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Benchmark to Reach Precocious Puberty in Replacement Heifers: A Review

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ABSTRACT

To achieve precocious puberty in heifers, female calf should be selected with their birth earlier in calving season i.e., heifers born in the first 21 days of calving season. Essential points for successful heifer raising include colostrum feeding to produce best start in the life, monitoring growth rate regularly, accommodation in spacious ventilated barn, body capacity and frame improved by quality forage supplementation. Proper disease control along with maintenance of health and welfare as well as use of sire selected for calving ease. Monitoring of nutrition and pre-weaning growth to achieve early weaning. Standardized target weight is essential to achiev optimum pregnancy at early age. Ionophores and hormones may be used, for achieving precocious puberty provided stair step gain in body weight along with vaccination and de-worming. Feeds with high phytoestrogen may be avoided. Scoring for Body condition, frame and reproductive tract is essential steps at interval for all heifers. Estrus synchronization together with on time estrus detection may be utilized to achieve better conception and pregnancy after early puberty.

Keywords: BCS, managemental practices, photoperiod, reproductive tract scoring, target weight

Productions of heifers for replacement of breeding animals are essential for cattle based livestock production system. They must be grown to replace unproductive females through voluntary culling. Rearing of heifer alone contributes 9-20% of expense on farm i.e., second only to feed cost of lactating cow (Bailey, 2009). Most affluent component of dairy farm operation protocol is raising heifers (Heinrichs *et al.,* 1993). It needs to display effective reproductive performance without excessive initial investment. Many systematic steps are required for successful development of heifers with the objective to achieve puberty earlier i.e., in timely manner. Effective management is essential for reproductive development during different phases like post-weaning, pre-pubertal and pubertal period. Puberty depends more on body weight rather age (Mcdonald *et al.,* 2007).

Weaned heifer if fed with additional concentrate or balanced feeding and cared properly for health and condition will be able to achieve puberty (Heinrichd *et al.,* 2005) or first ovulation before 300 days of age i.e., attain precocious puberty. High concentrate feeding is preceded by increasing frequency of LH pulses (Gasser *et al.,* 2006b), estrogen peak and ovarian maturation i.e., diameter of mature follicles (Gasser *et*

al., 2006a). Moreover attaining puberty very early may results in very small body size and increased incidence of dystocia which ultimately reduces fertility rate in subsequent years to come. Now a day heifers also selected on the basis of an index including calving ease as one of the important component.

Prenatal Environment: Initial 1000 day nutrition between pregnancy and second birth day lays the foundation for cognition and physical health of child says human nutritionist (13th annual state of the world's mothers report). In same line challenge feeding for last 60 days of pregnancy increase birth weight of calf in treatment group (34.2±1.24 vs. 31.8±1.28 kg) as compared to control though it was not significantly different (Kamboj *et al.,* 2016). Das *et al.* (2007) also reported positive effect of challenge feeding. Adequate energy and protein rather overfeeding is required during last trimester of pregnancy to avoid fetal oversize and excess fat deposition in birth canal results into dystocia (Mee, 2008).

Recording System: Good record keeping and monitoring tools are helpful to compare performance from year to year or month to month. Present performance should be evaluated with reference to past performance. Tracking average mortality rate, age at sexual maturity and calving interval provide a clear cut picture of farm. Growth rate can be tracked by recording trailer weight when calf moves from one facility to another.

Genetic Control of Puberty: Selection of animals based on their genetic merits is good approach to alter age at puberty. Genomic selection for single nucleotide polymorphism (SNP) related to age of puberty has been researched by different scientist. Age at puberty is polygenic traits, however after genome wide association studies an association was observed between IGF-1 receptor gene and age at puberty (Fortes *et al.,* 2013). Genetic selection can be used to decrease age at puberty in heifers although the impact is under debate for methods.

As phenotypic expression is interaction of genotype and environment. Environmental factors are more important for reproductive parameters due to its low heritability pattern. However, age and weight at puberty is moderately heritable ranges from 0.20-0.67 (King *et al.,* 1983) and 0.30-0.44 respectively. Heritability of pregnancy at 14 months of age is 0.50 in zebu cattle (Santana *et al.,* 2013). These findings suggest that mass selection for puberty (precocious puberty) in heifers has the potential to increase the proportion of females that reach puberty at an early age that may supports calving at 2 years of age. Diameter of graffian follicle on ovary at 12 month of age was related to precocious puberty in zebuheifers (Nogueira, 2004). Selection based on ovarian size and thickness of uterus is good indicator of precocity in heifers (Monteiro *et al.,* 2013). Environmental factors that alter gene expression (epigenitics) and influence age at puberty is explained in detail by Funston and Summers (2013). They observed that nutritional status of cow during pregnancy can affect reproductive competence of her progeny.

Age of Puberty: Puberty is defined as the time when heifers first show estrus or heat period and ovulate. Process of puberty involves growing sensitivity to hormones and receptors in the hypothalamus and the ovaries of females. Puberty occurs when heifer reach 65 to 67% of mature weight. Heifers born early in calving seasons are usually heavier at weaning and reach puberty earlier as compared to heifers born late in season. It is reported that conception rate is higher on third estrus as compared to first estrus. Average age of puberty in sahiwal heifer is 24.6 months (Jamara *et al.,* 2014). Gir heifers achieve puberty at 36.5 months (Malik and Ghei, 1977). In kankrej breed of cow the age of puberty is 22.5 months (Fulsounder *et al.,* 1984). In tropical condition age at puberty for Red Sindhi heifers is 36.7 months (McDowell *et al.,* 1976). Age at puberty in buffaloes varies from 36-42 moths (Ingawale and Dhoble, 2004).

Frame Score and Puberty: It is simplest method for estimating relative skeletal size. Weight is often used to characterize body size but actually it depends on body condition (fat deposits) and skeletal size/hip height. In 9 points scoring system, Small frame (SF) animals (less than or equal to 4.5 score) are of smaller physique, easier fleshing, early maturity as compared to large frame (LF) animals (more than 4.5 frame score) that tends to be heavier regardless of life stage, leaner and reach physiological maturity later in life (Beef Improvement Federation, 2010).

Selection of Breed: The breed should be selected with younger age at puberty, within breed for early maturity and by crossbreeding with another breed having similar or younger age at puberty. Age at puberty can be decreased by following selection methods:

- By selecting breed with early puberty age
- By selecting within the breeds for early puberty
- By cross breeding with breed that has similar or early age at puberty.

Growth and Body Weight: Well grown young stock help the herd running without spending energy to reach full size. They mature and cycle earlier, fewer difficulties in calving and produce milk efficiently over their life time.

Target Weight Concept: Target weight concept gives expert, a goal of having heifer to reach a percentage of mature weight to be achieved before entry into breeding season. After reaching threshold or target weight, nutrition would not be the limiting factor in heifers to proceed towards pregnancy. 65% of body weight is target weight since many years especially with respect to reduce calving difficulty or improve calving ease (Patterson *et al.,* 1992).Heifers with 64% of target weight improve conception rate by 15% as compared to heifers with 55% of target weight (Eborn *et al.,* 2013).

Once heifer are weaned, we need to ensure that they reach target weight and wither height for age and breed at critical junctures up to yearling period. Heifers should be regularly weigh and measured to monitor their progress.

Target Weight for HF Calf

Age	Target growth rate
1-60 days	Double the birth weight
61-120 days	Average daily gain 2.2 lb
121-180 days	Average daily gain 2.0 lb

Weight Calculated by Target Weight Calculator

Age	6 months	12 months	12 months *(Mating)*	18 moths	24 months *(Including weight of fetus)*
Target weight in Kg	150	260	315	385	532.5
% of mature weight	30%	50%	60%	75%	100%

Target weight is threshold, as after achieving it nutrition would not be limiting factor in setting pregnancy. Threshold target weight of 65% of mature body weight is superior over 55% of body weight (Roberts *et al.,* 2009). Achieving this target weight is very crucial for conception and calving ease.

Mammary Gland Development

High plane of nutrition during pre-pubertal stage had positive (Choi *et al.,* 1997) or negative (Serjrsen *et al.,* 2000) effect on mammary gland development. Researchers claims that feeding high energy diets hasten puberty; however, mammary gland growth is not proportional to body growth and reduces parenchyma in udder (Silva *et al.,* 2002; Meyer *et al.,* 2006; Lohakare *et al.,* 2012).

Managemental Interventions (Suckling Vs. Hand Feeding)

Suckling calves are healthier as compared to

calf maintained under weaning system. Early weaning of calf in order to increase profit with milk is inappropriate (Ryle and Orskov, 1990) especially in resource poor developing countries. This is due to prevalence of unhygienic condition while artificial feeding to the calves. Restricted suckling at the rate of 2.7 kg per day produces better growth in calf i.e., (552 Vs. 370 g/d) as compared to nipple feeding at the rate of 3 kg/ day (Khan and Preston, 1992). Similar finding in favor of restricted suckling was also reported by Gaya *et al.* (1977). However, author also reported high growth rate in direct suckling calf as compared to artificially reared calves (Sanh *et al.,* 1997). Above results support adoption of native practice to enhance daily growth rate to get healthier calf crop at door step of farmers. Maternal instinct is very prominent in zebu cattle and buffalo and therefore they require calf at the time of milking for proper let down or in absence of calf lactation may abandon or go down.

Nutritional Regulation of Precocious Puberty

Proteins and energy are most important nutrients essentially required for developing heifers in herd. Nutrition i.e., balanced ration play a major role in attaining proper weight on time (Martson *et al.,* 1995) in other words age at puberty is negatively associated with plane of nutrition (Schillo *et al.,* 1992)

Nutrition during pre-weaning (before 6 months of age) period is critical for heifer development. Heifer calf fed with high energy diet during age of 4-6 months show reduction in age at puberty by 2 months as compared to heifer calf fed limited energy during same period (Cardoso *et al.,* 2014). Pre-breeding adlib feeding in heifers improve pregnancy rate to AI as compared to heifer with restricted feeding (Bailey *et al.,* 2014). Buffalo calves with two different calf starter i.e., high energy protein vs. low energy protein produces a daily growth rate of 471g and 336 g respectively (Ahmad and Jabbar, 2000). Increasing CP% also improve weight gain; however, CP above 20% had no additional improvement (Akayezu *et al.,* 1994). Height of grass is important for maintaining heifer on pasture land. It should be maintained between, 7-10 cm for proper grazing of heifers (Marsh, 2009).

Colostrum, Key for Heifer Development: Successful heifer raising must be directed towards acquisition of passive immunity through colostrums feeding (Quigley, 1997) to minimize mortality and sickness. Quality and quantity of colostrums is first step in important foundation of heifer rearing as calves are born without crucial protection system. Colostrum from older cow is superior as compared to heifer calving for the first time. Colostrum should be hand fed to ensure intake of 8-10% of body weight (Bailey, 2009).

Bypass Fat and Protein: Cotton seed cake is very good example of bypass fat although the problem of gossypol and aflatoxin is there due to cotton seed feeding**.** A good source of available iron can reduce the chances of gossypol toxicity.

Herbal Immuno-modulators: Shatawari (*Asparagus racemosus*) feeding @ 150mg/ kg body weight significantly reduces ($p<0.05$) age at puberty by 26 days in Sahiwal heifer (Jamara *et al.,* 2014). Shatavari improves milk production, reproduction and udder health by boosting immune system (Kumar *et al.,* 2008).

Effect of Ionophores and Growth Promoters/ Somatotropin (bST) on Achieving Precocious Puberty

Ionophores are antibiotics produced by actinomycete which increases efficiency of feed utilization. Monensin feeding tended to decrease the age at puberty in heifers without affecting weight (Lalman *et al.,* 1993). Ionophores and growth promoters bring puberty earlier by around one month (Meinert *et al.,* 1992; Singh *et al.,* 2008) due to increase growth rate by improving efficiency of rumen and feed. Ionophores alone or in combination

with anthelmintics brings puberty at earlier age in heifers with spring season birth (Purvis and Whittier, 1996). Growth promoters include antibiotics, enzyme, probiotics and prebiotics.

Somatotropin is hormone of pituitary used in ruminants for improving growth and production (Bauman, 1992). Inject able bST @ 25µg/kg body weight to Holstein heifer reduced age at puberty by 24 days (Radcliff *et al.,* 1997). Moreover if bST is injected at dose rate as above along with high plane of nutrition in Holstein heifer reduces age at puberty by 90 days (Radcliff *et al.,* 2000).

Phytoestrogens

Leguminous plants like soybean, alfalfa and clover produces polyphenolic compounds i.e., phytoestrogen (weak estrogen) in animal feeding system which has estrogen like activity. Common phytoestrogen for livestock include isoflavonesgenistein and daidzein. Phytoestrogen may have negative effect on reproduction of cattle. Feed with high phytoestrogen like clover should be avoided as it may produce negative effect on reproduction (Woclawwek-Potocka *et al.,* 2013). Heifers fed with red clover showed increase excretion rate of phyto-estrogenic compound (Tucker, 2009). However, alfalfa showed limited effect on reproductive performance of heifers. This is alarming for farmers to be aware of existence of phytoestrogen and their likely part in disturbing reproduction. Therefore farmers are advised to limit the exposure of feeds having high concentration of phytoestrogen.

Role of IGF-1 in Regulation of Precocious Puberty

IGF-1 also called Somatomedin C produced by liver as endocrine hormone. It plays an important role in growth of young and continues to show anabolic effect on adult animals also. IGF-1 consists of 70 amino acids in single chain with three disulfide bonds to enter wine chain. Highest level of its production is observed during pubertal growth surge. IGF-1 concentration is significantly higher in heifers achieving precocious puberty as compared to heifers with late puberty (Maquivar, 2011).

Effect of Bio-Stimulation

Development of replacement heifers in herd in presence of mature sterile bull is management practices that 25% of heifers showed some sign of luteal activity before 300 days of age as compared to heifer without bull exposure yet the effect was not significant (Wehrman and Kinder, 1996).Males seem to trigger neuro-endocrine reflexes which alter reproduction in females (Signoret, 1980). Ovulation is induced in rabbit, cat and camel, where males are essential prerequisite for ovulation to occur. Pheromones and other similar cues can exert profound effects on reproductive activity via the hypothalamic system that generate pulses of GnRH (Rekwot *et al.,* 2001). Bio-stimulation induces onset of estrus cycle in pre-pubertal heifers and postpartum cows (Oliveira *et al.,* 2009).

Physiological Event Related to Early Puberty

Endocrine events in peri-pubertal heifers are similar with resuming cyclicity in post-partum in multiparous cows. Steps are as follow: Maturation of hypothalamus begins which leads to decrease in negative feedback of estradiol. Which further enhance development of ovarian follicle, enough estradiol release induces behavioral estrus and pre-ovulatory LH surge.

If a heifer attain puberty earlier prior to breeding season acceptable pregnancy rate can be achieved regardless of number of estrous cycle experienced prior to breeding season (Vraspir, 2014). Onset of puberty and sexual maturity is affected by genetic potential, season of year when puberty achieved, nutrition, exposure to photoperiod, social cues, growth rates (Martin *et al.,* 1992; Hall, 2013) and treatment with exogenous hormones.

RTS (Reproductive tract scoring)	Status of uterine horn	Ovaries $(mm)^3$	Follicle (mm)	Status of heifer
1.0	Undeveloped, < 20 mm diameter, no tone	15×10×8	Absent	Immature or infertile
2.0	20-25 mm diameter, no tone	18×12×10	8	Non cyclic
3.0	20-25 mm diameter, slight tone	22×15×10	8-10	Non cyclic
4.0	30 mm diameter, good tone	30×16×12	>10, CL present	Cycling or starts cycling within few weeks
5.0	> 30 mm diameter, good tone	32×20×15	CL present	Cycling

Body Composition

Critical amount of body fat around puberty is essential for attainment precocial puberty in heifers. Increase in adipose tissues was observed in heifers around puberty in comparison to pre-pubertal body composition. However this effect may perhaps be linked with nutrition, genetics and body weight gain (Waters, 2012).

Scrotal Circumference

Scrotal circumference considered as 'threshold trait'. This means, yearling bulls with a larger scrotal circumference (40 cm) breed more females with high pregnancy rate and tend to sire heifers that reach puberty earlier than bulls with smaller circumference i.e., 34cm (Boyles, 2007). For each cm increase in scrotal circumference age at puberty in daughter reduce by approximately one day. Breeds having scrotal circumference EPD (expected progeny difference) should be used to improve age at puberty.

Reproductive Tract Scoring (RTS)

Reproductive tract scoring is tool for measuring physiological readiness of replacement heifer for breeding. RTS along with body weight of heifers helpful in making decision about retaining heifers for breeding. As far as possible pregnancy or conception is concerned RTS 4-5 is best. Yearling heifer that have scored 3, 4 or 5 should be expected to conceive early in breeding season, however, more than one year (14 months) old heifer need to have a score of 4 or 5.

Estrus Synchronization and Artificial Insemination

Synchronization of estrus and artificial insemination is key and basic technologies for increasing number of heifers to mature earlier and controlling dystocia together. Artificial insemination after synchronization in heifers has greater life time productivity as compared to heifers bred with clean up bulls (French *et al.,* 2013). In general synchronization help to follow fixed time AI protocol are good choice for small herd. However, to realize greater pregnancy rate in large herd proper estrus detection facilities are required to be incorporated. Use of Heat-synch along with timed AI in buffaloes for fertility improvement to overcome problems of silent heat in summer is very good tool in hand of farm manager, since technique circumvent the need for heat detection (Mohan *et al.,* 2009).

Successful Protocol for Synchronization

Day 0	Day 5	Day 3	Reference
CIDR in + GnRH	CIDR out + PGF (two doses)	GnRH + TAI	Bridges *et al.,* 2008
CIDR in + GnRH	CIDR out + PGF (one dose)	GnRH + TAI	Rabaglino *et al.,* 2010

Hormones for Achieving Puberty

Age at which plasma progesterone level reaches

1.0 ng/ml is said to reach the puberty (Post and Reich, 1980). Oro-nasal application of Bull urine reduces the post-partum period to occurrence of estrus in a majority of cross bred cow (Ahmad *et al.,* 2010).

Hormone preparations for induction of puberty include administration natural or synthetic progesterone (Murugavel *et al.,* 2010; Nath *et al.,* 2011), prostaglandins, gonadotrophin and GnRH (Selvaraju and Rajasundaram, 2001) either alone or in combination. Puberty in late maturing kankrej heifer best induced by Norgestomet implant for nine day and 500 IU of PMSG injection on 9th day i.e., on day of removal of norgestomet (Chaudhari *et al.,* 2012).

Photoperiods

Photoperiod management refers to the application virtual duration of light at eye level of cattle. Photoperiod divided into long day (16-18 hors light) and short day (6-8 hours of light) photoperiod. Female calves under LDPP showed increased growth rate and mammary parenchyma cells (Dahl *et al.,* 2000) along with volatile fatty acid (VFA) in rumen (Osborne, 2007). Multiparous dry animals showed a positive response with SDPP however photoperiod treatment during last two months of gestation did not increase production in heifers. For cow 15 foot candle/162 lux, 1m (3') from floor of the stall showed a positive effect. Blue light suppress melatonin effectively i.e., reverse of sleep and rest. Red lights however are least likely to suppress melatonin level. Artificial lighting with 160 lux for 4 hours daily during winter season result in better growth and early onset of puberty in buffalo heifers (Roy *et al.,* 2016).Suitable lighting is also essential for animal well-being and safe healthy working condition at farm (Penev *et al.,* 2014).

Macro and Micro Climatic Effect

Housing: Heifers in loose house system was reported to be most efficient round the year (Singh *et al.,* 1985). Environmental stressors such as climate (heat, cold, humidity), nutrition (feeds, system of feeding, endocrine disruptors) and management (housing density and conditions, transportation, weaning practices), persuades biology of organism in general and endocrine system in particular

Stress related to housing includes shelter condition or structures including ventilation, flooring, cooling, animal density etc. Insufficient ventilation and cooling system induced by exposure to extreme heat or cold. High bull density results in acute rise in blood cortisol detrimental to growth. Interferon gamma is a mediator of immunological and pathological response to stress which increases due to different stressors (Kelley *et al.,* 1994). More than one stressor is combined to assess stress more accurately in cattle such as THI (Temperature humidity indices), Cold stress indices (CSI) and heat load indices (HLI). High environmental temperature may leads to delayed puberty, late onset of sexual maturity, irregularity in cycle length, estrus and ovulation along with abnormal morphology of ova (Hafez, 1964).

Protection from Disease

Artificial induction of active immunity in animals against specific infectious disease by introducing biological agents called vaccines into their system is common practice in farm for attaining puberty earlier. Biological agents consist of live-attenuated or killed virus or bacteria or their metabolic products. After vaccination there is lag period before development of antibodies in full strength. Vaccination, de-worming along with synchronization of estrus using norgestomet can be performed without adverse effect on estrus behavior and conception rate in crossbred heifers (Stormshak *et al.,* 1997).

CONCLUSION

Above mentioned points, if followed at farm or door step of farmer strictly without fail, the farm

will provide high quality replacement heifers at low input.

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