifers in a cohort divided by the average mature weight of the multiparous cows in the herd that produced the heifers.
  - Using this calculation, it has been reported that heifer cohorts fed diets to reach approximately 55% to 65% have better reproductive performance than heifer cohorts fed to reach lower weight ratios.
- The question confronting managers developing replacement heifers and their veterinary advisors is as follows: What cohort-level average daily weight gain between weaning and breeding is needed (and consequently, what diet needs to be fed) in order to have a sufficient number of heifers able to become pregnant during a 30- to 45-day or less breeding season?
- Because the actual weight at puberty and average daily weight gain on a specific diet for individual heifers varies, the targeted weight gain for the cohort will be greatly influenced by the percentage of the group needed to reach puberty by the target date ahead of breeding.
  - A relatively low targeted weight gain is used by some producers to reduce feed costs for the replacement heifer cohort with the understanding that a percentage far less than 90% (eg, 50%) of the heifer will have fertile cycles at the start of the breeding season.
  - Other producers may desire that a high percentage (eg, 90%) of the heifers have fertile cycles at the start of breeding, and they will formulate diets to reach a higher targeted weight gain so that nearly all the heifers in the cohort will meet or exceed the weight necessary for each individual to attain puberty (and accept the higher feed costs).
  - Because the breeding season for replacement heifers needs to be relatively short (ie, 30-45 days or less), producers targeting lower weight gain from weaning to breeding will need to have a larger number of heifers in the replacement cohort in order to end up with adequate numbers of pregnant heifers compared with producers targeting higher weight gain.
Research has indicated that heifer weight gain does not have to be consistent between weaning and breeding to achieve successful reproductive performance.\(^{35-37}\)

- Diets can be planned so that slower rates of weight gain can be targeted for an initial period after weaning followed by higher rates of gain in the weeks leading up to breeding, as long as a sufficient percentage of the replacement cohort reaches body weights consistent with puberty onset.
- Although this management technique can produce reproductive success, more management acumen is required to ensure that targets are met during the higher gain period as this system creates a smaller margin for errors.

The 1996 National Research Council’s (NRC) estimations of energy (Mcal) and metabolizable protein requirements for *Bos taurus* beef heifers from weaning through early pregnancy should be used as a guideline in formulating rations for developing heifers, but adjustments may need to be made to achieve the desired gains.\(^{38}\)

- Factors such as amount of activity required for grazing, environmental temperature, breed, and compensatory gain may decrease or increase the actual nutritional requirements when compared with the NRC’s estimates.\(^{39}\)
- Using the NRC’s estimates for forage nutrient content reveals that replacement heifers consuming moderate- or poorer-quality forages cannot meet the NRC’s requirements to meet targeted rates of weight gain. Therefore, except in situations whereby very high-quality forage is available, replacement heifers consuming moderate-quality forages must be supplemented with more energy-dense feeds.\(^{38}\)

**EVALUATION OF REPRODUCTIVE SOUNDNESS OF YEARLING HEIFERS**

- Examination of yearling heifers before breeding can provide information on the current pubertal status of the group and allow better predictions regarding success of the breeding season. Data used in the evaluation of breeding soundness of replacement heifers include body weight, days of age, reproductive tract maturity, and, potentially, pelvic area.
- The optimum timing of a reproductive soundness examination will depend on the nutrition, breeding, and marketing plans for specific herds.
  - Evaluating heifers 6 weeks before the breeding season offers the most time to correct low body weight and corresponds to optimal timing of prebreeding vaccination but will provide less certainty about the percentage of heifers that will be cycling when the breeding season starts.
  - Evaluating heifers immediately before synchronization or just before bull turnout provides very accurate information about the percentage of cycling heifers but affords no opportunity to make adjustments that may increase that number.
  - Confirming that a high percentage of replacement heifers are cycling before the start of the breeding season as well as identifying and removing freemartins, very immature heifers, and pregnant heifers will increase the success of an estrous synchronization and artificial insemination (AI) program.
- Potential replacement heifers should undergo a thorough physical examination, including determination of body weight and palpation of the reproductive tract.
  - Palpation of the reproductive tract to determine the presence of a CL or large follicles on the ovaries and to estimate the size of the uterus is done in order to determine if a heifer is cycling.
The use of pelvic area measurement at 1 year of age has been described extensively since the late 1970s, but its value to decrease the risk of calving difficulty should not be overestimated.

- Veterinarians have used pelvic area measurements of yearlings because the major cause of dystocia is a disproportionately large calf compared with the heifer’s pelvic area.
- The correlation between the yearling and 2-year-old pelvic area is 0.70; therefore, measuring pelvic area as a yearling is beneficial for predicting pelvic size at the time of parturition.
- Critics of using pelvic area measurements to decrease calving difficulty point out that pelvic area is also positively correlated to mature cow size and calf birth weight and that selection based on pelvic area alone did not significantly reduce the risk of dystocia in groups of heifers.
- Rather than using pelvic area measurement to select for maximum pelvic size, this tool should be used to set a minimum pelvic size as a culling criterion (such as 130–150 cm² at 1 year of age) without assigning preference for heifers that exceed the minimum.
- Pelvic area tends to increase more rapidly near the time of puberty than during the prepubertal period. This knowledge is used when concluding that a heifer that is cycling and is of adequate yearling weight but who has a small pelvis (<130 cm²) has a high probability of dystocia due to having a small pelvis at the time of calving as a 2 year old. However, a heifer with the same pelvic area that has not reached puberty and has not reached her target weight may very well have an adequate pelvis at calving if management changes are made so that she reaches puberty and becomes pregnant.

The Kansas State University replacement heifer evaluation system combines several of these assessments into a single 3-point classification system (ready, intermediate, and problem) to facilitate communication between the veterinarian and producer concerning heifer breeding management (Table 4).

- **Ready**: adequate weight and body condition, no structural flaws that impede fertility or longevity, palpable CL or large follicle with good uterine tone consistent with normal estrous cycles, and a normally shaped pelvis with a minimum pelvic area of 130 cm². (This cutoff is considered to be a minimum for cycling moderate-framed heifers. Producers and their veterinarians may choose a higher [eg, 150 cm²] cutoff for cycling heifers in herds with larger-framed heifers.)
- **Intermediate**: adequate weight and body condition, no structural flaws that impede fertility or longevity, some uterine tone and small palpable follicles but may not be cycling at the start of the breeding season
- **Problem**: heifers that are not adequately heavy or with frame size that does not meet herd goals, structural flaws that impede fertility or longevity, very immature reproductive tracts, ovarian abnormalities, eye lesions that impede vision, heifers with an abnormally shaped pelvis, freemartins, and, in most situations, pregnant heifers

These classifications are interpreted as follows:

- **Ready**: These heifers are ready to breed by AI or bull exposure.
  - If heifers are evaluated immediately before the initiation of an estrous synchronization protocol for AI breeding, the producer and veterinarian may elect to only include ready heifers to ensure the greatest response to synchronization and the highest percent of heifers bred with AI that conceive with the AI mating.
Intermediate: These heifers are expected to have good reproductive success with a 30- to 60-day exposure to bulls but may have only moderate success with an AI mating at the start of the breeding season. Whether or not to expose intermediate heifers to AI breeding, bull-exposure only, or to manage them as stocker heifers will be based on the length of time between prebreeding evaluation and the start of the breeding season and other herd-specific management and marketing goals and options.

- If the heifers are evaluated 4 to 6 weeks ahead of AI breeding, the veterinarian and producer may elect to include some or all of the intermediate heifers in the group to be synchronized based on criterion, such as age or weight.
- If natural service is used, the length of time between evaluation and the start of breeding will influence the pregnancy success of intermediate heifers.

Problem: These heifers are not ideal candidates for replacement heifers.

- In order for a high percentage of heifers to become pregnant with an AI mating or to become pregnant in the first 21 days of the breeding season if using natural service, at least 80% of the heifers must be cycling by the start of breeding, with many herds setting a goal of at least 90% cycling.
- Approximately 70% to 90% of cycling heifers are expected to express estrus and/or ovulate a viable oocyte at the time predicted by a properly administered synchronization protocol.\(^47-50\)
- Beef heifers that are bred with AI at an appropriate time relative to ovulation of a fertile oocyte have a 60% to 80% probability of establishing a pregnancy that can be detected at 50 days of gestation or later.\(^47,49,51\)
- Table 5 illustrates that the maximum percentage of pregnancies with an AI mating following estrous synchronization is 48% to 72% if all heifers have fertile estrous cycles and 38% to 58% if 80% of heifers have fertile estrous cycles.

### Table 4
The Kansas State University replacement heifer evaluation scoring system used at a time approaching the breeding season to classify potential replacement heifers as ready, intermediate, or problem

<table>
<thead>
<tr>
<th>Score</th>
<th>BCS</th>
<th>Weight</th>
<th>Reproductive Tract</th>
<th>Pelvic Area</th>
<th>Pelvic Shape</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>≥5</td>
<td>≥55%–65% of mature wt &amp; Cycling: CL present and/or &gt;10 mm follicles with good uterine tone</td>
<td>&amp; &gt;130 cm² or herd-specific cutoff</td>
<td>&amp; Normal</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>≥5</td>
<td>≥50%–60% of mature wt &amp; Not cycling but palpable ovarian structures and slight to good uterine tone</td>
<td>&amp; &gt;130 cm²</td>
<td>&amp; Normal</td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>&lt;5  or &lt;50% of mature wt or Immature uterus with no palpable follicles or follicles &lt;8 mm, freemartin, or pregnant</td>
<td>or &lt;130 cm² or herd-specific cutoff</td>
<td>or Abnormal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: BCS, body condition score; I, intermediate; P, problem; R, ready; wt, weight.
Table 5
Maximum percentage of synchronized heifers that maintain an AI pregnancy based on the initial percent cycling, the efficacy of the synchronization protocol, and the pregnancy success per mating

<table>
<thead>
<tr>
<th>Percentage of Cycling (Capable of Ovulating) (%)</th>
<th>Percentage of Cycling Heifers (Heifers Capable of Ovulating) that Actually Ovulate at a Time Predicted by a Properly Administered Ovulation Synchronization Protocol (%)</th>
<th>Pregnancy Success per Mating of Ovulating Heifer with Fertile Semen (%)</th>
<th>Expected Percentage of Heifers Exposed to a Synchronization Protocol that Maintain an AI Pregnancy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>80</td>
<td>60</td>
<td>48</td>
</tr>
<tr>
<td>90</td>
<td>80</td>
<td>60</td>
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<td>90</td>
<td>80</td>
<td>60</td>
<td>32</td>
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</table>
Table 5 illustrates that if the percentage of heifers that could respond to a synchronization protocol decreases to less than 80%, the percentage of synchronized heifers that could possibly conceive and maintain an AI pregnancy becomes quite low and the synchronization and breeding cost per AI pregnancy becomes high.

- A review of estrous and ovulation synchronization protocols reported that the percentage of synchronized beef heifers that become pregnant with AI averaged 50% to 60%, which is aligned with the estimates from Table 5 for situations when 90% to 100% of heifers have the ability to respond to a synchronization protocol and are bred with fertile semen by a competent technician. If the percent of heifers exposed to synchronization and AI that become pregnant decreases to less than expectations, then a lower-than-expected percentage of cycling heifers should be an important rule-out to consider.

**DETERMINATION OF MINIMUM NUMBER OF HEIFERS TO SAVE AT WEANING**

- The minimum number of heifers that should be retained at weaning as potential replacements depends on the following (Table 6):
  - The number of pregnant replacements desired to meet herd size goals
  - The expected percentage of the starting cohort that will meet herd-specific goals for prebreeding heifer evaluation classification (eg, 100% ready or 70% ready, and 30% intermediate, and so forth)
  - The expected response to synchronization protocol (if used) of heifers retained for breeding
  - The expected pregnancy success per mating

- The percentage values from Table 5 (or herd-specific values based on previous herd performance) can be used to calculate the minimum number of heifers to save at weaning using the following equation:

\[
\text{Number desired as replacements} \div \% \text{ pregnant in first 2 mating opportunities (or } \% \text{ pregnant with AI}) = \text{ minimum number of heifers to save at weaning}
\]

**Examples**

50 replacements needed (pregnant with AI) high input strategy \( \div 51\% \) expected to be pregnant to AI mating = \( \geq 98 \) heifers retained at weaning

50 replacements needed (pregnant in first 2 opportunities) moderate input strategy \( \div 50\% \) expected to be pregnant from first 2 mating opportunities = \( \geq 100 \) heifers retained at weaning

**BULL FERTILITY**

- All bulls used to breed heifers should be evaluated to be certain that their EPDs for birthweight or direct calving ease are consistent with the ranch’s goals.
- To ensure that bulls can deliver fertile semen to the reproductive tract of heifers, a thorough breeding soundness examination to evaluate semen quality, structural soundness, and health of all breeding bulls should be done before the start of the breeding season.
- Once the breeding season begins, producers should spend time observing activity in the breeding pasture to make sure that bulls are searching out
Table 6
The percentage of heifers retained at weaning as potential replacements that obtain desired pregnancy classification based on most likely estimate (and estimated range) for meeting prebreeding cutoff, synchronization success, and mating success

<table>
<thead>
<tr>
<th></th>
<th>Expected Percentage of Heifers that Meet Herd-Specific Evaluation Cutoff (R and/or I) (%)</th>
<th>Expected Response to Synch Protocol (%)</th>
<th>Expected Pregnancy Success per Mating (%)</th>
<th>Percentage of Heifers Pregnant with AI (%)</th>
<th>Percentage of Heifers Pregnant in First 2 Mating Opportunities (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-input development strategy</td>
<td>85 (80–90)</td>
<td>85 (80–90)</td>
<td>70 (60–80)</td>
<td>51 (38–65)</td>
<td>77 (70–84)</td>
</tr>
<tr>
<td>Moderate- to low-input development strategy</td>
<td>55 (50–60)</td>
<td>85 (80–90)</td>
<td>70 (60–80)</td>
<td>33 (24–43)</td>
<td>50 (44–56)</td>
</tr>
</tbody>
</table>

*Abbreviations: I, intermediate; R, ready; Synch, synchronization.*
heifers that are in heat and they are able to mount and complete the act of breeding.

○ It is particularly important the first 30 days of the breeding season to visually evaluate bull performance and estimate the percentage of heifers being bred each day.
○ Chin ball markers on bulls, tail head paint on cows, and other mounting detection aids can be valuable tools to evaluate the number of mating acts per day or per week in a breeding pasture (depending on frequency of observation).
○ If 80% to 100% of the heifers are cycling at the start of the breeding season, on average 4% to 5% should be bred each day.

DETERMINING SUCCESS OF ESTROUS SYNCHRONIZATION AND ARTIFICIAL INSEMINATION PROGRAM

- Heifers are ideal candidates for utilization of estrous synchronization and AI. Because they are not nursing calves and are often housed by themselves away from the mature cows, application of synchronization protocols and handling for insemination are much more convenient than with mature cows.
- If heifers have reached puberty and the synchronization system was applied appropriately, 70% to 90% or more of heifers should display estrus within the time window predicted by the synchronization system. If results do not meet this goal, the percentage of heifers that are pubertal, the accuracy of estrous detection, and the success of administering the synchronization system should all be investigated.
- If estrous response to synchronization is poor, alternate or additional synchronization systems can be implemented, the period of estrous detection and AI can be extended, or the date for the start of the natural breeding season can be altered.
- If heifers are synchronized and bred with AI, bulls should be held out of the breeding pasture for an appropriate length of time (e.g., 2 weeks) following the last day of AI breeding so that AI pregnancy rate can be accurately determined early in gestation via fetal aging by palpation or ultrasound examination.
- Sixty percent to 70% or more of the heifers identified in estrus and bred artificially should become pregnant with AI. Failure to meet this goal could indicate inaccurate determination of estrus, poor semen delivery by the AI technician, poor semen quality, or poor condition of the heifers (stress, high environmental temperature, losing weight).

DETERMINING SUCCESS OF BREEDING SEASON

- The final culling of prospective replacement heifers is done once pregnancy status is determined soon after the end of the breeding season.
- By selecting only those heifers that maintain a pregnancy from an AI mating or with natural service during a short breeding season, producers can be assured of selecting heifers that reach puberty at a young age and conceive early in the breeding season.
- By determining pregnancy status shortly after the breeding season so that fetal age can be estimated accurately (e.g., between 40 and 100 days’ gestation), the veterinarian can determine the pregnancy percentage for the first 30 days of breeding (AI and first return to estrus).
- Identification of heifers that are not pregnant allows the producer to determine the best marketing plan for those animals. In addition, if more pregnant heifers
are available than are needed as replacements, the excess can be marketed to other ranches needing pregnant animals.

**MONITORING BODY CONDITION SCORE IN MIDGESTATION TO LATE GESTATION**

- Because body condition at the start of the second breeding season is a good predictor of breeding season success, it is important that the ranch’s goal be met for the body condition score (BCS) (5–6 on a 9-point scale) and body weight (85% of mature weight).
- Adding body condition to a growing heifer that is lactating is very difficult; therefore, adequate BCS at calving is necessary to have adequate BCS at breeding.
- Growing, pregnant heifers require either high-quality forage sufficient to meet all nutritional demands or a supplementation strategy that adds adequate calories to the available forage base to meet their nutrient needs.

**EVALUATING CALVING INFORMATION**

- Data collected at calving are very valuable for evaluating overall heifer development management.
- The prediction of AI pregnancy percentage should be compared with the percentage of calves born in the first 2 weeks of the calving season. (Note: If the calving season start is based on 283 days after the date of AI, it is not uncommon that calves will be born before the start of the calving season.)
  - Failure to have a high percentage of calves born when predicted by palpation will allow the palpator to recalibrate his or her criteria for fetal aging and to determine the stage of pregnancy where he or she is most accurate to improve future predictions of calving date.
- The percentage of heifers confirmed to be pregnant but that fail to calve should not exceed herd-specific goals (eg, 2%), and an investigation should be initiated if the goal is not met.
  - High gestational loss should initiate a focus on biosecurity and vaccination protocols for diseases that cause pregnancy wastage.
- Calving ease scores should reflect herd-specific goals for the percentage of heifers experiencing dystocia (eg, <15%); levels exceeding that goal indicate a need to examine both growth of the heifers and birth weight EPDs of the bulls used as sires.
  - Excessive occurrence and severity of dystocia indicate that either heifers were underdeveloped or, more likely, the calf birth weight was excessive because of genetic predisposition by either the dam or sire.
  - Because each sire will affect many calves, accurate predictions of the sires’ influence on birth weight by using EPDs is critical to avoiding excessive dystocia.

**SUMMARY**

Proper selection and development of replacement heifers that results in a high percentage of heifers becoming pregnant early in the first breeding season, having a calf with little or no assistance, and then rebreeding early in the second breeding season are essential for efficient and profitable beef cattle production. Veterinary involvement in the selection process and continued evaluation of heifer replacements throughout the first 2 years of life can greatly assist beef producers in meeting their production goals.
SUPPLEMENTARY DATA

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.cvfa.2016.01.003.

REFERENCES