ALLOMETRIC COMPARISON OF GEORGIA DAIRY HEIFERS ON FARMS AND AT YOUTH SHOWS

by

DEBRA SIRES WHITE

(Under the Direction of William M. Graves)

ABSTRACT

Studies were conducted to determine the relationship between dairy heifer growth and placing in the show ring and the differences in growth between show heifers and non-show heifers. In the first study, 494 Holstein show heifers were evaluated. Measurements were taken for weight, head length, wither height, hip height, thurl width and tail length. A total of 72.47% of Holstein show heifers were underweight. When looking at the ability to predict how an animal will place in the show ring, wither height appears to be the most indicative of placing (P <0.0001). In the second study, differences were looked at between the growth patterns of show heifers versus non-show heifers. An additional 293 non-show Holstein heifers were evaluated for comparison. A total of 43.34% of non-show heifers were underweight. Differences between show heifer and non-show heifers show that the way show heifers are managed differs from how non-show heifers are raised.

INDEX WORDS: COMMERCIAL DAIRY HEIFER PROGRAM, ALLOMETRIC GROWTH, SKELTAL GROWTH, WEIGHT, HEIFER MASS INDEX, AVERAGE DAILY GAIN

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By

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DEDICATION

This work is dedicated to all of my family and friends who have helped and supported me throughout this journey. First of all, I would like to thank my husband Jacob, who gives me unconditional love and support. I appreciate everything you have done in helping me complete this project. I love you more than you will ever know and am very blessed to have you in my life. Next, I want to thank my parents, Mat and Paige Sires who have supported me in my endeavors my entire life and instilled in me the importance of hard work, treating people right and looking to God in everything I do. To my younger sister Dana, I could not have asked for a better sister. I cherish the memories that we have made together and would not trade them for anything! To my grandparents, aunts, uncles and cousins, thank you so much for your support over the years, it means more than you know. To family members that are no longer with us, my older sister Diana, Granddaddy, and Uncle Gary I know you are here in spirit. To all my friends, those that I still keep in touch with and those that time has separated us, my college experience would not have been the same without you, thank you for all of the support, encouragement and good times!

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

An important part of any successful dairy operation is rearing dairy heifers to replace cows in the milking herd. About 30% of the average milking herd must be replaced each year (Gillespie, 2004). Dairy producers need replacement heifers to meet or exceed current levels of milk production on the farm (Bath et al., 1985). There are several aspects of heifer rearing that must be considered and implemented in order to have an efficient replacement dairy heifer program.

Proper management of the replacement heifer from birth to weaning, weaning to puberty, and puberty to calving ensure adequate growth, mammary development and life time productivity in the milking herd. The dairy producer must decide whether or not to raise replacement heifers on the farm, purchase replacement heifers or utilize a custom replacement heifer grower. Management decisions, such as the utilization of sexed semen versus conventional semen on replacement heifers affect the dairy operation as well. The bottom line for any replacement heifer operation is the cost of the program. Dairy producers strive to create a replacement heifer program that is as economically efficient as resources will allow.

Dairy youth programs have become popular and are very important across the United States. Youth that come from both rural and urban backgrounds have the opportunity to participate in programs such as 4-H Dairy Quiz Bowl, Skillathons, Dairy Judging Contests, National 4-H Dairy Conference and showing dairy animals, including the popular Georgia Commercial Dairy Heifer Program.

Although there are seven breeds of dairy cattle in the United States, the Holstein breed seems to remain the most popular. The Holstein's are well represented in most dairy youth contests and activities across the United States. More relevant to this study is the fact that the majority of youth participating in the Georgia Commercial Dairy Heifer Program choose Holstein heifers.

Characteristics of Holstein-Friesian Dairy Cattle

The Holstein-Friesian breed, commonly called the Holstein originated in the Netherlands (Gillespie, 2004). Early Dutch settlers were responsible for the first importations of Holsteins into the United States between 1621 and 1664 (Gillespie, 2004). There are currently more than 19 million cattle registered with the Holstein Association (Holstein Breed Characteristics, 2013).

Holsteins are historically characterized by clearly defined black and white markings (Lattig and Nordby, 1948). Color markings which prevent registry of an animal from the Holstein Association are solid black, solid white, black in the switch, black belly, black encircling leg touching hoof, black from hoof to knee or hock, black and white intermixed to give a color other than distinct black and white (Lattig and Nordby, 1948). The horns, if present, should incline forward, be incurving, small at the base, refined, medium length and tapering toward the tips (Lattig and Nordby, 1948). Horns are generally removed at 2 to 4 months of age.

A mature Holstein in milk should weigh about 680 kg and stand 147 cm tall at the withers (Lattig and Nordby, 1948, Holstein Breed Characteristics, 2013). Holsteins rank first among the dairy breeds in average milk production, with the 2011 average actual production for all U.S. Holstein herds enrolled in testing programs being 10,607.26 kg (Holstein Breed

Characteristics, 2013). Top producing Holsteins have been known to produce over 32,658.65 kg of milk in a year (Holstein Breed Characteristics, 2013). They have an average of 3.5 fat % and an average of 3.05 protein % (Gillespie, 2004, Field and Taylor, 2008). Dairy producers understand the importance of selecting for animals that will be profitable in their herd.

Judging and Phenotypic Selecting Criteria for Dairy Cattle

Judging dairy animals is a process of comparing the individuals being judged with the ideal dairy type (Gillespie, 2004). The ideal dairy type is described in the Dairy Cow Unified Score Card which was developed by the Purebred Dairy Cattle Association (PDCA) (Gillespie, 2004). There are four major categories when evaluating dairy cattle 1) Udder 2) Dairy Strength 3) Rear Feet and Legs and 4) Frame (Dairy Judging, 2012).

Udder is the largest category, representing 40% of the score card. The main purpose of the dairy cow is to produce milk which means her udder is the most important part of her body (Gillespie, 2004). A desirable udder has strong fore and rear udder attachments, strong median suspensory ligament, correct teat size, length and placement, and appropriate depth for the age of the animal. Dairy strength counts for 25% of the score card in which a combination of dairyness and strength that supports sustained production and longevity is desirable (Dairy Judging, 2012). The intent is to shift emphasis away from really thin cows and move toward a balance of dairy character with strength (Dechow, 2013). Strong cows are more robust, rather than just big (Dechow, 2013). Major consideration is given to general openness and angularity while maintaining strength, width of chest, spring of fore rib and substance of bone without coarseness when evaluating an animal for dairy strength (Dairy Judging, 2012). Rear feet and legs account for 20% of the score card in which the evaluator is looking for correct movement, set to the rear legs, pastern angle, straightness of the rear legs from behind and thurl placement (Dairy Judging, 2012). Frame is 15% of the score card and encompasses the skeletal parts of the cow, with the exception of the rear feet and legs (Dairy Judging, 2012). When evaluating frame the evaluator looks for a wide rump, pins slightly lower than hip bones, straight, strong and nearly level back and long bone pattern throughout the body structure (Dairy Judging, 2012).

Dairy heifers are judged much the same way as dairy cows except they do not have udders (Gillespie, 2004). Since, udder is not generally taken into account on heifers that makes dairy strength the most important trait, followed by rear feet and legs and finally frame. Although an official heifer score card does not exist, suggestion has been made that in heifers, dairy strength should count 40%, rear feet and legs 35% and frame 25%. It should be brought to the attention of the evaluator that pregnant heifers may carry excess body condition and appear coarse over the withers, both of which will disappear once the heifer calves and begins her first lactation (Gillespie, 2004).

The desirable traits listed and described on the score card are related to the ability of the cow to produce milk over her lifetime (Gillespie, 2004). Dairy producers seek heifers that will have a combination of high milk production and longevity in the milking herd. Evaluating dairy heifers serves the purpose of predicting the most physically correct animals out of a particular group. Showing dairy cattle in both open and junior purebred shows, youth commercial shows, as well as youth and collegiate dairy cattle judging contests are popular ways in which animals are evaluated and compared against each other as well as against the ideal animal developed by the appropriate breed associations.

Dairy Programs for Youth

The 4-H and FFA organizations offer opportunities for youth to become involved in the dairy industry nationwide (Schwanke, 1997). Dairy centered youth programs serve to build the knowledge base of youth who intend to pursue an education and eventually a career in the dairy industry (Schwanke, 1997). As the number of youth who come from rural, dairy backgrounds decreases, youth organizations are seeing a greater proportion of youth coming from more urban backgrounds that are interested in dairy programs learning about the dairy industry (Schwanke, 1997). Collegiate dairy clubs can play a role in youth programming by combining enthusiasm, student power and organization with extension and industry guidance, expertise and support to contribute to these programs (Olver, 1997). 4-H Dairy Quiz Bowl, Skillathons, National 4-H Dairy Conference, Dairy Judging and The Commercial Dairy Heifer Program are among the most popular dairy youth programs that not only teach youth about the importance of the dairy industry, but also imparts valuable life skills that will be of great benefit no matter what career path is pursued in the future. The most popular dairy programs are described below.

4-H Dairy Quiz Bowl

Dairy quiz bowls began in the late 1970's with the 4-H organization (Spike, 1997). Contests are now held at both the state and the national levels as well as included in the state and national agenda of several junior breed associations (Spike, 1997). The 4-H Dairy Quiz Bowl strives to meet five objectives, they are 1) to increase knowledge of dairy animals 2) to increase awareness of the dairy industry 3) to expand the opportunity for participation by older 4-H members 4) to include 4-H members who do not have project animals and 5) to develop individual alertness and self-confidence (Spike, 1997).

The Dairy Quiz Bowl is a team competition that is conducted as a double elimination and divided into three phases. The first phase consists of a written quiz that tests individual knowledge and is used to initially pair the teams together as evenly as possible (Spike, 1997). The second phase consists of five questions with multiple part answers that are addressed to the entire team and collaborative team work is encouraged to answer each question (Spike, 1997). The third and final phase emphasizes quick recall by individuals using lock out buzzers, where if three different members of a team answer a question correctly a bonus question is addressed to the entire team for collaborative team work (Spike, 1997). The team with the highest score wins.

Skillathons

Skillathons provide youth with a livestock learning experience through hands-on activities and learning laboratories (Spike, 1997). Contestants participate in a series of mini learning stations, including dairy, that each have a specific task that tests their knowledge and abilities as well as help each participant develop project life skills (Spike, 1997). The six objectives for skillathons are 1) provide laboratories that increase knowledge of different animal industries 2) develop critical thinking and problem solving skills 3) help participants gain self-confidence and communication skills 4) increase ability of youth to communicate with adults 5) develop responsibility and 6) provide additional opportunities to recognize youth for their accomplishments (Spike, 1997). Skillathons are a great example of experiential learning.

National 4-H Dairy Conference

The National 4-H Dairy Conference is a four day event that provides a mixture of both youth leadership and educational programs (Davis et al., 1997). Since, 1970, The Wisconsin Extension, Madison has hosted the National 4-H Dairy Conference which is held the week of the World Dairy Exposition (Davis et al., 1997). Participants 15 to 18 years of age are selected from a pool of applicants from different states who at the time of application indicate their activities and levels of participation in local organizations (Davis et al., 1997, Spike, 1997). The objectives of this program include 1) increasing knowledge and understanding of the dairy industry 2) learning about opportunities in the dairy industry 3) practicing group participation and good citizenship and 4) developing individual competence (Davis et al., 1997).

Throughout the duration of the event, participants participate in educational workshops, skillathons, hands-on activities, and seminars and lectures about animal welfare, careers, computers, dairy foods and marketing (Davis et al., 1997). Tours to dairy related industries are arranged including prominent farms such as Hoards Dairyman Farm, Hoards Magazine Publishing and National Dairy Shrine Museum (Davis et al., 1997). At the end of the Conference, the grand finale is visiting the World Dairy Expo (Davis et al., 1997). Participants are encouraged to take the opportunity to take on leadership roles, meet the speakers in person from the dairy industry and interact with other participants from different areas of the country (Davis et al., 1997).

Dairy Cattle Evaluation

Dairy judging contests were initially conducted as a way to help identify animals that were genetically superior and has remained popular among youth over the years (Guthrie and Majeskie, 1997, Schwanke, 1997). Dairy judging contests are historically broken into sections, depending on the division and organization. In the first section of the contest, participants place a set number of classes of dairy cows and heifers of various breeds. Each class consists of four animals of comparable age and the same breed. The second part is giving oral reasons on pre-assigned classes to an official. Teams of four compete; the lowest score on the team is dropped and does not count towards the final total. The team with the highest overall score wins the contest. There are many benefits and life-skills obtained through dairy judging, such as, decision making skills, communication skills, team work, self-discipline, critical thinking skills, situation analysis and organizational skills (Guthrie and Majeskie, 1997).

Georgia Commercial Dairy Heifer Program

Managerial projects allow youth without a farm background or youth from farms with grade animals to participate in shows (Schwanke, 1997). Commercial Dairy Heifer Programs are popular throughout the United States. It is a great way for youth who do not have or cannot afford an animal to get hands on experience with dairy cattle that they might not otherwise be exposed to. The Georgia Commercial Dairy Heifer Program is thriving. According to London et al. (2012) 82 youths entered the first year which was 1995 and have had at least 300 entries since 2002. Lease agreements are commonly used for most exhibitors involving the youth, their parents and the dairy producer providing the calf (Schwanke, 1997). The producer lends the heifer and in some cases even provides support for feed and hay for the duration of the show season. The youth, parents and leaders are responsible for the well-being of the animal for the duration of the lease.

In order to be eligible for the Georgia Junior National Livestock Show held annually in Perry, each heifer must be born between March 1st and September 30th of the previous year and weigh at least 113 kg but no more than 385 kg at the time of check in (2012 – 2013 Georgia 4-H and FFA Livestock Shows Rules and Regulations, 2012). Dairy heifers must be in possession of the youth no later than November 15th of the previous year. A maximum of three heifers may be shown by any one exhibitor (2012-2013 Georgia 4-H and FFA Livestock Shows Rules and Regulation, 2012).

The Georgia Commercial Dairy Heifer Show has two sections, showmanship classes and weight classes. Judging in the show ring is done by comparison (Lattig and Nordby, 1948). Showmanship is sorted into student classes according to grade in school; the judge is evaluating the showman who is striving to present the animal to the best of its ability. Cleanliness, fitting and grooming of the animal as well as knowledge and control of the animal are evaluated during showmanship classes. Fitting should start at least six to eight weeks before the first show (Lattig and Nordby, 1948). Faults by either the animal or the showman result in slight, moderate or serious discrimination by the judge. The judge then places each showman according to the number and seriousness of the faults with the individual possessing a combination of the fewest and least severe faults placing at the top of the class (PDCA Showmanship Evaluation Card, 2011). In the second section of the Georgia Commercial Dairy Heifer Show, heifers are sorted according to weight for the second part which is weight class. In this part of the show the judge is evaluating conformation of the animal using the Purebred Dairy Cattle Association (PDCA) Scorecard as a guide. The judge compares all of the heifers and selects the ones which most nearly approaches the ideal and then ranks the class from top to bottom (Lattig and Nordby, 1948).

The Georgia Commercial Dairy Heifer Program allows the exhibitor the opportunity to not only exhibit a dairy heifer, but be responsible for the training and care of the animal throughout the duration of the show season. Youth learn valuable personal qualities, such as dependability, responsibility, punctuality, patience and team work that will benefit them throughout their life. Dairy showing is a strong learning area, and the activity is a great way to teach life skills to youth while allowing them the added benefit of working with a living animal (Schwanke, 1997).

There are a variety of dairy programs specifically for youth in the state of Georgia as well as across the United States. These programs provide the opportunity for youth to learn about the dairy industry and its importance. There is something for everyone, whether or not the youth is from an urban non-dairy background or from a rural dairy background. Whether or not youths want to take a hands-on approach by raising heifers or to learn about the industry through team competitions, every youth who participates in a dairy youth program will take away valuable life skills regardless of whether or not they choose a future in the dairy industry.

Importance and Objectives of the Replacement Phase of Dairy Heifer Production

Dairy heifers are important to dairy producers as they serve as successors for cows in the milking herd, a portion of which must be replaced each year due to voluntary or involuntary culling (Mourits et al., 1997). The heifer calves born today should become milking cows in the herd in two years. These animals should be the most fertile and genetically superior animals on the farm (Raising Replacement Heifers: What are the Options?, 2012). Culling is the act of identifying and removing a cow from the herd and, assuming a constant or expanding herd size, replacing the cow with another animal which is often a first-lactation heifer (Hadley et al., 2006).

Examples of voluntary culling include low milk production, cow aggression or when a cow is sold to another farm for dairy purposes (Hadley et al., 2006). Involuntary culling includes sales due to illness, injury, infertility or death (Hadley et al., 2006). A replacement heifer program is an investment in the future of the farm in which the goal is to rear replacement heifers that develop their full lactation potential at the desired age with minimal economic and environmental cost; thereby producing the best possible herd mates (Sejrsen and Purup, 1997, Esser et al., 2009, Raising Replacement Heifers: What are the Options?, 2012).

The dairy producer can raise their own replacement heifers, utilize a custom heifer grower or buy replacement heifers and introduce them onto the farm. Dairy producers choosing to raise their own replacement heifers have a closed herd system and this facilitates prevention of new diseases from entering the herd. Also, this option gives the producer better control over the genetics in the herd (Raising Replacement Heifers: What are the Options?, 2012). Buying replacement heifers frees up land, labor, feed needed to raise heifers from birth to calving. On the other hand, having an open herd system carries the risk of introducing infectious pathogens and possibly inferior genetics. Utilizing a custom or contract heifer grower carries the same benefits as buying replacement heifers, as well as having better control over herd genetics (Raising Replacement Heifers: What are the Options?, 2012). No matter the manner taken to raise replacement dairy heifers, it is important to understand the different stages of dairy heifer growth and development and adhere to industry standards.

Growth of the Replacement Heifer from Birth to Weaning

To some, there is no more important detail in the care and management of a dairy herd than the rearing of the calves (Yapp and Nevens, 1941). Well grown, vigorous animals are usually those that have had excellent care from birth (Yapp and Nevens, 1941). Recognition that events in early life can have significant long-term impacts on overall growth, maturation and productivity of the animal highlight the importance of properly caring for young calves (Heinrichs et al., 2005).

Calves that are born in clean, dry surroundings and receive adequate colostrum have the best chance of not only surviving, but thriving during the critical first 30 days of life (Parsons, 2005). General practice is to remove calves from their dam shortly after birth. Colostrum milk is the first milk secreted by the cow after calving and is high in fat, solids not fat, total protein, and maternal antibodies as compared to regular milk (Gillespie, 2004). The first milking colostrum is the most important for calves as it is the highest in immunoglobulins and nutritional value (Bath et al., 1985). It is critical that the calf receive high quality colostrum within a few hours after birth because the ability of the calf to directly absorb antibodies drops sharply after 24 hours (Gillespie, 2004). It is best if the calf gets its first colostrum about 30 minutes after birth (Gillespie, 2004). Calves need to be fed colostrum at 8% to 10% of their body weight (Parsons, 2005, Huuskonen et al., 2011). A colostrometer measures specific gravity of colostrum and estimates total gamma globulin as well as to estimate IgG concentration in colostrum (Quigly, 1998).

The calf may be fed whole milk or milk replacer at three days of age. The young calf needs a ration which not only furnishes all the nutrients necessary for maintenance and growth, but which is strikingly different from rations of mature animals in that it must be highly digestible (Yapp and Nevens, 1941). Milk contains mainly proteins, sugar, butterfat, minerals, vitamins and water, all of which are very readily digested and utilized by the young calf (Yapp and Nevens, 1941). Milk proteins are distinguished from most proteins of vegetable feeds by having all the amino acids, which are needed for growth (Yapp and Nevens, 1941). Milk is in fact, the only feed so far known that will satisfactorily nourish the calf from birth until it is several weeks old (Yapp and Nevens, 1941).

The preferred alternative to whole milk is milk replacer which is a dry commercial product that must be reconstructed and has less fat and protein than whole milk (Parsons, 2005). Using milk replacer instead of raw milk prevents the spread of Johne's in the herd and is easier to store and handle (Coleen and Heinrichs, 2007). A milk replacer should contain at least 20 to 22 % crude protein if all protein sources are from dairy products and a crude fat level of 10 to 20 % (Gillespie, 2004).

Large breeds, such as Holsteins should be fed about seven pounds a day of whole milk or milk replacer but should not be forced to drink more than it will take in three to five minutes as this can cause scours (Gillespie, 2004). From birth to 3 weeks of age, young ruminants are described as pre-ruminants because the rumen is not yet anatomically mature or physiologically functional (Rey et al., 2012). Rumen function is the ability to ferment cellulosic feeds. The digestive tract of a calf when it is a few days old cannot digest rough feeds such as hay, oat hulls, corn stover etc. that are high in fiber content (Yapp and Nevens, 1941). Investigations show that calves can digest very little pure starch until they are a week or more of age; their ability to digest starch increases up to the time they are four weeks old (Yapp and Nevens, 1941). Calves usually start eating a small amount of dry starter mix at about one week of age (Bath et al., 1985). Calf starter grain usually has vitamins A, D, and E along with minerals and antibiotics added (Gillespie, 2004).

The environment in which the calf is raised has a profound effect on its health and growth (Heinrichs et al., 2005). Dairy calves are typically either housed individually in hutches or pens or in a group pen (Field and Taylor, 2008, De Paula Vieira et al., 2010). Several studies have reported increased weight gains for group-housed dairy calves compared with individually housed calves during the feeding and weaning periods, while other studies have reported no effect or even increased weight gains for singly housed calves (De Paula Vieira et al., 2010). The higher the weight gain for calves housed in groups is often attributed to social facilitation of feeding, an effect reported in many farm species (De Paula Vieira et al., 2010).

In commercial herds, when solid food intake increases with age of calves, milk allowance is gradually decreased until weaning (Rey et al., 2012). As soon as the calf is consuming at least 0.45 kg of starter daily, feeding milk or milk replacer can be discontinued (Bath et al., 1985). Calves can be weaned as early as 4 to 6 weeks of age; however, the average age for weaning in the U.S. has been reported to be 8 weeks (Quinn, 1980, Schoonmaker, 2006a). At this time, producers strive to have calves weight about 83.91 kg and be 86 cm tall (Broadwater and Chester-Jones, 2009).

Calf mortality is critical in any dairy cattle operation, but it is more critical if the herd is a closed herd system (Fitchette, 2003). Previous research has shown that the most common causes of pre-weaning mortality are gastrointestinal infectious diseases. The most common cause of post weaning mortality is undifferentiated bovine respiratory disease (Henderson et al., 2011). The effects of calf and heifer mortality are substantial from the economic, genetic and animal welfare points of view (Henderson et al., 2011). Costs include the loss in value of the calf and the genetic loss, which is rather hard to quantify, because genetic progress accrues over generations (Henderson et al., 2011).

Growth of Heifers from Weaning until Puberty

At weaning, heifers are moved from individual or group hutches to group pens or pastures. The heifers are grouped according to size and have access to adequate forage, concentrate and water. It is important to carefully watch heifers during this transition after weaning. This is a high stress period due to drastic changes in diet and environment. Mismanagement can cause weight gain and growth to be at a lower rate than desired. At this stage of development producers want heifers to gain an average of 0.7 to 0.8 kg per day (Kertz et al., 1987, Abeni et al., 2000).

Both overfeeding and underfeeding replacement heifers have negative effects on proper development of the replacement heifer. Overfeeding heifers can cause them to become over-conditioned which can lead to breeding problems and calving difficulties (Hopkins and Whitlow, 2013). Feeding a ration that is high in energy but low in protein to heifers before they reach puberty can cause excess fat deposit in the mammary gland. This inhibits development of mammary secretory tissue and thus impairs future milk production capability (Hopkins and Whitlow, 2013, Macdonald et al., 2005). Underfeeding heifers causes stunted growth and can delay or suppress estrus. This will delay breeding, calving and entry into the milking herd (Hopkins and Whitlow, 2013). Poorly developed heifers are also prone to more calving difficulties than larger heifers (Hopkins and Whitlow, 2013).

Puberty is more related to body weight than age. Heifers should be 30 to 40 % of their mature weight (Broadwater and Chester-Jones, 2009, Graves, 2011). Holstein heifers should be fed to reach puberty at an average age of 12 to 13 months (Puberty in Heifers, 2013). Factors that influence puberty include genotype, season of year, growth or nutritional intake, social cues and treatment with exogenous hormones (Puberty in Heifers, 2013).

Puberty is defined in heifers as the time when they show estrus and ovulate (Boyles, 2007). The process involves sensitivity to hormones and receptors in the brain and ovaries (Boyles, 2007). At the time that heifers reach puberty, hormonal patterns that regulate estrus cycles begin developing and result in the heifer coming into heat on a regular basis (Graves, 2011). The first heats may be erratic and anovulatory, but after a couple of cycles, heifers should cycle regularly every 20 to 21 days (Graves, 2011).

More rapid rearing of replacement dairy heifers in order to reach puberty earlier can be advantageous as they will enter the milking herd sooner (Capuco et al., 1995). Research has shown that the use of long-day photoperiod to hasten the onset of puberty could potentially reduce the age of heifers at first calving as well (Rius et al., 2005). Heifers that do not reach puberty do not respond to synchronization protocols used often by producers to bring groups of animals into estrus for insemination. Heifers should be bred once they reach puberty and adequate body size, so they calve at two years of age.

Growth of Heifers from Puberty until Calving

Dairy producers strive to breed heifers when they weigh 374 to 397 kg which is about 55 % of her mature body weight and typically are 14 to 15 months of age (Gillespie, 2004, Schoonmaker, 2006b). The age at which a heifer is first bred is important because of its effects. Productive and reproductive performance during the first and subsequent lactations are the two most important effects (Lin et al., 1988). Research has shown that there is a significant increase in lifetime milk production for heifers that calve at 22 to 24 months of age compared to those that calve when they are older (Gillespie, 2004).

Gestation in dairy cattle is approximately 283 days. The first six months of pregnancy the heifer should maintain an average daily gain of 0.7 to 0.8 kg per day (Gillespie, 2004). Heifers should be fed to grow more rapidly during the last two or three months of gestation, gaining up to 2 pounds per day (Gillespie, 2004). Feeding additional supplemental concentrate or grain should begin about six weeks before calving and be fed at the rate of one percent of body weight (Gillespie, 2004). It is important to limit salt intake during this time as well because excess salt can cause udder edema (Gillespie, 2004). At the time of calving replacement heifers should weigh approximately 60 % of their mature body weight and stand approximately 137 cm at the withers (Hopkins and Whitlow, undated).

Relationship of Heifer Growth to First Calving

Calving is a key event in the life of a dairy heifer (Eaglen et al., 2012). Heifers of adequate skeletal growth and body weight have reduced dystocia. Skeletal size is critical in minimizing dystocia (Shamay et al., 2005). Heifers that are underfed prior to calving tend to be smaller than heifers properly fed and the former have increased rates of dystocia (Schultz, 1969). Dystocia has negative effects on both the dam and the calf. In the newborn calf, prolonged hypoxia and significant acidosis are common problems in calves that experience prolonged or severe dystocia, which can be immediately fatal or reduce long term survival (Lombard et al., 2007). In the heifer dystocia can lead to uterine infection, retained placenta and prolonged calving interval (Cady). Dystocia not only means a greater expense for the producer, but negatively affects the health of the heifer. This can lead to a more difficult transition period when entering the milking herd for the first time.

Mammary Development of the Replacement Dairy Heifer

Mammary development is crucial to the overall growth of the replacement dairy heifer. There are five stages of mammary development in the female dairy animal: fetal, pre-pubertal, post-pubertal, pregnancy and lactation (Ford et al., 1999, Sejrsen et al., 2000). Nutrition of the replacement heifer also plays a role in mammary development and has a large impact on potential milk yield. For the purposes of this review only pre-pubertal, post-pubertal and lactation stages of mammary development will be discussed.

Pre-pubertal mammary growth begins as isometric growth (growing at the same rate as the rest of the body) from birth until about 3 months of age and turns into allometric growth (growing at rates two to four times faster than the rest of the body) from 3 months of age to 9 months of age (Bar-Peeled et al., 1997, Ford et al., 1999). Studies reveal that in heifers this allometric growth phase in mammary development is initiated at two or three months of age, well in advance of the first estrus (Sinha and Tucker, 1969). Mammary growth before puberty is mainly seen as an increase in connective tissue, ductal growth, and growth of the fat pad (Ford et al., 1999). This accelerated mammary growth continues until a plateau is reached at nine months of age (Sinha and Tucker, 1969). Mammary development in the bovine is stimulated mainly during the estrogenic phase of the estrous cycle (Sinha and Tucker, 1969).

Post-pubertal mammary growth is rapid through the first several estrous cycles (Ford et al., 1999). After this early post pubertal mammary development, the estrogens present during subsequent estrous cycles continues to stimulate mammary growth, although most of this growth is lost through regression during the luteal phase of each estrous cycle (Ford et al., 1999). Consequently, the number of estrous cycles after puberty and before pregnancy can influence total mammary growth (Ford et al., 1999). The majority of mammary growth occurs during pregnancy but is a continuous, exponential process from conception to parturition, with the greatest increase in mass of parenchymal tissue occurring in late pregnancy (Ford et al, 1999). The udder increases noticeably in size due to the elongation of the mammary ducts, the formation of alveoli, and the reduction of identifiable fat cells in the fat pad (Ford et al., 1999). Mammary epithelial cells complete differentiation during pregnancy and milk synthesis begins (Ford et al., 1999). In the last month of pregnancy, the alveoli show secretory activities, and the udder begins increasing in size due to the accumulation of the secretory material (Ford et al., 1999). The primary cause of mammary growth during pregnancy is the simultaneously elevated blood concentrations of estrogen and progesterone, though nutrition has also been shown to have a role (Ford et al., 1999).

The age at which mammary glands of the young heifer are connected is significantly associated with size and shape, and attachments of udder in first lactation and mature cows (Rader et al., 1972). The time period between three months of age and puberty is critical to mammary development (Schoonmaker, 2006b). In fact, the mammary gland grows more rapidly during this time than after puberty (Schoonmaker, 2006b). Data shows that gains greater than 0.91 kg per day for Holsteins causes impaired mammary development (Schoonmaker, 2006b).

Mammary growth relative to body growth is decreased when heifers approximately 3 to 10 months of age are fed high-energy diets, resulting in over conditioned heifers with decreased milk yield potential (Rincker et al., 2008). This age range coincides with the period of allometric growth relative to overall body growth (Rincker et al., 2008).

Prior to puberty, elevated caloric intake has been shown to negatively affect pre-pubertal mammary development in the heifer (Meyer et al., 2006). Being that, pre-pubertal mammary development consists of branching and elongation of the mammary ducts into the surrounding mammary fat pad (Meyer et al., 2006). More extensive branching, elongation, and ultimately the appearance of secretory alveolar cells occur only after conception under the direction of the pregnancy hormones (Meyer et al., 2006). Post natal mammary growth occurs at an allometric rate prior to puberty and returns to an isometric rate after puberty (Meyer et al., 2006). It has been consistently demonstrated that parenchymal (PAR) mass, DNA content, or both are reduced in heifers reared on an elevated caloric intake during pre-pubertal allometric growth (Meyer et al., 2006).

Role of Genetics in Heifer Growth and Productive Life

Genetics is one of the main factors that play a role in replacement dairy heifer growth and productive life in the milk herd. Genetics determine the inherent potential for an embryo to grow into a highly profitable adult cow while feeding and management determine the extent to which that potential will be realized (Lee, 1997). For this reason it is important to ensure that the feeding program encourages rapid growth in order to allow the full expression of the genetic potential of heifers (Pirlo et al., 1997). One of the many goals of dairy producers is to use genetic selection for improved health and longevity (Henderson et al., 2011). The success of this goal cannot be accurately determined until performances of offspring are analyzed (Aitchison et al., 1972).

Previous studies have shown that there is a high genetic correlation between body weight as a heifer and productivity in the first lactation, even when weight is measured in heifers as young as the age of six months (Harville and Henderson, 1966). Different studies suggest that the tendency for heifers to voluntarily consume large amounts of forage is associated with the genetic capacity of yearling heifers to gain body weight and to utilize accumulated body reserves to support high milk yield during first lactation (Lee et al., 1992). However, a positive genetic correlation between body size and production means that selection for production will result in larger cows, with increased growth and maintenance costs (Harville and Henderson, 1966). Even though growth rate is heritable, its magnitude is one half or less than that of milk production in the first lactation (Hargrove, 1974).

Relationship of Replacement Heifer Growth Measurements

Growth is defined as maturation of the reproductive system, as well as an increase in body size and weight, which is affected by many factors such as genetics, nutrition and management (Heinrichs and Hargrove, 1987). Holsteins with greater growth rates are raised in dairy herds with higher than average milk production, as shown in recent studies (Heinrichs, 1993, Heinrichs and Losinger, 1998). In order to tell whether or not heifers are growing well, their growth must be measured (Chart the growth of heifers, 2004). There are several ways to measure growth in heifers. The most common way to measure body weight and look at average daily gain; however, recent studies have explained skeletal measurements, searching for a more accurate method of measuring replacement dairy heifer growth. Understanding heifer growth is facilitated by the use of body measurements and management’s effects on growth (Heinrichs et al., 1992). There is belief that an estimation of replacement heifer body size from composition selection traits could benefit dairy producers, provided the selection for these traits would help to further the efficiency and productivity of replacement heifer growth, and future milk yield (Hoffman, 1997).

Body weight has always been considered a good measure of size, as it is an easy measurement to obtain (Clark and Touchberry, 1962). The body weight of an animal is influenced by its age, genotype, and the environmental conditions under which it is raised (McDaniel and Legates, 1965). A large number of dairy producers do not have scales on the farm and therefore rely on a more convenient method of weighing replacement heifers. Research has shown that using a weigh tape to measure heart girth correlates well to body weight, making this method a reliable indicator of how much heifers weigh (McDaniel and Legates, 1965, Quaife, 2004, Dingwell et al., 2006). This method consists of a measuring tape placed around the circumference of the animal just behind the withers (Dingwell et al., 2006). The downside to only looking at body weight is that it is a multi-dimensional measurement in which size (skeletal development), fatness, and gut fill are major determinants (Enevoldsen and Kristensen, 1997). Wither height, hip height, and hip width are indicators of skeletal development that are relatively easy to obtain (Enevoldsen and Kristensen, 1997). Perhaps it would be beneficial if more producers used skeletal measurements to assess heifer development.

Skeletal measurements do not take into account gut fill and body condition of the heifer and therefore may be more reliable indicators of true growth. Another advantage is that height and width measurements represent two extremes with respect to skeletal development (Enevoldsen and Kristensen, 1997). Changes in skeletal measurements would identify only the most inadequate rations because skeletal measurements are hard to change and do not fluctuate up and down as body weight does (Clark and Touchberry, 1962, Martin et al., 1962). Mature height of the heifer is developed first and mature hip width is developed last (Enevoldsen and Kristensen, 1997). Research has shown that a body size measurement such as height is a potentially important determinant of the gross production efficiency of the animal (Enevoldsen and Kristensen, 1997).

Height can be measured by either the withers or the hips as long as it is accurate (Quaife, 2004). When measuring withers, animals need to stand straight with their head up (Quaife, 2004). Hip height is measured directly over the hip bones when the animal is standing on a level surface (Dolezal and Coe, 1996). Orientation of the head is less important when measuring hips (Quaife, 2004). Recently, the hipometer (Dairy Innovations, Alexander, N.Y.) has been developed to estimate body weight in Holstein heifers (Dingwell et al., 2006). A custom measuring device was also developed by London et al. (2012) that is effective in measuring hip width.

Research shows a statistically significant correlation between placing rank in the show ring and average daily gain rank in a particular class of show heifers with a P-value of 0.0034 (London et al., 2012). According to a study conducted by London et al. (2012) hip height measurements were near the lower range of industry guidelines and hip width is near the upper range for younger heifers, decreasing their average ranking as heifers get older. When evaluating the weight of heifers shown, out of 1,489 heifers only 36.25% met or exceeded industry standards (London et al., 2012). For these heifers that are not meeting weight guidelines, the results will be disastrous with these heifers calving later in their life, producing less milk, increasing the nonproductive period of the female and increasing the cost to raise the dairy replacement heifer (London et al., 2012).

Research over the years has looked at correlations between different skeletal measurements as well as how these measurements relate to average daily gain, linear evaluation of genetic traits, placing in the show ring and milk production. Height at withers is found to be the body measurement least influenced by differences in body condition (Wickersham and Schultz, 1963). Research indicates that hip width is one of the skeletal measurements more highly related to body weight that is not greatly influenced by body condition (Dingwell et al., 2006). London et al. (2012) found that after evaluating frame measurements of show heifers that height at the withers had the strongest relationship to placing within their respective conformation classes. There is a positive correlation between body weight at calving and first lactation milk production (Harville and Henderson, 1966, Shamay et al., 2005, Moallem et al., 2010). Body weight at first calving has a high positive correlation with mature body weight inferring that limiting skeletal growth of dairy heifers may reduce subsequent milk yields (Koenen and Groen, 1996, Rius et al., 2005). Birth weight has been shown to have a positive correlation with weight and growth rate (Legault and Touchberry, 1962). An indirect relationship exists between age of the animal and average daily gain (London et al., 2012). In order to fully understand how well replacement heifers are growing, several measurements and comparisons of these measurements, with age and average daily gain should be examined.

Body Mass Index in Humans

Body mass index (BMI) is a number calculated using a person's weight and height (Body Mass Index, 2013). In humans, BMI provides a reliable indicator of body fat and is used to screen for health problems (Body Mass Index, 2013). The formula for measuring body mass index is BMI = weight (kg)/height^2(m) (Hartley, 2013). BMI can be used to determine whether or not teens and older children are on track in terms of their growth (Hartley, 2013). Using similar indexes that include both weight and height on heifers may prove beneficial.

The concept of BMI originated in the 19^{th} century by Adolphe Quetelet as an index of weight adjusted for height (Hall and Cole, 2006). It was reinvented by Ancel Keys in the 1950s and called body mass index (Hall and Cole, 2006). Cole first proposed its use in children in 1979, showing that it adjusted weight for both height and age (Hall and Cole, 2006).

BMI is currently the best human body measurement that estimates body fat for public health purposes (Hall and Cole, 2006, About BMI for Adults, 2011). Although BMI does not measure body fat directly, research has shown that BMI correlates to direct measures of body fat, such as underwater weighing and dual energy x-ray absorptiometry (DXA), making it an economical alternative for direct measures of body fat (About BMI for Adults, 2011). BMI is inexpensive, only requiring height and weight. BMI can be used easily by clinicians and the general public (About BMI for Adults, 2011).

BMI is calculated the same for both children and adults. For adults 20 years and older, BMI is interpreted using standard weight status categories that are the same for all ages and for both men and women (About BMI for Adults, 2011). For children and teens, the interpretation of BMI is both age and sex specific as shown in Table 1 (About BMI for Adults, 2011). The amount of body fat changes with and age and differs between girls and boys.

Table 1: BMI Index Chart for Children and Teens

BMI Index Chart for Children and Teens						
	Boys			**Girls**		
Age in Years	**Underweight**	**Overweight**	**Obese**	**Underweight**	**Overweight**	**Obese**
	BMI is <	**BMI is >**	**BMI is >**	**BMI is <**	**BMI is >**	**BMI is >**
2	14.9	17.8	18.8	14.6	17.8	18.7
3	14.5	17.2	18.0	14.3	17.0	18.0
4	14.3	16.8	17.7	13.9	16.6	17.7
5	14.1	16.7	17.7	13.7	16.5	17.8
6	13.9	16.7	17.9	13.7	16.7	18.3
7	13.9	17.0	18.5	13.7	17.2	18.9
8	14.0	17.4	19.3	13.8	17.6	19.8
9	14.2	18.1	20.3	13.9	18.4	20.9
10	14.4	18.8	21.2	14.2	19.2	22.0
11	14.8	19.6	22.2	14.7	20.1	23.0
12	15.3	20.3	23.2	15.2	21.0	24.1
13	15.8	21.1	24.1	15.7	21.7	25.0
14	16.3	21.9	24.8	16.2	22.4	26.0
15	16.8	22.6	25.6	16.7	23.1	26.8
16	17.4	23.4	26.4	17.2	23.7	27.5
17	18.0	24.2	27.2	17.6	24.3	28.2
18	18.6	24.9	27.9	17.9	24.8	28.7

In adults as shown in Table 2, a person with a BMI below 18.5 has a weight status of Underweight, a BMI between 18.5 and 24.9 falls in the category of normal whereas a BMI between 25.0 and 29.9 is considered overweight and lastly a BMI of 30.0 and above is placed in the category of obese (About BMI for Adults, 2011).

Table 2: BMI categories for Adults

BMI Categories for Adults	
Category	**BMI**
Underweight	Below 18.5
Normal	18.5 – 24.9
Overweight	25.0 – 29.9
Obese	30.0 and Above

Although BMI is very useful, it does have limitations and variables (Aim for a Healthy Weight, 2013). It may overestimate body fat in athletes who have a muscular build and in women who tend to have more body fat than men. It also may underestimate body fat in older adults who have lost muscle (Aim for a Healthy Weight, 2013, About BMI for Adults, 2011). The BMI ranges are based on the relationship between body weight, disease and death (About Adult BMI, 2011). Overweight and obese individuals are at an increased risk for many diseases and health conditions, such as hypertension, high LDL cholesterol, low HDL cholesterol, high triglycerides, type 2 diabetes, coronary heart disease, stroke, gallbladder disease, osteoarthritis, sleep apnea, respiratory problems and cancer (About Adult BMI, 2011).

For clinical and research purposes, obesity is divided into three categories (Table 3): Class I (30-34.9 BMI), Class II (35-39.9 BMI) and Class III has been further divided into three sections due to the growth of extreme obesity; 40 to 49.9 BMI, super-obesity (50-59 BMI) and super-super obesity (60 and above BMI) (Why Use BMI?, 2013).

Table 3: Classes of Obesity

Classes of Obesity	
Obesity Category	**BMI**
Class I	30 – 34.9
Class II	35 – 39.9
Class III	40 – 49.9
	50.0 – 59.9 (super-obesity)
	60 and above (super-super obesity)

The location of body fat is also important; fat that accumulates around the waist and chest may be more dangerous for long-term health than fat that accumulates around the hips and thighs (Why Use BMI?, 2013). Some researchers argue that waist circumference could be a better indicator of disease and that BMI should be discarded in favor of this new idea (Why Use BMI?, 2013). This is unlikely due to the fact that BMI is easier to measure, has a longer history of use and reliability, and does an excellent job of predicting disease risk (Why Use BMI?, 2013). However, combining BMI and waist circumference may be a better way to predict someone's weight-related risk (Why Use BMI?, 2013). Our interest in BMI is not as much from a disease standpoint, but to develop an index combining growth and weight to better evaluate heifer growth.

Implications of Sexed Semen on Dairy Operations and Heifer Development

Researchers have toyed with sexed semen for decades and there is definitely a demand for the technology's end result – a live heifer calf (Sattler, 2005). Over the past two and a half decades, artificial reproductive technologies have come to the forefront of reproductive research

(Moore and Thatcher, 2006). Dairy producers and breeders have tried for centuries to manipulate the sex of the offspring (Norman et al., 2010). The ability to alter the sex ratio in favor of heifer calves is a great advantage to the dairy industry for producing replacement heifers (Moore and Thatcher, 2006). Fulfilling an AI contract is about the only time a dairy producer strives to get a bull calf (Sattler, 2005). Until recently, the only option was to sex embryos (Moore and Thatcher, 2006). In 1987, Larry Johnson with the USDA introduced what is now called the Beltsville Sperm Sexing Technology in which to sort sperm based on DNA content (Moore and Thatcher, 2006). Sperm sexing is an assisted reproductive technology that can increase the efficiency of breeding programs in dairy herds (Cerchiaro et al., 2007). Dairy producers' interest in sexed semen is a function of desire for herd expansion, internal herd growth, genetic progress and increased biosecurity (Olynk and Wolf, 2007).

The Beltsville Sperm Sexing Technology or fluorescence-activated cell sorting approach licensed to XY Inc. (Fort Collins, CO) is the proven method of sorting sexed semen (Olynk and Wolf, 2007). Sexed semen is semen in which the fractions of x-bearing and y-bearing sperm have been modified from the natural mix through sorting and selecting (De Vries et al., 2008). The goal of sexed semen is to produce a calf of a specific sex (De Vries et al., 2008). The Beltsville Sperm Sexing Technology works by staining sperm with a DNA-binding fluorescent dye (De Vries et al, 2008). The bovine Y-chromosome bearing sperm contain 3.8% less DNA than the X-chromosome bearing sperm thus allowing for their separation by a fluorescence-activated cell sorter (De Vries et al, 2008).

Only 25% of the sperm processed are actually sexed, meaning that many sperm are damaged or distinction cannot be made (Moore and Thatcher, 2006, Olynk and Wolf, 2007). However, this method has an accuracy rate of 85% to 95% of the sperm containing the desired chromosome (Sattler, 2005, Moore and Thatcher, 2006, Olynk and Wolf, 2007, De Vries et al., 2008).

As with everything, there are advantages and disadvantages to sexed-semen. The two major draw backs when using sexed semen are 1) it is a very slow process with only 150 to 200 straws of sexed semen produced per machine per day (Moore and Thatcher, 2006). This number is very low considering that approximately 44,000 straws of semen are used each day by dairy producers in the United States (Moore and Thatcher, 2006). 2) lower conception rates are generally seen with sexed semen (Moore and Thatcher, 2006). Straw production technology should continue to improve. There are a few other possible disadvantages to consider when deciding whether or not to use sexed semen. Research has shown that conception rates in virgin heifers with sexed semen average 35% as compared to virgin heifers with conventional semen averaging 55% (Moore and Thatcher, 2006, DeJarnette et al., 2011). There is some evidence that milk yield may be reduced in cows producing daughters compared with cows producing sons as a result of a positive association between birth weight and milk production, however, to what degree is not known (De Vries et al., 2008).

Advantages of using sexed semen for the dairy producer include an increased supply of replacement heifers, thereby reducing dairy heifer purchase, sale prices and easier within herd growth (De Vries et al., 2008). This obvious benefit creates more profit generating units for the dairy operation (Sattler, 2005). An increase in the number of heifers helps improve herd genetics quicker as well as allows merchandising of cattle from producers' most valuable cattle (Sattler, 2005). Increased effectiveness of artificial insemination progeny testing programs, in-vitro embryo programs, multiple ovulation and embryo transfer schemes and reduced dystocia are other advantages of using sexed semen to producers (De Vries et al., 2008).

Studies have shown that first calf heifers experience fewer difficult births when giving birth to a heifer compared to a bull (Sattler, 2005). According to the National Association of Animal Breeders (NAAB) calving ease data, 10.9% calving from first calf heifers are difficult when a bull calf is born as compared to 5.3% difficult calving when a heifer calf is born (Sattler, 2005).

When deciding whether or not to use sexed semen a dairy producer must consider the economic benefits for the farm. Historically, milk prices, pregnant replacement heifer prices, and cull cow prices have been positively related (De Vries et al., 2008). The economics of dairy cattle replacement means that essentially all possible pregnancies are needed to produce enough dairy heifer calves to replace cull cows as well as pregnancies needed to start new lactations and boost milk production (De Vries et al., 2008). The price of dairy heifers is very sensitive to supply and demand (De Vries et al., 2008).

Economic benefits of sexed semen may be obtained as a result of higher prices for female dairy calves which can bring $450 compared with male dairy calves which are normally only worth about $50, the marketing value of calves not used as replacements, optimized turnover rates, reduced dystocia, increased rate of genetic progress, and possibly improved biosecurity if open herds could be closed (De Vries et al., 2008 and De Vries, 2009). An increased supply of heifers may also provide greater opportunity to cull poor growing heifers, thereby avoiding future losses as poor performing cows (De Vries et al., 2008). According to Sattler (2005) sexed semen is a good option for expanding herds but it is best to use sexed semen on virgin heifers due to their increased fertility and compensation for the decrease of conception rates observed when using sexed semen versus conventional semen (Sattler, 2005, Olynk and Wolf, 2007).

Continued advances in semen sorting technology, improved fertility of sexed semen, and increased marketing will likely increase the use of sexed semen in the dairy industry in the next decade on a much wider scale (De Vries et al., 2008). Altering sex ratio in favor of heifer calves is a great advantage for the dairy industry for producing replacement heifers (Moore and Thatcher, 2006). The decision to use sexed semen should, however, be based on whether producers can economically justify the additional costs associated with the use of sexed semen to obtain heifer calves (Olynk and Wolf, 2007). There is currently limited opportunity to increase the number of heifers on farm by using sexed semen without additional costs (De Vries et al., 2008). Many dairy farms do not have the facilities, feed, labor or capital needed to raise additional heifers (De Vries et al., 2008). If more heifer calves are produced as a result of the use of sexed semen, an increase in specialized heifer growing operations is anticipated (De Vries et al., 2008). With the advent and increasing practice and success of sexed semen, the future looks promising to have plenty of heifers for youth to select from.

Custom Replacement Dairy Heifer Grower Industry

Dairy farms in the United States have been increasing in size and specialization for decades; recent years have seen an acceleration of these trends (Wolf, 2003). Management, labor, and capital constraints may necessitate a movement towards outsourcing activities that were once part of a smaller, but more diversified dairy operation (Wolf, 2003). Utilizing a custom dairy replacement heifer grower is an increasingly popular example of outsourcing among dairy producers (Wolf, 2003). This option is also referred to as heifer contracting, which is essentially the collaboration between the dairy farmer and the custom dairy heifer grower (Andersson, 2010).

There are both advantages and disadvantages for the dairy producer in choosing to contract with a custom replacement dairy heifer grower. According to Wolf (2003) the major advantages to the dairy producer include the potential for free labor, management, and feed or facilities for use by the milking herd. Disadvantages include cash outflow, loss of management control, biosecurity risks, and potential for conflict (Wolf, 2003).

A contract is a necessity for any business because it defines the terms of the relationship between involved parties (Karszes and Cady, 2000). Producers and custom heifer growers enter into a heifer raising contract in order to protect the interest of both the replacement heifer grower and the dairy producer (Bunfert, 1998). The contract between the dairy producer and the custom replacement dairy heifer grower serves four main purposes and contains five major elements (Karszes and Cady, 2000).

The four main purposes of the contract are 1) a management tool that requires joint planning between the grower and the owner, describing how business will be conducted and the implications of these decisions, thus improving communication 2) clearly defines expectations and responsibilities of each party before the relationship is entered into 3) provides direction and legal recourse for the parties if conflicts occur and 4) Provides documentation of a legal relationship to third parties such as bankers, regulators, or government agencies (Karszes and Cady, 2000).

There are five major elements associated with the ideal contract between dairy producers and custom dairy replacement heifer growers. These elements are 1) time period 2) billing and payment procedures 3) definition of each party's responsibilities 4) amendments, renegotiations, and renewal and 5) conditions for termination of agreement (Karszes and Cady, 2000). When these elements are included in the contract it ensures that both parties are protected to the best of the contract's ability.

There are two different ways to engage in a contract with a custom replacement dairy heifer grower. The first way is to board heifers while retaining ownership of each heifer and the second way is to transfer ownership of the heifers with buy back as an option (Karszes and Cady, 2000). There are several different methods of payment of which five of the most popular are described below.

Per Day Per Animal: This route entails a flat fee that is charged per animal per day which allows easy budgeting by both parties but all risk of cost changes are assumed by the grower (Karszes and Cady, 2000). Minimum standards on growth, body condition scores and weight requirements may be set to go along with the per day per animal basis (Karszes and Cady, 2000).

Per Animal: A set fee is implemented per animal raised to a specific average weight or for a set period of time where there is usually no differentiation based on performance of animals (Karszes and Cady, 2000). Growth rate, body condition score and weight requirements may be set (Karszes and Cady, 2000). The grower assumes all cost uncertainties (Karszes and Cady, 2000).

Per Pound of Gain: This rate is based on animal weight gain while under the grower's care which gives the grower an incentive to maintain high growth rates (Karszes and Cady, 2000). Growth rates and body condition score standards should be predetermined to protect against fat heifers as well as anticipated time an animal is on the farm, feeding systems and shrinkage (Karszes and Cady, 2000). Under this method it is difficult to budget income amounts without historical performance records, however; the grower assumes cost uncertainty (Karszes and Cady, 2000).

Feed Plus Yardage: The route is based on actual feed costs, plus a charge for services and supplies provided (Karszes and Cady, 2000). This plan is similar to per day per animal plans but allows for rate adjustment based on changing feed costs which makes it difficult for the dairy producer to budget expense because it allows the grower to transfer some uncertainty of changing costs to the producer (Karszes and Cady, 2000).

Option to Purchase: Under this plan, animal ownership transfers to the grower with a first option to buy back at a set price held by the dairy producer (Karszes and Cady, 2000). The producer may choose not to buy back the animal at which point the grower can sell the animal on the open market (Karszes and Cady, 2000). Risk to the grower is highest in this plan because he assumes all cost risks, not necessarily guaranteed a sale, and will usually have only intermittent cash flow (Karszes and Cady, 2000). However, this plan is often the first option for growers who are just getting started and need to develop a reputation for excellent service (Karszes and Cady, 2000).

Raising quality replacement dairy heifers is a full time job (Fitchette, 2001). The custom replacement dairy heifer grower industry presents a potentially profitable business opportunity that may productively utilize facilities, labor and management (Wolf, 2003).

Cost of Raising Replacement Dairy Heifers

A dairy herd can be considered as a multiple component system, with two principle components, the milking herd (including dry cows) and the replacement herd (Tozer and Heinrichs, 2001). Heifers should not be viewed as a cost but rather an investment (Schoonmaker, 2003). Rearing replacement heifers from birth to first calving is costly, accounting for approximately 20% of the total operation expenses, and being the second largest expense behind feed costs for the milking herd in the annual operating expenses of a dairy farm

(Radcliff et al., 1997, Hansen et al., 1999, Gabler et al., 2000, Shamay et al., 2005, Rincker et al., 2008). Minimizing heifer rearing investments while maintaining the productive integrity of the replacement heifers as well as maximizing future milk yields should be the primary objective of replacement heifer management (Hoffman and Funk, 1992, Fox et al., 1999, Gabler et al., 2000). Dairy operations have a variety of resources and objectives, such that the most economical method of obtaining replacement heifers is only determined by individual farm budget analysis (Gabler et al., 2000).

Because of the nature of replacement heifer management, a dairy operation must invest feed, labor and capital for 22 to 24 months without receiving any realized benefits (Gabler et al., 2000). The interaction between the components determines the number of replacements required by the milking herd and the number of potential replacements retained by the dairy producer (Tozer and Heinrichs, 2001). The number of replacement heifers raised on a dairy farm depends on several factors within the milking and the replacement herds (Tozer and Heinrichs, 2001).

The factors within the milking herd that influence the number of heifers raised include the voluntary and involuntary culling within the dairy herd, the calving interval, and the live calving rate of the dairy herd (Tozer and Heinrichs, 2001). In the replacement herd these factors include calf and heifer mortality rates, the age at first calving, the reproductive efficiency of the replacement and other involuntary heifer culling (Tozer and Heinrichs, 2001).

The largest cost component of heifer rearing is feed cost (Kertz et al., 1998). The costs of rearing heifers depend on growth of the heifers: faster growing heifers cost more in feed on a daily basis as they require a ration with greater concentration of costly ingredients (Tozer and Heinrichs, 2001). However, this increase in daily feed costs is offset by lower total feed cost (Tozer and Heinrichs, 2001). Other variable costs, such as labor and housing are also reduced as the animals are kept for shorter periods of time, meaning a reduced time interval between birth and first calving (Tozer and Heinrichs, 2001, Moallem et al., 2004). The opposite occurs for slower growing heifers; daily feed costs are lower but total feed costs are higher (Tozer and Heinrichs, 2001).

The cost of rearing dairy replacement heifers can be reduced by accelerating growth and early breeding (Hoffman et al., 1996). Minimizing age at first calving requires dairy producers to keep heifers for a shorter period and need a fewer number of replacement heifers, therefore reducing the total costs of rearing replacement heifers, getting an earlier return on investments and the option to sell surplus heifers at the most profitable age (Gardner et al., 1988, Hansen et al., 1999, Tozer and Heinrichs, 2001). Reducing the average age at first calving by one month can lower the costs of a replacement program by approximately $1400 (Hansen et al., 1999).

Culling rate of the herd also has an impact on the cost of raising replacement dairy heifers. The lower the culling rate of the herd; the fewer replacement heifers that are needed. A milking herd culling rate greater than 25% can lead to a deficit in replacements to maintain herd size (Tozer and Heinrichs, 2001). The costs of rearing replacements could be reduced by approximately $1000 to $1500 per 1% reduction in the milking herd culling rate (Tozer and Heinrichs, 2001).

For economical heifer development the growth rate should be moderate and should result in uniform rates of gain without noticeable fattening (Swanson, 1971). The cost to raise a heifer per day and the cost per pound of gain increases with size (Bungert, 1998). Because feed costs make up roughly 60% of the cost to raise a replacement heifer it is crucial for dairy producers to keep feed costs inline without hurting growth rates (Schoonmaker, 2004).

CHAPTER 2

ALLOMETRIC COMPARISON OF GEORGIA DAIRY HEIFERS ON FARMS AND AT YOUTH SHOWS[1]

[1]White, D.S., M.A. Froetschel, K.J. Duberstein, J.K.Bertrand, A.H. Nelson, W.M. Graves. To be submitted to *The Journal of Dairy Science.*

Abstract

Studies were conducted to determine the relationship between Holstein dairy heifer growth and placing in the show ring (study 1) as well as the differences in growth between Holstein show heifers and non-show Holstein heifers (study 2). In the first study, 494 Holstein show heifers were evaluated at the 2012 and 2013 Georgia Jr. National Livestock Shows. Measurements were taken for weight, head length, wither height, hip height, thurl width and tail length. Calculations were made for HMI (heifer mass index), ADG, age and levelness. A total of 72.47% of Holstein show heifers were underweight, not meeting industry standards. The average ADG was 0.63 kg which is below the recommended 0.7 kg to 0.8 kg per day (Kertz et al., 1987, Abeni et al., 2000). The PSU GMS (Pennsylvania State University, 2013) showed that the majority of show heifers from both years were below the median for weight, but were meeting skeletal growth guidelines for wither height, hip height and hip width. The variables were ranked and converted to percentages in order to account for differences in class size. The GLMSELECT Stepwise Selection (SAS Institute, 2008) was used to determine predictability of placing in the show ring, wither height ($P < 0.0001$), head length ($P = 0.0003$) and HMI ($P = 0.008$) appears to be indicative of placing.

In the second study, differences were looked at between the growth patterns of show heifers versus non-show heifers. An additional 293 non-show Holstein heifers were evaluated using the Pennsylvania State Growth Monitor Spreadsheet (Pennsylvania State University, 2013). A total of 43.34% of non-show heifers were underweight and not growing to industry standards. The average ADG for non-show heifers is 0.71 kg which is within industry recommendations (0.7 to 0.8 kg per day). According to the PSU GMS show heifers weigh less for their age than non-show heifers and this was confirmed using the GLM Procedure. Show heifers also tended to be taller at the withers than non-show heifers. HMI scores are similar for

younger heifers but older show heifers have lower HMI scores than non-show heifers of the same age. Show heifers had HMI scores that were further from the ideal than non-show heifers. As show heifers mature ADG decreases, whereas non-show heifers mature ADG increases.

These differences between show heifer and non-show heifers reflect the way the heifers were managed. Youth, leaders and parents need to be aware of the importance of growing replacement heifers correctly so that heifers calve at 22 to 24 months of age and become profitable members of the milking herd without causing the dairyman to lose profits because of delayed development.

INDEX WORDS: COMMERCIAL DAIRY HEIFER PROGRAM, ALLOMETRIC GROWTH, SKELETAL GROWTH, WEIGHT, HEIFER MASS INDEX, AVERAGE DAILY GAIN

Introduction

An important part of any successful dairy operation is rearing dairy heifers to replace cows over time in the milking herd. Dairy producers depend on replacement heifers to eventually maintain or exceed current levels of milk production on the farm (Bath et al., 1985). Proper management of the replacement heifer from birth to weaning, weaning to puberty, and puberty to calving ensure adequate growth, mammary development and success in the milking herd.

Growth is often characterized by the maturation of the reproductive system, and defined as an increase in body size and weight, which are affected by genetics, nutrition and management (Heinrichs and Hargrove, 1987). Dairy producers strive to raise their replacement heifers as efficiently as possible, minimizing costs and maximizing profitability by breeding at 14 to 15 months of age and calving between 22 and 24 months of age. In order to achieve this goal, heifers are grown so that they are of adequate skeletal size and weight by weaning, puberty, breeding and calving. Both underfeeding and overfeeding heifers can have negative effects on puberty, calving, mammary development and milk production.

Growth is indicative of developmental maturation. Body weight and average daily gain are the most common indices for measuring growth. However, recent studies are exploring skeletal measurements, because these are not as influenced by gut fill and body condition and may be more reliable indicators of true growth. Body mass index (BMI), calculated in humans, as a function of weight and height provides a practical yet reliable indicator of body fat and is used in health screening (Body Mass Index, 2013). Using similar indexes on heifers may prove beneficial to monitor growth and development for optimal production.

There are several programs in which youth can become involved in and learn about the dairy industry through the 4-H and FFA organizations. As the number of youth who come from rural dairy backgrounds decreases, youth organizations are seeing more and more youth coming from urban backgrounds that are interested in learning about the dairy industry (Schwanke, 1997). 4-H Dairy Quiz Bowls, Skillathons, National 4-H Dairy Conference, Dairy Judging and Dairy Heifer Shows are among the most popular dairy youth programs. These programs impart valuable life skills to youth that will be of great benefit as well as an understanding and appreciation of the dairy industry.

The Georgia Commercial Dairy Heifer Program has developed into a popular program in Georgia since its inception in 1997. The program allows youth coming from both rural and urban backgrounds that either do not have access to dairy animals or lack the resources to purchase dairy animals, the opportunity to gain hands on experience caring for and showing borrowed heifers at little or no cost to the youth. London et al. (2012) reported that only 82 youths entered the first year of this program, but there have been at least 300 entries since 2002.

Several youth have pursued degrees and careers in the dairy industry after their participation in the Georgia Commercial Dairy Heifer Program as well as other livestock programs (London et al., 2012). Assessment of growth and development of replacement heifers in this program is important to insure producer involvement. Setting show guidelines for heifer growth should be based on practical and accurate measurements.

The objective of the first study was to examine the relationship between weight, age, Average Daily Gain (ADG), Heifer Mass Index (HMI), head length, wither height, hip height, thurl width, tail length and placing of commercial Holstein dairy heifers shown in the Georgia Jr. National Livestock Show in 2012 and 2013. As part of this objective, a new index to utilize skeletal traits with weight to better evaluate growth will be developed. Animals were also compared to industry standards using the Penn State Growth Monitor Software. The objective of the second study was to look at the growth of Holstein dairy heifers from three farms across the state of Georgia over the same consecutive two years, using the same parameters and measurements as the first study and compare them to the Holstein show heifers. The GLM Procedure in SAS software (SAS Institute, 2008) was used to look for differences and similarities in growth patterns between the two groups.

Materials and Methods

Evaluation of Commercial Dairy Show Heifers

In the first study, 454 Holstein commercial show heifers shown at the Georgia Jr. National Livestock Show were evaluated. Data was collected for two consecutive years (2012 and 2013). According to the Georgia Jr. National Livestock Show rulebook, all heifers were born between March 1st and September 30th of the previous year (2012 – 2013 Georgia 4-H and FFA Livestock Shows Rules and Regulations, 2012). Each youth exhibitor completed and submitted an entry form, stating their name, grade, county, organization, animals' identification number, breed and birthdate. Animals were identified using photographs (spotted calves) or tattooed (solid colored calves). Our study must rely on the accuracy of the information provided, especially birthdates which are assumed to be accurately provided by the exhibitor. Birthdates were used to calculate age in days and average daily gain. Heifers exhibited at the Georgia Jr. National Livestock Show each have a state ear tag with a unique number not shared by any other animal in the barn. State tags were used as the identification number for the Holstein Commercial Show Heifers.

Data was collected at check-in at the Georgia Jr. National Livestock Show in Perry. Identification number, birthdate and county origin were obtained for each animal. Weight for the show heifers was obtained using a calibrated digital scale at the time of check-in. Head length, wither height, hip height, thurl width and tail length were the skeletal measurements taken on each heifer. Every measurement except thurl width was taken using a Ketchum Deluxe Livestock Measuring Device (Ketchum Manufacturing, Inc. Brookville, Ontario Canada). Head length was measured as the distance from the back of the poll to the tip of the muzzle. Wither height was measured as the distance from the point of the withers to the ground. Hip height was measured from the top of the hip to the ground. Tail length was measured from the tail head to the end of the tail bone. Some producers prefer to dock their heifers' tails for cleanliness and ease of milking. These heifers were excluded from the tail length analysis. Thurl width was taken using a custom-designed measuring device developed by The University of Georgia Instrument Shop (Athens). The thurl width measurement is defined as the distance between the thurl joints (London et al., 2012).

Levelness of the back was determined by subtracting wither height from hip height. Heifer mass index was obtained by taking the weight of the heifer in kilograms and dividing by hip height squared (BMI Formula, 2012). This formula is adapted from the human body mass index formula; instead of using height from head to toe as you would in humans, height at the hip was used in this calculation. Hip height is more consistent than wither height and used by the Holstein Association in linear evaluation. Average daily gain is determined by subtracting the weight at the show from the average birth weight; then dividing the difference into the age in days of the heifer (London et al., 2012). Average birth weight for a Holstein calf is 42.2 kg (London et al., 2012). Age in days of the heifer is calculated by subtracting the birth date of the heifer from the date measurements were taken (London et al., 2012).

Measurements for the 454 commercial heifers shown in the 2011 and 2012 Georgia Jr. National Livestock Show were entered into the Growth Monitor Spreadsheet (Pennsylvania State University), and used to determine whether these heifers were being developed properly. Date of the measurement taken, identification number, birth date, weight, wither height, hip height, and thurl width were input into the Growth Monitor Spreadsheet. From this information the program calculated age in months of each heifer, created graphs and identified heifers that were underweight by industry standards.

Weight, average daily gain, head length, tail length, wither height, hip height, thurl width, heifer mass index, county, grade and organization were correlated with heifers' placement in the show. Rankings were assigned to each class in the show for placing, heifer mass index, ADG, age, weight, head length, wither height, hip height, thurl width, and tail length of each heifer. Rankings were converted to percentages to account for small differences in the number of animals in each class. Both percentages and unranked variables were then correlated using the

Spearman correlation calculations in SAS (SAS Institute, 2008). The General Linear Model (GLM) Select Stepwise Selection was used to determine which measurements had a significant impact on placing of the animal in the show ring (SAS Institute, 2008).

Comparison of Show Heifers and Non-show Heifers

In order to effectively compare the growth of the show heifers, 293 heifers from three farms in Georgia were evaluated and analyzed using the same criteria as used for the show heifers. The final step was to compare these heifers from Georgia farms to those measured at the shows.

Evaluation of Non-show Heifers

The non-show heifers selected for allometric evaluation had to meet the same age requirements and criteria as the Holstein show heifers from the first study. Data was collected at each individual dairy farm. Farm Identification numbers were used as the Identification number for each non-show Holstein heifer. The birthdate was provided for each heifer by the producer and each farm was coded Farm 1, Farm 2 or Farm 3 as the origin of the heifer. Since this group of heifers were never shown; placing, grade, county and organization were not evaluated. A Dairy Weight Tape (Nasco, Wisconsin) was used to estimate weight of non-show heifers, as most dairy producers do not have scales on their farms. Research has shown that using a weigh tape to measure heart girth correlates well to body weight, making this method a reliable indicator of how much heifers weigh (McDaniel and Legates, 1965, Quaife, 2004, Dingwell et al., 2006). All measurements but weight were done the same for farm heifers as for the commercial dairy show heifers. Measurements for the non-show heifers were also entered into the Growth Monitor Spreadsheet (Pennsylvania State University) and compared against industry standards the same way as for the show heifers in the first study. The Spearman Correlation Calculations in SAS were used to correlate the unranked variables (SAS Institute, 2008).

Comparison of Measurements of Show Heifers to Non-show Heifers from Dairy Farms

We were then able to compare the 293 Holstein non-show heifers to the 454 show heifers in study 1. Scatterplot graphs using Microsoft Excel were created for weight, head length, wither height, hip height, hip width, tail length, heifer mass index, average daily gain, and levelness. Scatterplots were created with age in months on the X-axis and the measurement on the Y-axis. A linear average line was developed for each individual group on each graph. The formula used is $y = ax + b$ where "x" and "y" are coordinates of any point on the line, "a" is the slope of the line and "b" is the y-intercept. These graphs were used to visualize differences between non show heifers and show heifers. Data from both groups of heifers were compared to each other by SAS (SAS Institute, 2008) using the GLM Procedure to determine whether or not there are differences between the four groups (show year 1, show year 2, farm year 1 and farm year 2) by calculating the slope for each group for each variable. Each measurement was tested individually. The measurement was the dependent variable and age by year group was the independent variable.

Results and Discussion

Evaluation of Commercial Dairy Show Heifers

A total of 454 show heifers at the Georgia Jr. National Livestock Show in 2012 (year 1) and 2013 (year 2) were used in this study. The PSU GMS (Pennsylvania State Growth Monitor Spreadsheet) (Pennsylvania State University, 2013) was used to determine the percent of underweight heifers not meeting industry growth standards. The spreadsheet assumes a target body weight of 55% of mature weight at first conception and 85% of mature weight after first calving, as cited in the 2001 Dairy NRC (Pennsylvania State University, 2013). Height targets are assumed to be 55% of mature height at birth and 96% of mature height at first calving; 50% of height growth from birth to calving is assumed to occur between birth and 6 months with an additional 25% between 6 and 12 months and the final 25% between 12 months and calving (Pennsylvania State University, 2013). These targets were derived from a comparison of heifer growth data from all breeds to mature heights calculated by assuming mature body weight and using the relationship between withers height and body weight determined by Heinrichs et al., 1992 and Kertz et al., 1998 (Pennsylvania State University, 2013).

The average ADG for the show heifers was 0.63 kg per day in this study. This is below the recommended ADG of 0.7 to 0.8 kg per day (Kertz et al., 1987, Abeni et al., 2000). London et al. (2012) found similar results with show heifers and reported having an ADG of 0.65 kg during the four years prior to this study. A total of 72.47% (329 heifers) of Holstein show heifers at the 2012 and 2013 Georgia Jr. National Livestock Show were underweight, not meeting industry standards. Only 27.53% (125 heifers) of Holstein show heifers met industry standards. This percentage has increased from a study in which 63.75% of Holstein heifers from 2007 to 2010 failed to meet industry standards (London et al., 2012). Heifers not meeting weight guidelines return to their farm of origination behind their herd mates of the same age in terms of development. This results in the strong potential of delayed puberty and subsequently calving at an older age than desired resulting in delayed and/or loss of profit. A complete breakdown of the percentage of underweight show heifers and show heifers meeting weight requirements can be found in Appendix 10.

The PSU GMS (Pennsylvania State University, 2013) was also used to graph weight, wither height, hip height and hip width and compared these measurements against industry standards. These graphs are broken down into year 1 and year 2 for each measurement and can be found in Appendices 11-18. The majority of show heifers from both year 1 and year 2 are below the median for weight. This observation corresponds with the lower than recommended ADG, indicating once again that the majority of show heifers are not as developed as they should be for their age. The graphs for wither height for both year 1 and year 2 show that the majority of show heifers are above the 75^{th} percentile, while the majority of show heifers fall in between the upper and lower range for hip heights. Hip width graphs for year 1 and year 2 show that younger heifers are on the upper end, having wide hips for their age, but as they get older hip width is not as much.

According to the PSU GMS, the majority of show heifers are meeting skeletal growth guidelines. Mature height of the heifer is developed first and mature hip width is developed last (Enevoldsen and Kristensen, 1997). Changes in skeletal measurements only identify the most inadequate rations (Clark and Touchberry, 1962, Martin et al., 1962). The weights of the majority of the show heifers are not meeting industry standards, which indicate a problem with nutritional programs fed show heifers. The differences for each county are listed below in Table 4. Only four counties had 50% or more growing according to industry standards.

Table 4: A closer look at show heifers underweight, meeting weight, and ADG by county

Growth of Show Heifers by County				
	Number of Heifers	**Percent of Heifers Not Growing to Industry Guidelines**	**Percent of Heifers Growing to Industry Guidelines**	**Average Daily Gain (kg)**
Brantley	17	100	0	0.49
Burke	23	47.83	52.17	0.74
Chattooga	19	52.66	47.34	0.70
Clarke	6	83.33	16.67	0.53
Coweta	21	52.38	47.62	0.72
Dawson	27	88.89	11.11	0.61
Dooly	5	0	100	0.77
Elbert	30	93.33	6.67	0.50
Gordon	1	100	0	0.70
Greene	5	60	40	0.69
Gwinnett	1	100	0	0.59
Habersham	3	100	0	0.57
Hart	7	85.71	14.29	0.64
Houston	31	61.29	38.71	0.66
Jasper	4	50	50	0.72
Lee	47	97.87	2.13	0.56
Macon	6	100	0	0.56
Madison	30	66.67	33.33	0.70
Meriwether	1	100	0	0.44
Morgan	18	66.67	33.33	0.67
Oconee	50	68	32	0.64
Oglethorpe	6	83.33	16.67	0.61
Perry	11	100	0	0.58
Putnam	24	54.17	45.83	0.72
Ringgold	19	36.84	63.16	0.77
White	15	66.67	33.33	0.66
Wilcox	13	84.62	15.38	0.63
Wilkes	9	100	0	0.51
Whitfield	6	66.67	33.33	0.63

The unranked variables were analyzed using the Spearman Correlation Coefficients Method. The correlations and P-values between variables of the show heifers are shown in more detail in Appendix 1. An r value (correlation coefficient) indicates how strongly the two variables are related. The closer the r value is to 1.0 or -1.0 the stronger the relationship, while the closer the r value is 0.0 the weaker the relationship between the two variables. A positive r value means as one value gets larger, the other value gets larger; however, a negative r value means as one value gets larger the other value gets smaller. Age has a weak relationship to ADG a correlation coefficient of 0.05. HMI has a strong relationship to age (r = 0.62) and ADG (r = 0.70). Tail length has a moderate relationship to ADG (r = 0.52) and a strong relationship to age (r = 0.67) and HMI (r = 0.77). Hip width has a strong relationship to ADG (r = 063), age (r = 0.72) and tail length (r = 0.78). Hip width has a very strong relationship to HMI (r = 0.86). Hip height has a moderate relationship to ADG (r = 0.56). Hip height also has a strong relationship to age (r = 0.76), HMI (r = 0.73), and tail length (r = 0.78). Hip height has a strong very strong relationship to thurl width (r = 0.89). Wither height has a moderate relationship to ADG (r = 0.57), a strong relationship to age (r = 0.76), HMI (r = 0.78), and tail length (r = 0.78). Wither Height also had a very strong relationship to thurl width (r = 0.89) and hip height (r = 0.95). Head length had a moderate relationship with ADG (r = 0.50), a strong relationship with age (r = 0.76), HMI (r = 0.76) , tail length (r = 0.71) and a very strong relationship with thurl width (r = 0.87) and wither height (r = 0.85). Weight had a strong relationship to ADG (r = 0.68), age (r = 0.74) and a very strong relationship with HMI (r = 0.93), tail length (r = 0.82), thurl width (r = 0.95), hip height (r = 0.92), and head length (r = 0.88). It is not surprising that many of these allometric traits are related. The strongest relationship was between withers and hips. Hip height and wither height were also very related to thurl width.

The mean, standard deviation, standard error, minimum and maximum for each unranked variable for the show heifers can be found in Table 5. The unranked variables do not take into account the size variation of the classes in the show. However, it is necessary for comparison with the non-show heifers as they do not have recorded placing because they were never shown. The average mean for weight was 209.81 kg and ranged from 54.09 kg to 360.00 kg, head length average was 47.65 cm and ranged from 31.12 cm to 68.58 cm, wither height average was 116.51

cm and ranged from 92.71 cm to 138.43 cm, hip height average was 117.65 cm and ranged from 95.89 to 138.43 cm, thurl width average was 35.82 cm and ranged from 26.04 to 53.98, tail length average was 61.81 cm and ranged from 31.12 cm to 85.09 cm, Average HMI was 148.59 and ranged from 102.91 to 213.89, age in days average was 265.02 and ranged from 142.00 cm to 357.00 cm and Average ADG was 0.63 kg and ranged from 0.28 kg to 1.13 kg.

While too low of an ADG can cause delayed development, over feeding heifers can cause them to become over conditioned which can lead to breeding problems and calving difficulties (Hopkins and Whitlow, 2013). Feeding a ration that is high in energy but low in protein to heifers before they reach puberty can cause excess fat deposit in the mammary gland, which impairs future milk production capability (Hopkins and Whitlow, 2013, Macdonald et al., 2005). Underfeeding heifers causes stunted growth and can delay or suppress estrus. This will delay breeding, calving and entry into the milking herd (Hopkins and Whitlow, 2013). Reducing the average age at first calving by one month can lower the costs of a replacement program by approximately $1400 (Hansen et al., 1999).

Since HMI is a new index, there are no values to compare the average value for the show heifers of 148.59 nor the range of 102.91 to 213.89. However, these numbers should be useful in future studies looking at the body mass of dairy heifers.

Ranked variables were analyzed to account for differences in the number of heifers in each class of the Georgia Jr. National Livestock Show. Unranked variables were analyzed in order to compare them with the non-show heifer group, since non-show heifers are not shown there is no placing data in which to rank the heifers.

Table 5: Unranked variables for show heifer data

Unranked Show Heifers								
Variable	**Sample Number**	**Mean**	**SD**	**SE**	**Median**	**Min**	**Max**	**Coefficient of Variation %**
Weight (kg)	454	209.81	57.44	2.70	207.73	54.09	360.00	27.4
Head Length (cm)	454	47.65	4.54	0.21	47.95	31.12	68.58	9.53
Wither Height (cm)	454	116.51	9.37	0.44	116.84	92.71	138.43	8.04
Hip Height (cm)	454	117.65	8.94	0.42	117.48	95.89	138.43	7.6
Thurl Width (cm)	454	35.82	4.13	0.19	36.20	26.04	53.98	11.53
Tail Length (cm) *	428	61.81	7.94	0.38	61.60	31.12	85.09	12.85
HMI	454	148.59	21.65	1.02	147.63	102.91	213.89	14.57
Age (days)	454	265.02	64.25	3.02	271.00	142.00	357.00	24.24
ADG (kg)	454	0.63	0.14	0.007	0.63	0.28	1.13	22.22

**Animals with docked tails were omitted*

The following were significant using the Spearman Correlation Coefficients Method after the variables were ranked and converted to percentages to account for differences in class size. Coefficient number and P-value for each correlation are presented in more detail in Appendix 2. Thurl width pct had a weak relationship to tail length pct (r = 0.05). Hip height pct had a weak relationship to tail length pct (r = 0.20) and thurl length pct (r = 0.16). Wither height pct had a weak relationship to tail length pct (r = 0.14) , thurl length pct (r = 0.15) and a strong relationship to hip height pct (r = 0.70). Head length pct had a weak relationship to tail length pct (r = 0.13), thurl width pct (r = 0.200, hip height pct (r = 0.31), and wither height pct (r =

0.34). Weight pct had a weak relationship to tail length pct (r = -0.06), thurl width pct (r = 0.14), hip height pct (r = 0.15), wither height pct (r = 0.17) and head length (r = 0.16). Age pct has a weak correlation with tail length pct (r = -0.24), thurl width pct (r = -0.07), hip height pct (r = -0.21), wither height pct (r = -0.20), head length pct (r = -0.26) and weight pct (r = -0.03). ADG pct had a weak relationship to tail length pct (r = -0.23), thurl width pct (r = -0.023), hip height pct (r = -0.18), wither height pct (r = -0.16), head length pct (r = -0.21), weight pct (r = 0.12) and a very strong relationship to age pct (r = 0.95). HMI percent had a weak relationship to tail length pct (r = -0.17), thurl width pct (r = -0.03), head length pct (r = -0.18), weight pct (r = 0.17), age pct (r = 0.25) and ADG pct (r = 0.29). HMI had a moderate relationship to wither height pct (r = -0.54) and a strong relationship to hip height pct (r = -0.80). Placing pct had a weak relationship to tail length pct (r = -0.02), thurl width pct (r = -0.03), hip height pct (r = 0.32), wither height pct (r =0.34), head length pct (-0.009), weight pct (r = 0.05), age pct (r = 0.01), ADG pct (r = 0.02) and HMI (r = -0.28).

As in the unranked variable, hip height and wither height had a strong relationship in the ranked variables. Also, HMI had a strong relationship to hip height. This is not surprising since height is involved in its formula.

The GLMSELECT Stepwise Selection (SAS Institute, 2008) was used to determine which measurements were significant when placing was the dependent variable. Table 6 shows that HMI (P = 0.008), head length (P = 0.0003) and wither height (P < 0.0001) were found to have a significant effect on placing in the show ring with an R-Square value of 19%, meaning that this model explains 19% of the variation. HMI, wither height and head length were ranked within each class and then using SAS were compared to their placing in each class. Therefore, the heifer in each class who had the highest HMI score would rank 1 and so on and so forth.

This was also done for wither height and head length.

Table 6: GLMSELECT stepwise selection for show heifers.

GLMSELECT Stepwise Selection – Show Heifers					
Source	**Degrees Freedom**	**Type III SS**	**Mean Square**	**F Value**	**Pr > F**
Year Class	39	1.22	0.31	0.44	0.10
HMI	1	0.49	0.49	6.92	0.01
Head Length	1	0.96	0.96	13.49	0.0003
Wither Height	1	2.33	2.33	32.66	<0.0001

Table 7: HMI rank and placing rank within each class

HMI Ranks and Placings				
	HMI Rank		Placing Rank	
Rank	HMI	Mean Placing	HMI	Mean HMI rank
1	161.49	9.23	143.07	8.73
2	155.65	8.50	146.20	6.24
3	151.99	8.51	147.10	7.61
4	149.99	7.45	144.21	8.06
5	148.58	6.98	146.65	6.70
6	145.76	5.94	148.72	6.31
7	144.22	7.10	152.33	4.61
8	145.33	6.28	149.04	5.61
9	141.07	6.77	144.98	5.63
10	145.73	7.16	148.59	5.14
11	143.34	5.35	153.25	4.97

As shown in Table 7 HMI Rank, although significant, appears to be backwards as the heifers ranking first in HMI rank have a lower placing in the show and the heifers placing first in the show have a lower HMI rank for their respective class. This table shows that the lower HMI animals placed higher in each class, mass appears to be lacking in those animals winning each class.

When looking at wither height rank and placing in Table 8, the tallest animals in a class on average placed higher than shorter animals. The same results can be seen in placing; the animals placing first tended to be the tallest animals in the class. This is expected as frame is important when judging and selecting heifers; and taller heifers are preferred over shorter ones.

Table 8: Wither height rank and placing rank within each class

Wither Height Ranks and Placings				
	Wither Height Rank		Placing Rank	
Rank	Wither Height (cm)	Mean Placing	Wither Height (cm)	Mean Wither Height Rank
1	121.63	5.73	119.46	3.06
2	118.48	5.17	118.11	3.92
3	119.39	6.12	118.24	4.71
4	117.10	6.34	117.07	5.13
5	117.00	6.00	117.13	5.24
6	114.73	7.53	116.84	5.80
7	113.20	8.73	116.49	6.35
8	115.44	8.06	114.38	7.10
9	112.82	7.18	114.08	6.31
10	114.80	8.43	113.61	7.14
11	114.74	9.47	116.03	7.39

Head length is a skeletal measurement that is difficult to change or manipulate. It is expected to see animals placing first in the show ring having the lowest average head length rank, meaning that while they may not have necessarily had the longest head lengths in the show, they were among the top and collectively had longer heads than any other placing in the show (Table 9). It is only natural to assume that heifers with longer heads have achieved greater skeletal development than heifers of the same age with shorter heads. This appears to be happening with larger heads placing higher.

Table 9: Head length rank and placing rank within each class

Head Length Ranks and Placings				
	Head Length Rank		Placing Rank	
Rank	Head Length (cm)	Mean Placing	Head Length (cm)	Mean Head Length Rank
1	50.18	8.00	48.24	4.61
2	48.47	6.15	47.12	5.97
3	48.62	7.51	47.58	5.32
4	47.21	6.43	47.28	5.65
5	47.27	6.68	47.83	5.16
6	47.71	6.89	47.77	6.40
7	47.63	8.03	47.85	5.58
8	44.76	7.71	46.15	6.29
9	47.09	7.52	47.05	5.11
10	47.13	6.67	46.75	5.97
11	45.86	7.68	48.69	5.18
12	47.84	5.00	49.01	4.96

Comparison of Show Heifers and Non-show Heifers

In order to compare the growth of the show heifers with heifers who are never shown and are raised completely on the dairy farm for production, data was collected on 293 Holsteins from three different farms in Georgia. The same criteria were used for the non-show heifers as were used for the show heifers.

Evaluation of Non-show Heifers

A total of 293 heifers were evaluated using the PSU GMS (Pennsylvania State University, 2013) to determine the percentage of underweight heifers not growing according to industry standards. Only 43.34% (127 heifers) of non-show heifers were underweight and not growing to industry guidelines. This means that 56.6% (166 heifers) of non-show heifers are growing to industry guidelines. A more detailed look at non-show heifers growing to industry guidelines is shown in Appendix 10. The average ADG for the non-show heifers is 0.71 kg which is within the suggested ADG of 0.7 to 0.8 kg per day (Kertz et al., 1987, Abeni et al., 2000). The 43.34 % of non-show heifers that were underweight is much less than the 72.47 % found with the show heifers. This appears to be a major problem with the show animals.

The PSU GMS (Pennsylvania State University) created graphs for weight, wither height, hip height and hip width and compared them to industry standards. The majority of non-show heifers fell at about the median for weight for year 1 and year 2. When looking at wither height, the majority of the heifers were above the median. Most of the non-show heifers were between the upper and lower range for hip height and above the upper range for hip width. A more detailed look at of the Penn State Graphs for non-show heifers can be found in Appendices 19-42.

The mean, standard deviation, median, minimum and maximum can be found for each variable in more detail in Table 10. The average for weight was 226.01 kg and ranged from 101.60kg to 409.14 kg, head length average was 41.64 cm and ranged from 30.48 cm to 56.52 cm, wither height average was 111.32 cm and ranged from 89.54 cm to 132.08 cm, hip height average was 114.90 cm and ranged from 91.44 cm to 142.88 cm, thurl width average was 35.83 cm and ranged from 23.75 cm to 48.26 cm, tail length average was 61.47 cm and ranged from 36.20 cm to 82.55 cm, HMI average was 165.95 and ranged from 110.50 to 269.57, age average was 256.69 days and ranged from 122.00 to 416.00, and ADG average was 0.71 kg ranged from 0.46kg to 0.97kg.

Table 10: Unranked variables for non-show heifer data

Unranked Non-show Heifers								
Variable	**Sample Number**	**Mean**	**SD**	**SE**	**Median**	**Min**	**Max**	**Coefficient of Variation %**
Weight (kg)	293	226.01	68.41	3.40	229.06	101.60	409.14	30.26
Head Length (cm)	293	41.64	5.90	0.34	41.28	30.48	56.52	14.17
Wither Height (cm)	293	111.32	10.36	0.61	112.40	89.54	132.08	9.03
Hip Height (cm)	293	114.90	11.04	0.64	116.21	91.44	142.88	9.61
Thurl Width (cm)	293	35.83	5.28	0.31	36.50	23.75	48.26	14.74
Tail Length (cm)	274	61.47	10.57	0.64	62.23	36.20	82.55	17.2
HMI	293	165.95	24.94	1.46	166.16	11.50	269.57	15.03
Age (days)	293	256.69	83.87	4.90	253.00	122.0	416.00	32.67
ADG (kg)	293	0.71	0.09	0.005	0.71	0.46	0.97	12.67

The results from the Spearman Correlation Coefficient Method are as follows: Age had a weak correlation to ADG (r = 0.23). HMI had a moderate relationship to ADG (r = 0.57) and a strong relationship to age (r = 0.79). Tail length had a weak relationship to ADG (r = 0.35), a strong relationship to HMI (r = 0.76) and a very strong relationship to age (r = 0.89). Thurl width had a moderate relationship to ADG (r = 0.49) and a very strong relationship age (r = 0.87), HMI (r = 0.85) and tail length (r = 0.86). Hip height had a moderate relationship to ADG (r = 0.46), HMI (r = 0.67) and a very strong relationship to age (r = 0.87), tail length (r = 0.87) and thurl width (r = 0.86). Wither height had a moderate relationship to ADG (r = 0.45), strong relationship to HMI (r = 0.72) and a very strong relationship to age (r = 0.90), tail length (r = 0.89) and thurl width (r = 0.88). Head length had a moderate relationship to age (r = 0.52), a strong relationship to age (r = 0.75), HMI (r = 0.71), tail length (r = 0.73) and a very strong relationship to thurl width (r = 0.81), hip height (r = 0.83) and wither height (r = 0.81). Weight had a moderate relationship to ADG (r = 0.56) and a very strong relationship to age (r = 0.92), HMI (r = 0.88), tail length (r = 0.89), thurl width (r = 0.93), hip height (r = 0.92), wither height (r = 0.94) and head length (r = 0.84). HMI had a strong relationship with age, tail length and withers. Age and hip height, wither height and weight had a very strong relationship. A complete table with the correlation coefficient and the P-value for each correlation is listed in Appendix 3.

Comparison of Measurement of Show Heifers to Non-show Heifers from Dairy Farms

When looking at ADG between show heifers and non-show heifers, on average, non-show heifers had an ADG of 0.71 kg per day which is within the recommended range of 0.7 kg to 0.8 kg per day versus show heifers which had a lower than recommended ADG at 0.63 kg per day. According to PSU GMS (Pennsylvania State University, 2013) 43.34% of non-show heifers are not meeting industry guidelines for weight while 72.47% of show heifers are not meeting industry guidelines for weight. This indicates that heifers that are shown are managed differently from heifers on Georgia farms. The Penn State Graphs created for weight reinforce that show heifers weigh less for their age than heifers that are not shown. A majority of non-show heifers are above the median while the majority of show heifers are below the median.

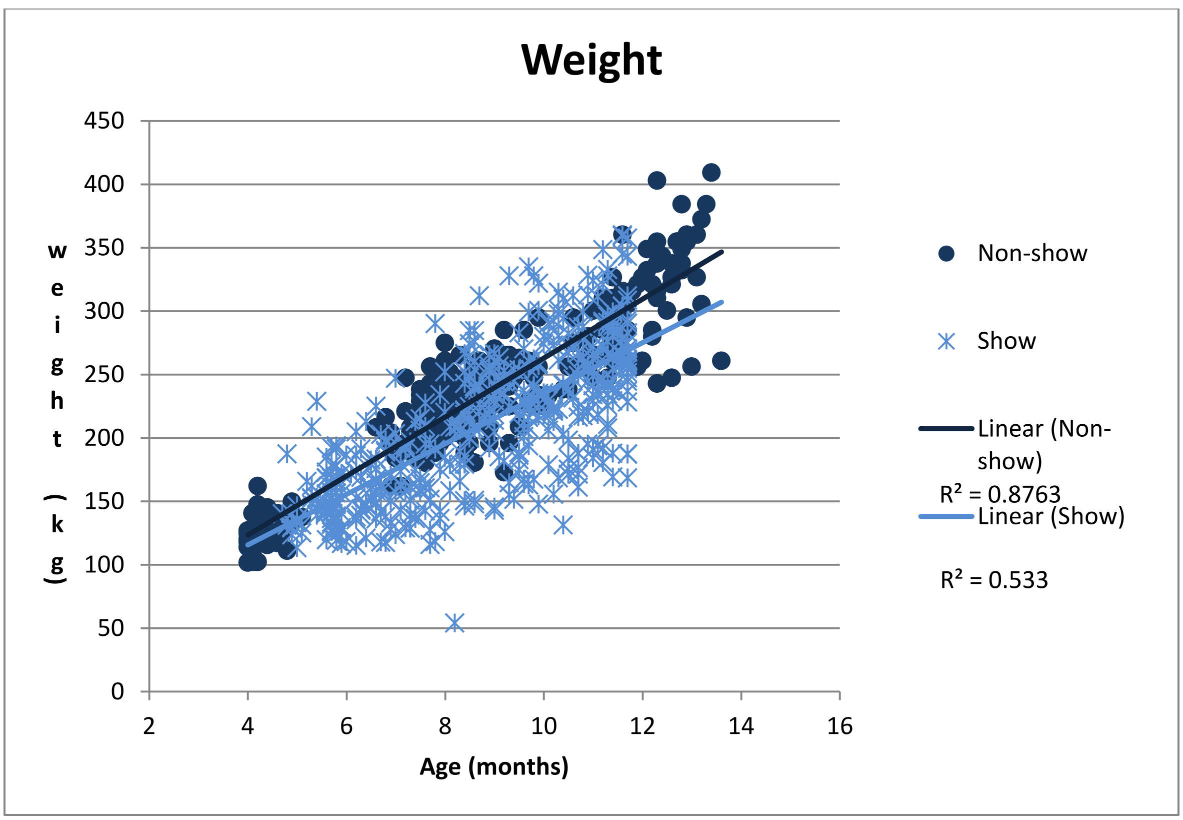
SAS software was used to run the GLM Procedure Age * Yeargroup (Table 11) to determine whether there are differences between show heifers and non-show heifers using the measurements as the dependent variable and age by year group as the independent variable. Four groups were used (Show year 1, Show year 2, Farm year 1 and Farm year 2). It was not possible to remove year because it was the variable that tied the show and non-show heifers together and year was significant. A P-value of 0.05 or less means that at least one of the four groups is different from the other three groups. However, it was not possible to determine exactly which group or groups were different. The R-Square value represents what percent of the variation is explained by the model. As seen in Table 11 differences between the groups were seen for every variable.

*Table 11: GLM Procedure – Age * Yeargroup comparison between show heifers and non-show heifers.*

GLM Procedure – Age * Yeargroup					
Measurement	**Degrees of Freedom**	**Type III SS**	**Mean Square**	**R-Square**	**Pr > F**
Weight (kg)	3	23543.45	7847.82	0.72	0.0001
ADG (kg)	3	0.24	0.08	0.14	0.001
HMI	3	8397.29	2799.10	0.61	<0.0001
Head Length (cm)	3	663.07	221.02	0.75	<0.0001
Wither Height (cm)	3	313.57	104.52	0.72	0.01
Hip Height (cm)	3	546.18	182.06	0.71	0.0003
Thurl Width (cm)	3	278.97	92.99	0.67	<0.0001
Tail Length (cm)	3	962.12	320.71	0.69	<0.0001

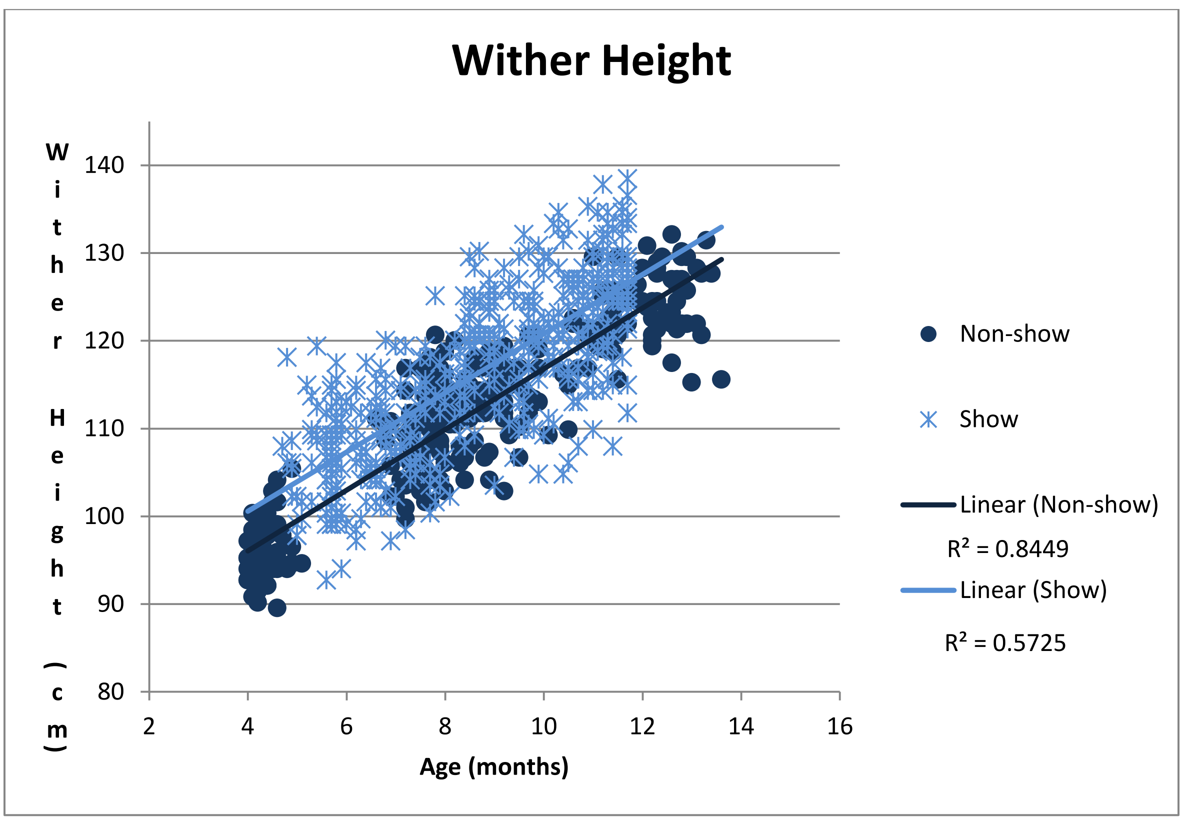
Graphs were created using Excel that compared the measurements between the show heifers and the non-show heifers. The Excel graph for weight, (Figure 1) agrees with the PSU GMS (Pennsylvania State University, 2013) that show heifers weigh less for their age than non-show heifers of the same age. This indicates a difference in the way that show heifers are managed versus non-show heifers. The slopes are parallel, meaning both groups are gaining weight at the same rate as they get older. It appears that the show heifers do not catch up with non-show heifers of the same age. When looking at R^2, this model explains about 87% of the variance for the non-show heifers and 53% of the variance for the show heifers. Hopkins and Whitlow (2013) state that poorly developed heifers are prone dystocia than larger heifers, not to mention delayed entry into the milking herd.

Figure 1: Comparison of weight between show heifers and non-show heifers



The Excel graph for wither height (Figure 2) shows that show heifers were taller at the withers on average than non-show heifers. This model accounts for 84% of the variance for the non-show heifers and 57% of the variance for the show heifers. This is expected, as ideally the best animals are selected to show and animals that walk uphill and are taller at the withers are desired. Height at the withers is found to be the body measurement least influenced by differences in body condition (Wickersham and Schultz, 1963). A heifer should achieve 50 percent of her calving height during the first 6 months of life (Kertz, 2013). To date, there isn't any data showing that heifers are able to compensate later for poor initial growth (Kertz, 2013). London et al. (2012) found that after evaluating frame measurements of show heifers that height at the withers had the strongest relationship to placing. Since heifers do not have a developed udder, frame is given more weight when judging.

Figure 2: Comparison of wither height between show heifers and non-show heifers



According to the Excel graphs for hip height (Figure 3), the show heifers and non-show heifers appear to be similar and as non-show heifers become older their hip width (Figure 4) is greater for their age than non-show heifers. This model explains 82% of the variation for non-show heifers and 58% of the variation for show heifers. Height at the hips can be viewed as easier to obtain than wither height because orientation of the head is not as important. Research indicates that hip width is one of the skeletal measurements more highly related to body weight that is not influenced by body condition (Dingwell et al., 2006). Heifers with greater hip width tend to be wider from head to tail, possessing greater dairy strength. Producers strive for thurl width because it translates into more dairy strength, less calving difficulty and an easier transition period into the milking herd.

Figure 3: Comparison of hip height between show heifers and non-show heifers

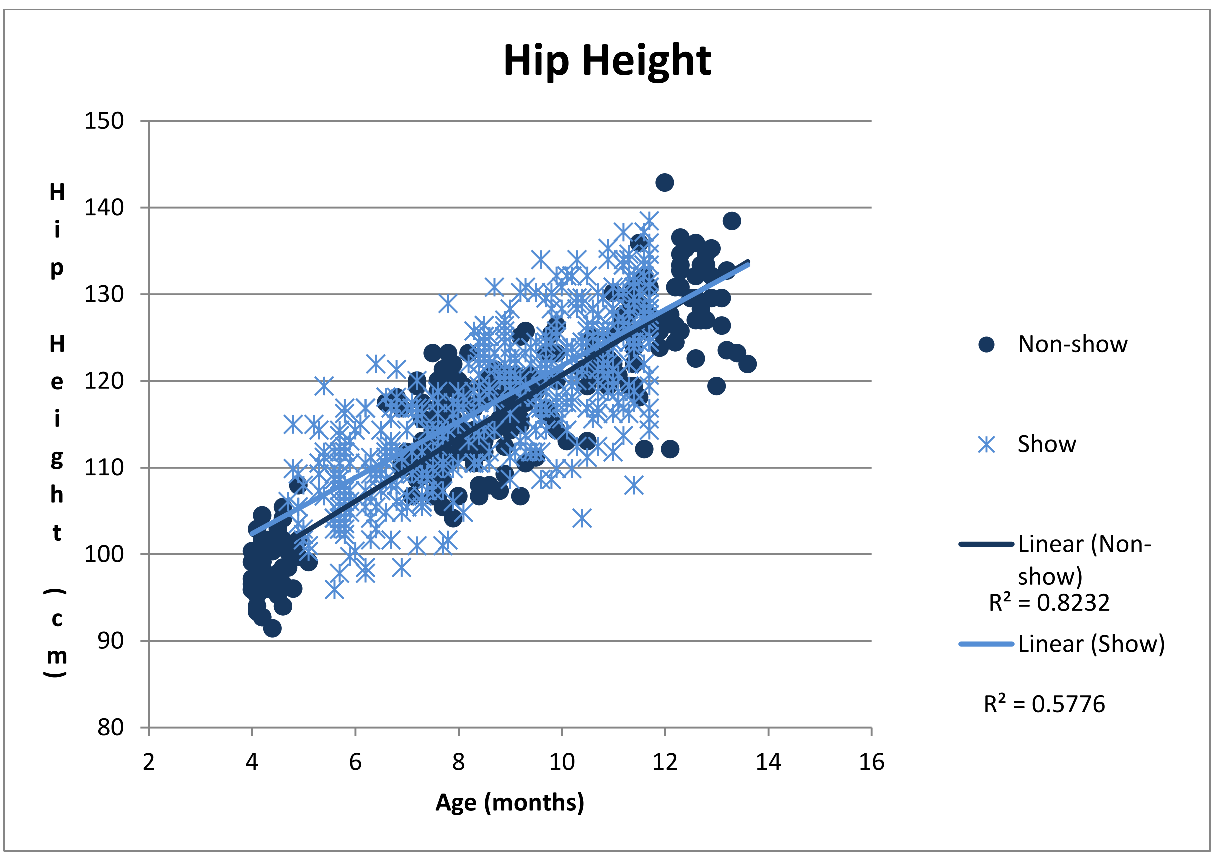
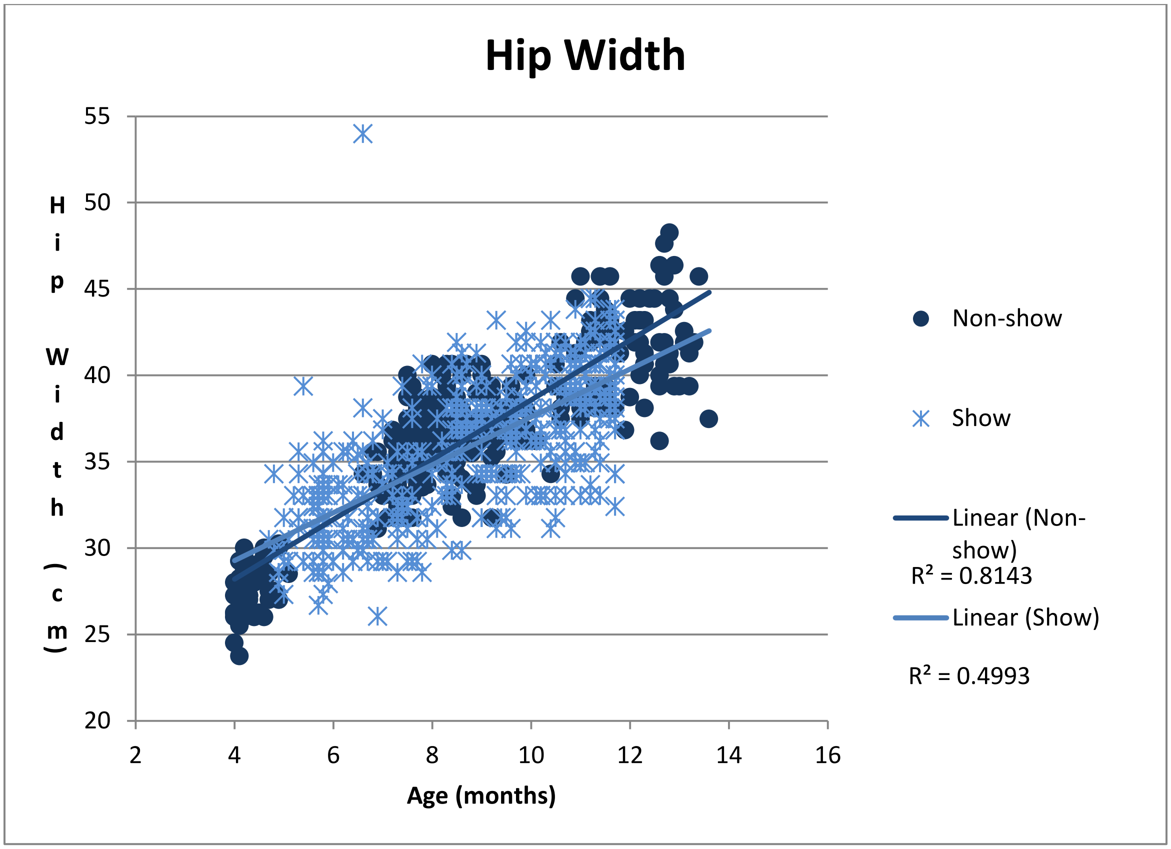
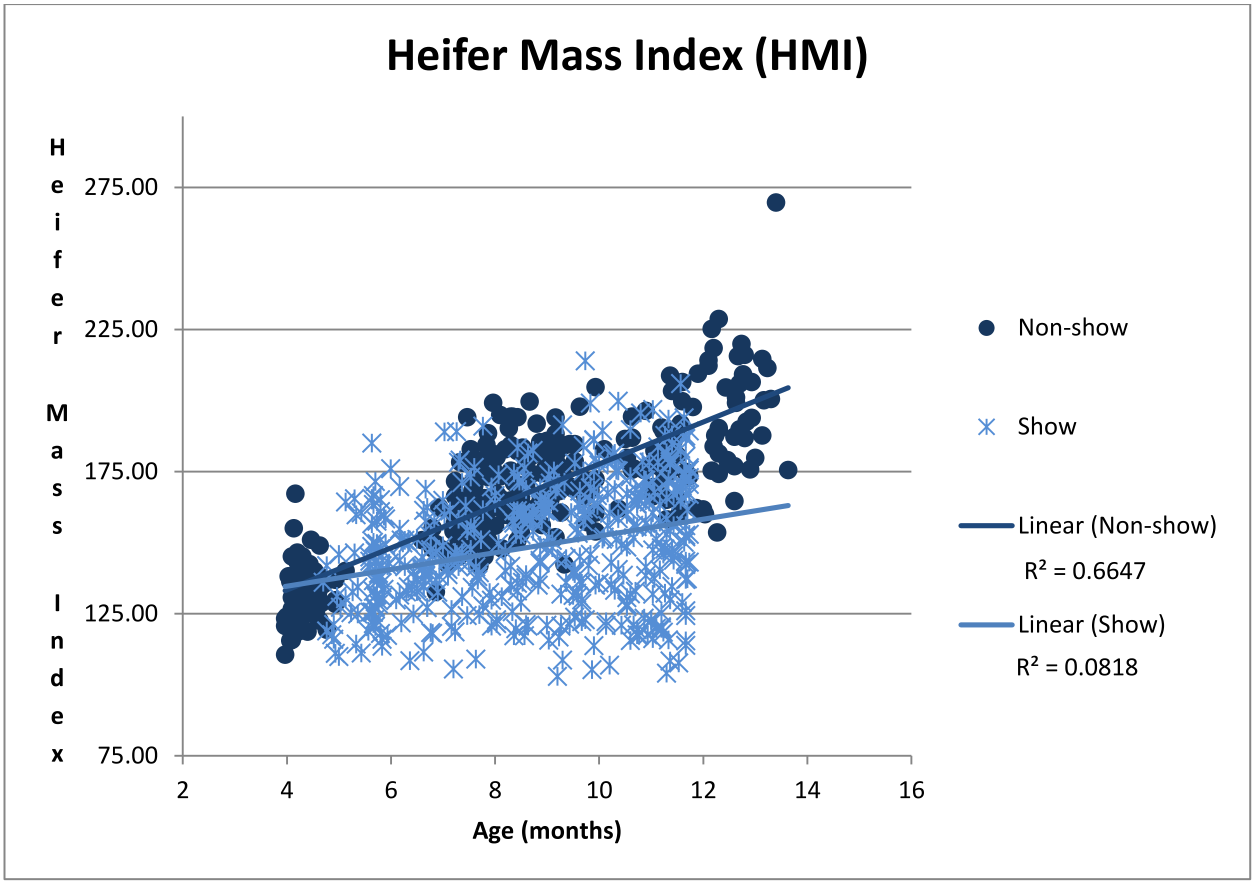


Figure 4: Comparison of hip width between show heifers and non-show heifers



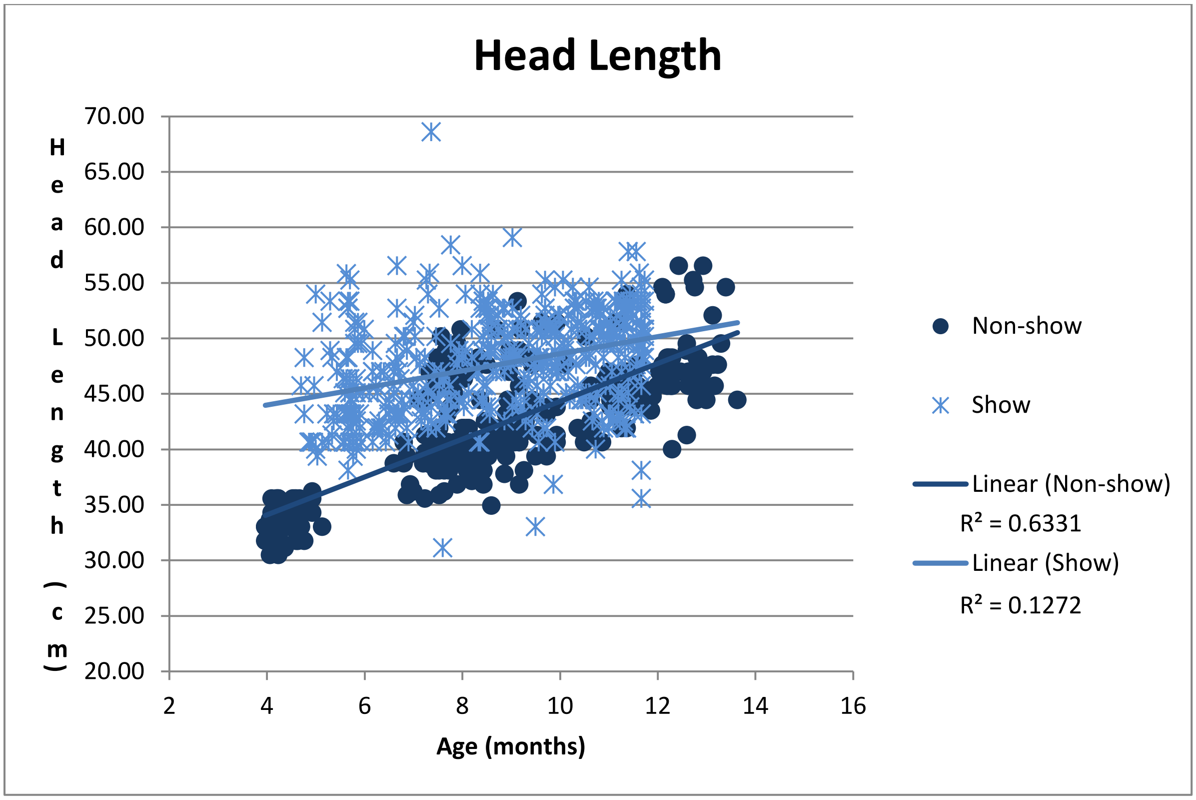
The HMI Graph (Figure 5) shows that both show and non-show heifers begin with similar HMI scores when they are younger, but as they get older, show heifers have less HMI scores than do non-show heifers. This model explains 66% of the variance for non-show heifers and 8% of the variance for non-show heifers. This indicates that while the show heifers are obtaining the same or greater skeletal growth than the non-show heifers, they do not have as much body mass as non-show heifers of the same age. Showing heifers using an index like HMI may be useful in the future because it uses two variables, weight and height to develop an index to rank heifers. Mass should play a major role in growth, especially with onset of puberty.

Figure 5: Comparison of HMI between show heifers and non-show heifers



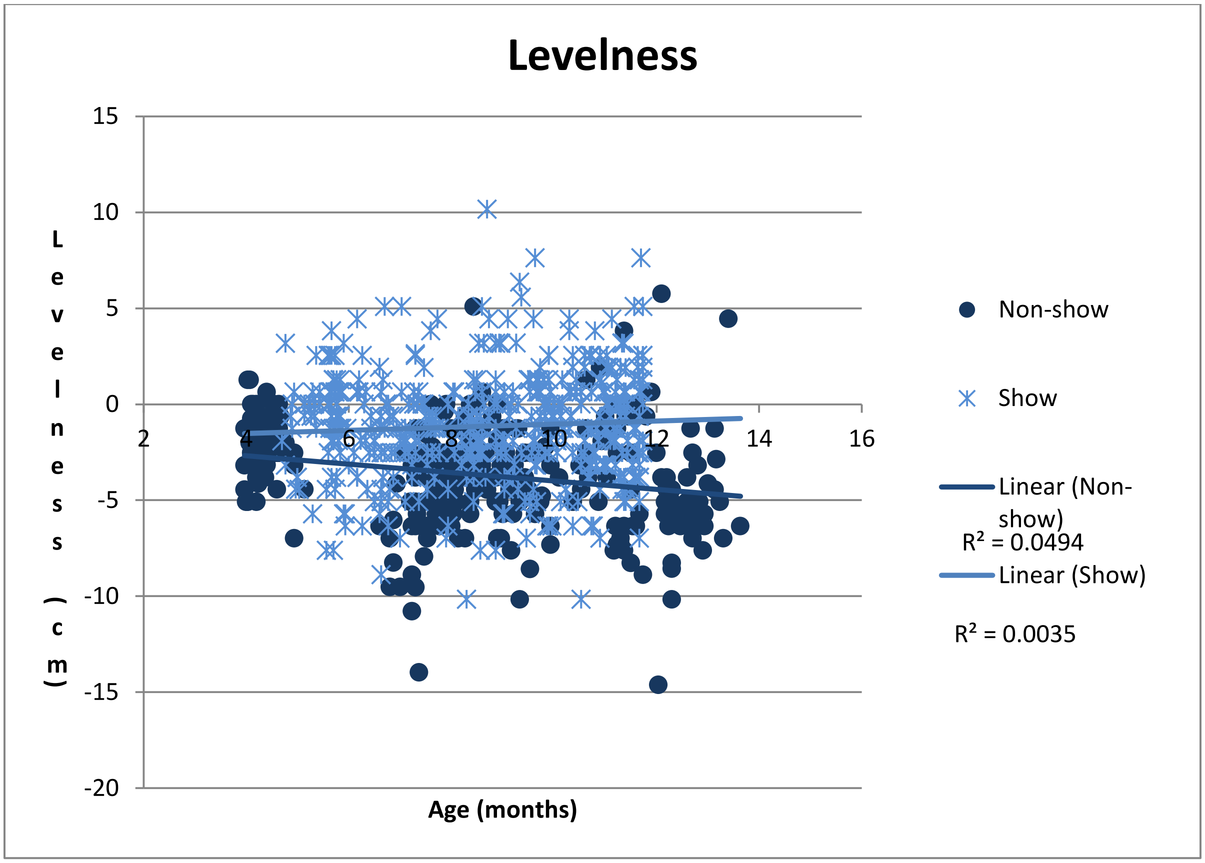
The graph plotting head length (Figure 6) indicates that show heifers have longer heads than non-show heifers at a young age, but as they get older the head lengths between the two groups become more similar. This model explains 63% of the variance for non-show heifers and only about 13% of the variance for show heifers. It is possible something like larger heads can be used to see which ages may not be correct on show entry information.

Figure 6: Comparison of head length between show heifers and non-show heifers



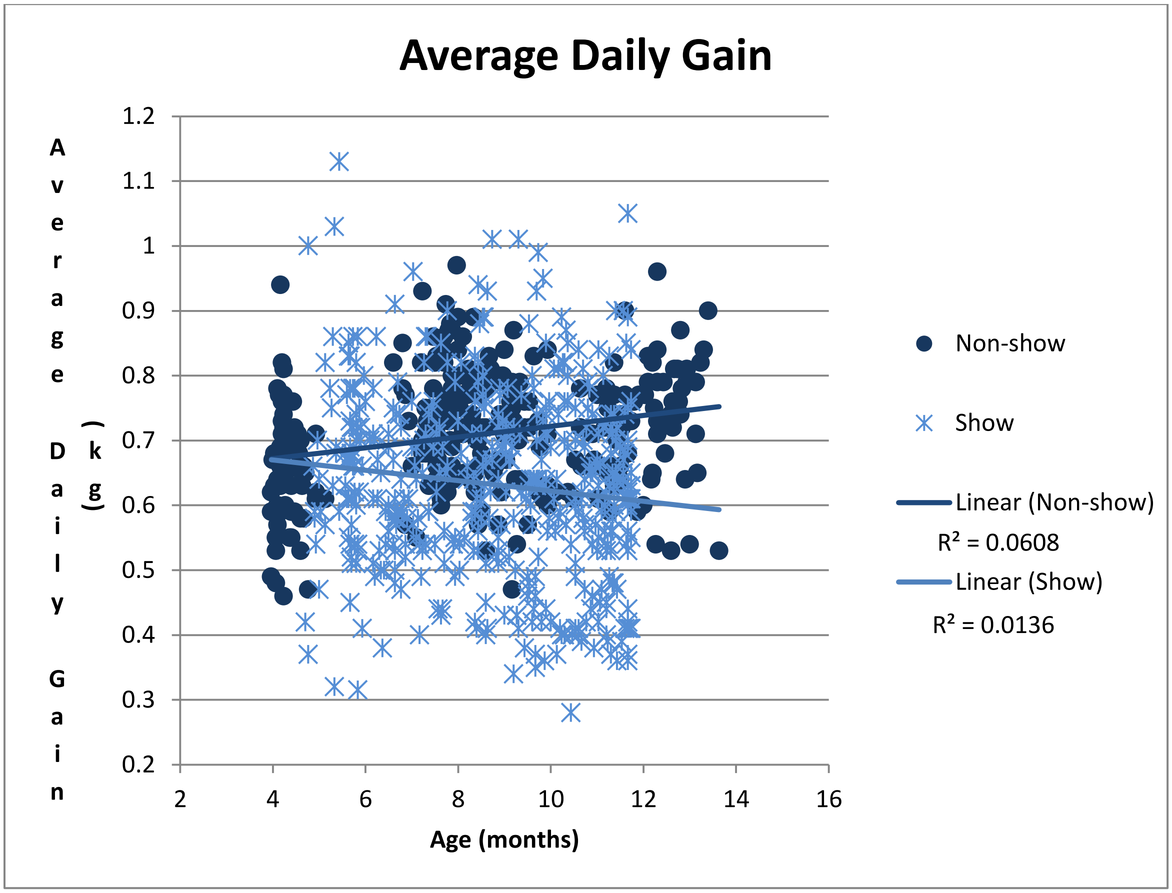
When looking at the graph for levelness (Figure 7), show heifers on average have much more level top lines than do non-show heifers, which have a tendency to walk downhill as expected because a desirable show heifer is uphill and ideally the most desirable animals are selected out of a population to show. Uphill or level animals also tend to be stylish and very eye appealing in the show ring. This model explains only 5% of the variance for non-show heifers and 0.4% of the variance for show heifers. The show heifers appear to be much more level than non-show heifers. There also appears be more uphill heifers in the show heifers as expected.

Figure 7: Comparison of levelness between show heifers and non-show heifers



The Excel graph for ADG (Figure 8) shows that for non-show heifers as the animal gets older the ADG increases, but for show heifers as the animal gets older the ADG decreases. This indicates once again a difference in management and feeding of show heifers versus non-show heifers. This model explains 6% of the variance for the non-show heifers and 1% of the variation for the show heifers. Programs need to be developed to teach leaders and youth to monitor ADG and increase gain as animals get older. It is obvious that show heifers are further from the ideal that non-show heifers.

Figure 8: Comparison of average daily gain between show heifers and non-show heifers



The Excel graph for tail length (Figure 9) shows that non-show heifers increase tail length as they age at a much faster rate than show heifers. However, non-show heifers begin with shorter tail lengths around 4 months of age than show heifers of the same age, but around 8 to 10 months of age, not only catch up to the show heifers but surpass them. This model explains 83% of the variance for non-show heifers and 8% of the variance for show heifers. Tail length, may not be as useful and accurate as head length when determining age because of the wide range of data.

Figure 9: Comparison of tail length between show heifers and non-show heifers

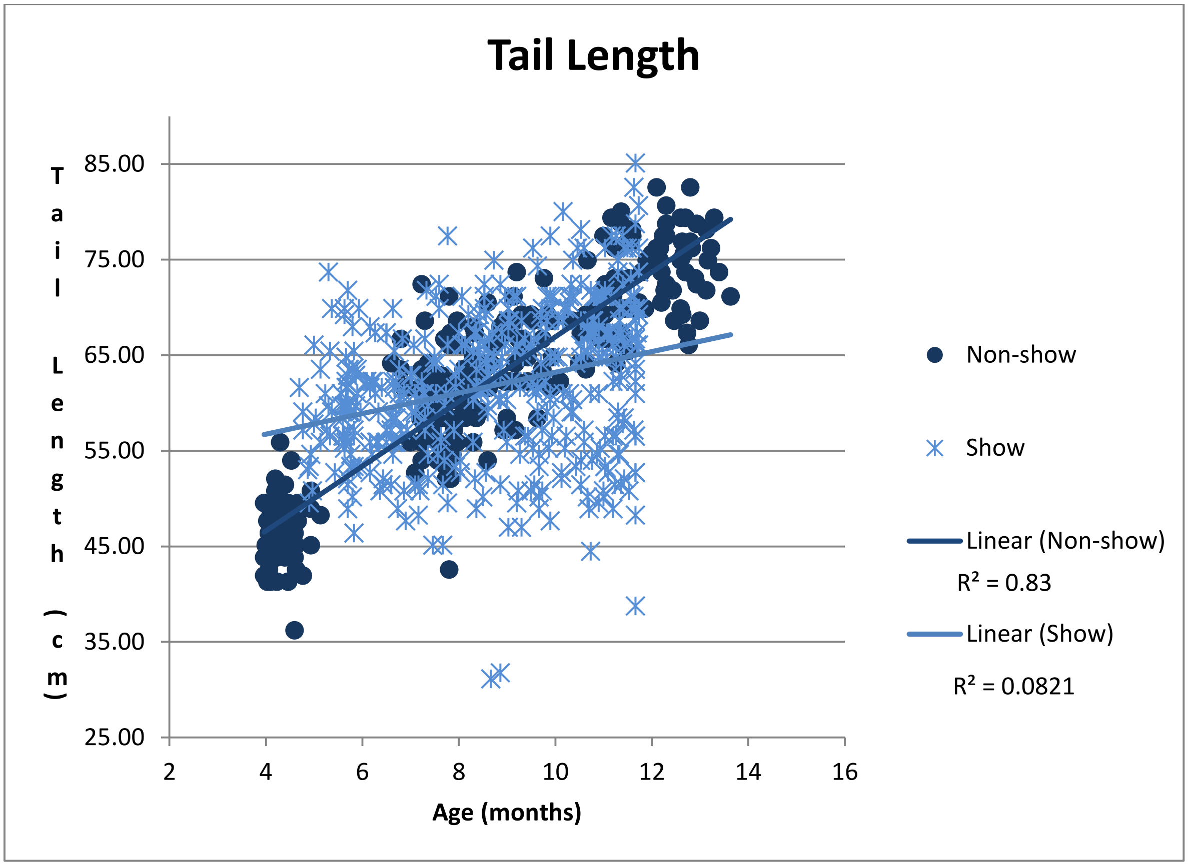
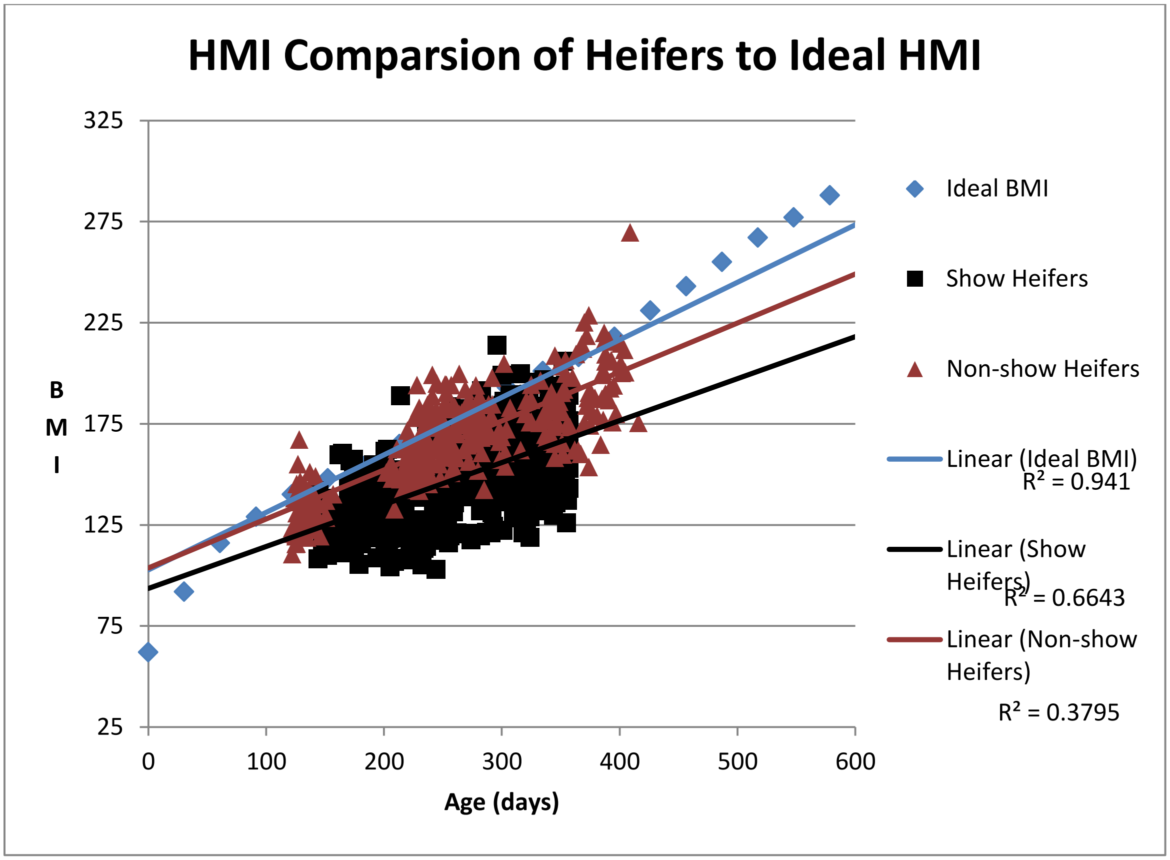


Figure 10 compares the HMI of the show and non-show heifers to the optimum HMI as described by the Customized Heifer Growth Chart (Pennsylvania State University, 2013). Monitoring HMI may be helpful when monitoring heifer growth. The optimum HMI trend line has an R^2 value of 0.941 while the R^2 value for the non-show heifers is 0.6643 and 0.3795 for the show heifers.

Figure 10: HMI comparison of heifers to ideal HMI



Heat stress occurs when high ambient temperatures, sometimes with high relative humidity and excessive sunlight prevent adequate heat loss by an animal (West, 2001). Heat stress has a huge economic impact on the United States Dairy Industry (West, 2001). Research shows that cows that are heat stressed deliver smaller calves with females weighing 6 to 10 % less and birth and approximately 16 % lower body weight at maturity, however; cows that were shaded (versus not shaded) during the dry period, or that had supplemental cooling (fans and sprinklers) during the dry period delivered larger calves (West, 2001). This would perhaps account for some of the differences between the PSU Ideal BMI averages and the Georgia Farm or non-show heifers' averages shown in Figure 10.

Conclusions

In conclusion according to this study, wither height ($P < 0.0001$), HMI ($P = 0.008$) and head length ($P = 0.003$) seem to be the most indicative of placing. When comparing show heifers and non-show heifers, show heifers weigh less for their age than non-show heifers of the same age. Show heifers also have a decreased HMI score for their age than their non-show heifer counterparts. HMI scores for non-show heifers are closer to the optimum than HMI scores for show heifers. ADG for show heifers decreases as the animal gets older, while ADG increases for non-show heifers as age increases. These findings indicate a difference in management and nutritional programs of show heifers and non-show heifers. It is important that heifers are returned to the producer at the appropriate size so that they are bred to calve at 22 to 24 months of age and continue on to become profitable members of the milking herd. Bringing awareness to the youth and leaders involved in the Commercial Dairy Heifer Program on the proper growth of dairy heifers will ensure that producers continue to lend animals and support the program in the future.

Chapter 3

IMPLICATIONS

The purpose of this research was to determine whether or not heifers shown are grown differently from those that are not as well as looking at several measurements and determining their relationship to placing in the show ring. According to this study, show heifers are grown differently from non-show heifers. Youth, teachers, leaders and parents need to be aware of the importance of raising dairy heifers properly and the negative results that potentially can occur such as delayed puberty, calving and dystocia that occur for the producer if the heifer is returned to the farm of origination developmentally behind the rest of its herd mates of the same age. Wither height appears to be the most predictive of placing in the show ring. Further research in the area may find a better measurement to use besides weight when showing dairy heifers. A skeletal measurement is difficult to change and is not affected by water or feed in the stomach like weight measurement is. Skeletal measurements or a combination of measurements may give a more accurate description of the growth and maturity of the heifers involved in the Commercial Dairy Heifer Show.

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Appendix 1: Spearman correlation coefficients method on unranked show data. The number on the first row is the correlation coefficient and the number on the second row is the p-value

Spearman Correlation Coefficients Method – Show Heifer Unranked									
	Weight (kg)	**Head Length (cm)**	**Wither Height (cm)**	**Hip Height (cm)**	**Thurl Width (cm)**	**Tail Length (cm)**	**HMI**	**Age (days)**	**ADG (kg)**
Weight (kg)	1.00	0.88 <.0001	0.93 <.0001	0.92 <.0001	0.95 <.0001	0.82 <.0001	0.93 <.0001	0.74 <.0001	0.68 <.0001
Head Length (cm)	0.88 <.0001	1.00	0.88 <.0001	0.88 <.0001	0.87 <.0001	0.71 <.0001	0.76 <.0001	0.76 <.0001	0.50 <.0001
Wither Height (cm)	0.92 <.0001	0.85 <.0001	1.00	0.95 <.0001	0.86 <.0001	0.75 <.0001	0.76 <.0001	0.76 <.0001	0.56 <.0001
Hip Height (cm)	0.92 <.0001	0.88 <.0001	0.95 <.0001	1.00	0.89 <.0001	0.78 <.0001	0.73 <.0001	0.76 <.0001	0.56 <.0001
Thurl Width (cm)	0.95 <.0001	0.87 <.0001	0.89 <.0001	0.89 <.0001	1.00	0.78 <.0001	0.86 <.0001	0.72 <.0001	0.63 <.0001
Tail Length (cm)	0.82 <.0001	0.71 <.0001	0.78 <.0001	0.78 <.0001	0.78 <.0001	1.00	0.77 <.0001	0.67 <.0001	0.52 <.0001
HMI	0.93 <.0001	0.76 <.0001	0.78 <.0001	0.73 <.0001	0.86 <.0001	0.77 <.0001	1.00	0.62 <.0001	0.70 <.0001
Age (days)	0.74 <.0001	0.76 <.0001	0.76 <.0001	0.76 <.0001	0.72 <.0001	0.67 <.0001	0.62 <.0001	1.00	0.05 0.27
ADG (kg)	0.68 <.0001	0.5 <.0001	0.57 <.0001	0.56 <.0001	0.63 <.0001	0.52 <.0001	0.70 <.0001	0.05 0.27	1.00

Appendix 2: Spearman Correlation Coefficients Method for show heifer data after it has been ranked and converted to percentages; pct stands for percentage. The number on the first row is the correlation coefficient and the number on the second row is the p-value.

Spearman Correlation Coefficients Method – Show Heifer Ranked										
	Placing pct	**HMI pct**	**ADG (kg) pct**	**Age (days) pct**	**Weight (kg) pct**	**Head Length (cm) pct**	**Wither Height (cm) pct**	**Hip Height (cm) pct**	**Thurl Width (cm) pct**	**Tail Length (cm) pct**
Placing pct	1.00	-0.28 <.0001	0.02 0.65	0.01 0.78	0.05 0.33	-0.01 0.85	0.34 <.0001	0.32 <.0001	-0.03 0.51	-0.02 0.67
HMI pct	-0.28 <.0001	1.00	0.29 <.0001	0.25 <.0001	0.17 0.0002	-0.18 0.0001	-0.54 <.0001	-0.80 <.0001	-0.03 0.52	-0.17 0.0006
ADG (kg) pct	0.02 0.65	0.29 <.0001	1.00	0.95 <.0001	0.12 0.01	-0.21 <.0001	-0.16 0.0006	-0.17 0.0002	-0.02 0.62	-0.23 <.0001
Age (days) pct	0.01 0.78	0.25 <.0001	0.95 <.0001	1.00	-0.03 0.49	-0.26 <.0001	-0.20 <.0001	-0.20 <.0001	-0.07 0.16	-0.24 <.0001
Weight (kg) pct	0.05 0.33	0.17 0.0002	0.12 0.009	-0.03 0.49	1.00	0.16 0.0007	0.16 0.0005	0.15 0.003	0.14 0.003	-0.06 0.26
Head Length (cm) pct	-0.01 0.85	-0.18 0.0001	-0.21 <.0001	-0.26 <.0001	0.16 0.0007	1.00	0.34 <.0001	0.31 <.0001	0.20 <.0001	0.13 0.007
Wither Height (cm) pct	0.34 <.0001	-0.54 <.0001	-0.16 0.0006	-0.20 <.0001	0.16 0.0005	0.34 <.0001	1.00	0.70 <.0001	0.15 0.002	0.14 0.005
Hip Height (cm) pct	0.34 <.0001	-0.80 <.0001	-0.17 0.0002	-0.20 <.0001	0.14 0.003	0.31 <.0001	0.70 <.0001	1.00	0.15 0.001	0.20 <.0001
Thurl Width (cm) pct	-0.03 0.51	-0.03 0.52	-0.02 0.62	-0.07 0.16	0.14 0.003	0.20 <.0001	0.15 0.002	0.16 0.001	1.00	0.05 0.30
Tail Length (cm) pct	-0.02 0.67	-0.17 0.0006	-0.23 <.0001	-0.24 <.0001	-0.06 0.26	0.13 0.007	0.14 0.005	0.20 <.0001	0.05 0.30	1.00

Appendix 3: Spearman correlation coefficients method on non-show heifers unranked data. The number on the first row is the correlation coefficient and the number on the second row is the p-value

Spearman Correlation Coefficients Method – Non-Show Heifers Unranked									
	Weight (kg)	**Head Length (cm)**	**Wither Height (cm)**	**Hip Height (cm)**	**Thurl Width (cm)**	**Tail Length (cm)**	**HMI**	**Age (days)**	**ADG (kg)**
Weight (kg)	1.00	0.84 <.0001	0.94 <.0001	0.92 <.0001	0.93 <.0001	0.89 <.0001	0.88 <.0001	0.92 <.0001	0.56 <.0001
Head Length (cm)	0.84 <.0001	1.00	0.81 <.0001	0.83 <.0001	0.81 <.0001	0.73 <.0001	0.71 <.0001	0.75 <.0001	0.52 <.0001
Wither Height (cm)	0.94 <.0001	0.81 <.0001	1.00	0.96 <.0001	0.88 <.0001	0.89 <.0001	0.72 <.0001	0.90 <.0001	0.45 <.0001
Hip Height (cm)	0.92 <.0001	0.83 <.0001	0.96 <.0001	1.00	0.86 <.0001	0.86 <.0001	0.67 <.0001	0.87 <.0001	0.46 <.0001
Thurl Width (cm)	0.93 <.0001	0.81 <.0001	0.88 <.0001	0.86 <.0001	1.00	0.86 <.0001	0.85 <.0001	0.87 <.0001	0.49 <.0001
Tail Length (cm)	0.89 <.0001	0.73 <.0001	0.89 <.0001	0.87 <.0001	0.86 <.0001	1.00	0.76 <.0001	0.89 <.0001	0.35 <.0001
HMI	0.88 <.0001	0.71 <.0001	0.72 <.0001	0.67 <.0001	0.85 <.0001	0.76 <.0001	1.00	0.80 <.0001	0.57 <.0001
Age (days)	0.92 <.0001	0.75 <.0001	0.90 <.0001	0.87 <.0001	0.87 <.0001	0.89 <.0001	0.80 <.0001	1.00	0.23 <.0001
ADG (kg)	0.56 <.0001	0.52 <.0001	0.45 <.0001	0.46 <.0001	0.49 <.0001	0.35 <.0001	0.57 <.0001	0.23 <.0001	1.00

Appendix 4: Unranked variables for non-show heifers Farm 1

Non-Show Heifers Unranked Farm 1							
Variable	**Sample Number**	**Mean**	**Standard Deviation**	**Standard Error**	**Median**	**Minimum**	**Maximum**
Weight (kg)	35	255.37	66.86	11.29	233.60	184.16	409.14
Head Length (cm)	35	46.40	4.44	0.75	46.99	36.20	56.52
Wither Height (cm)	35	116.81	7.97	1.35	114.30	102.24	132.08
Hip Height (cm)	35	121.92	7.71	1.30	119.38	110.49	138.43
Thurl Width (cm)	35	37.29	3.48	0.59	36.20	31.75	45.72
Tail Length (cm)	35	63.19	8.58	1.45	58.42	52.07	79.38
HMI	35	169.14	26.81	4.53	160.49	141.85	269.57
Age (days)	35	274.06	73.09	12.35	237.00	202.00	409.00
ADG (kg)	35	0.77	0.08	0.01	0.79	0.63	0.96

Appendix 5: Spearman Correlation Coefficients Method for Non-show heifers unranked Farm 1. The number in the first row is the correlation coefficient and the number in the second row is the p-value.

Spearman Correlation Coefficients Method – Non-Show Heifers Unranked Farm 1									
	Weight (kg)	**Head Length (cm)**	**Wither Height (cm)**	**Hip Height (cm)**	**Thurl Width (cm)**	**Tail Length (cm)**	**HMI**	**Age (days)**	**ADG (kg)**
Weight (kg)	1.00	0.51 0.0018	0.85 <.0001	0.87 <.0001	0.93 <.0001	0.65 <.0001	0.92 <.0001	0.78 <.0001	0.70 <.0001
Head Length (cm)	0.51 0.002	1.00	0.63 <.0001	0.56 0.0005	0.64 <.0001	0.18 0.31	0.35 0.04	0.66 <.0001	0.17 0.33
Wither Height (cm)	0.85 <.0001	0.63 <.0001	1.00	0.95 <.0001	0.89 <.0001	0.64 <.0001	0.68 <.0001	0.82 <.0001	0.41 0.02
Hip Height (cm)	0.87 <.0001	0.56 0.0005	0.95 <.0001	1.00	0.90 <.0001	0.69 <.0001	0.68 <.0001	0.75 <.0001	0.49 0.003
Thurl Width (cm)	0.93 <.0001	0.64 <.0001	0.89 <.0001	0.90 <.0001	1.00	0.64 <.0001	0.82 <.0001	0.83 <.0001	0.54 0.0007
Tail Length (cm)	0.65 <.0001	0.18 0.31	0.64 <.0001	0.69 <.0001	0.64 <.0001	1.00	0.64 <.0001	0.55 0.0007	0.28 0.11
HMI	0.92 <.0001	0.35 0.04	0.68 <.0001	0.68 <.0001	0.82 <.0001	0.64 <.0001	1.00	0.72 <.0001	0.61 0.0001
Age (days)	0.78 <.0001	0.66 <.0001	0.82 <.0001	0.75 <.0001	0.83 <.0001	0.55 0.0007	0.72 <.0001	1.00	0.19 0.28
ADG (kg)	0.70 <.0001	0.17 0.33	0.41 0.02	0.49 0.003	0.54 0.0007	0.27 0.11	0.61 0.0001	0.19 0.28	1.00

Appendix 6: Unranked variables for Non-Show Heifers Farm 2

Non-Show Heifers Unranked Farm 2							
Variable	**Sample Number**	**Mean**	**Standard Deviation**	**Standard Error**	**Median**	**Minimum**	**Maximum**
Weight (kg)	104	241.34	44.75	4.39	244.94	161.93	360.15
Head Length (cm)	104	43.90	5.19	0.51	43.82	34.93	56.52
Wither Height (cm)	104	113.55	6.63	0.65	113.67	99.70	127.00
Hip Height (cm)	104	118.26	7.01	0.69	118.43	104.14	134.62
Thurl Width (cm)	104	37.05	3.01	0.30	37.47	31.12	45.72
Tail Length (cm)	104	65.83	6.49	0.64	65.73	52.71	80.65
HMI	104	171.13	17.51	1.72	166.29	132.63	225.16
Age (days)	104	287.81	57.62	5.65	272.00	207.00	416.00
ADG (kg)	104	0.70	0.10	0.01	0.68	0.47	0.97

Appendix 7: Spearman Correlation Coefficients Method for Non-show heifers unranked Farm 2. The number in the first row is the correlation coefficient and the number in the second row is the p-value.

Spearman Correlation Coefficients Method – Non-Show Heifers Unranked Farm 2									
	Weight (kg)	**Head Length (cm)**	**Wither Height (cm)**	**Hip Height (cm)**	**Thurl Width (cm)**	**Tail Length (cm)**	**HMI**	**Age (days)**	**ADG (kg)**
Weight (kg)	1.00	0.79 <.0001	0.85 <.0001	0.87 <.0001	0.91 <.0001	0.73 <.0001	0.76 <.0001	0.78 <.0001	0.47 <.0001
Head Length (cm)	0.79 <.0001	1.00	0.60 <.0001	0.63 <.0001	0.82 <.0001	0.45 <.0001	0.69 <.0001	0.53 <.0001	0.52 <.0001
Wither Height (cm)	0.85 <.0001	0.60 <.0001	1.00	0.95 <.0001	0.77 <.0001	0.78 <.0001	0.41 <.0001	0.80 <.0001	0.21 <.0001
Hip Height (cm)	0.87 <.0001	0.63 <.0001	0.95 <.0001	1.00	0.79 <.0001	0.77 <.0001	0.38 <.0001	0.77 <.0001	0.27 0.005
Thurl Width (cm)	0.91 <.0001	0.82 <.0001	0.77 <.0001	0.79 <.0001	1.00	0.68 <.0001	0.70 <.0001	0.68 <.0001	0.47 <.0001
Tail Length (cm)	0.73 <.0001	0.45 <.0001	0.78 <.0001	0.77 <.0001	0.68 <.0001	1.00	0.41 <.0001	0.69 <.0001	0.16 0.12
HMI	0.76 <.0001	0.69 <.0001	0.41 <.0001	0.38 <.0001	0.70 <.0001	0.41 <.0001	1.00	0.49 <.0001	0.55 <.0001
Age (days)	0.78 <.0001	0.53 <.0001	0.80 <.0001	0.77 <.0001	0.68 <.0001	0.69 <.0001	0.49 <.0001	1.00	-0.14 0.16
ADG (kg)	0.47 <.0001	0.52 <.0001	0.21 0.04	0.27 0.005	0.47 <.0001	0.16 0.12	0.55 <.0001	-0.14 0.16	1.00

Appendix 8: Unranked variables for non-show heifers Farm 3

Non-Show Heifers Unranked Farm 3							
Variable	**Sample Number**	**Mean**	**Standard Deviation**	**Standard Error**	**Median**	**Minimum**	**Maximum**
Weight (kg)	154	208.99	77.09	6.21	221.58	101.60	384.19
Head Length (cm)	154	39.02	5.32	0.43	39.37	30.48	48.26
Wither Height (cm)	154	108.56	11.96	0.96	108.59	89.54	130.81
Hip Height (cm)	154	111.02	12.35	1.00	111.76	91.44	142.88
Thurl Width (cm)	154	34.67	6.45	0.52	36.20	23.75	48.26
Tail Length (cm)	135	57.66	12.11	1.04	55.88	36.20	82.55
HMI	154	161.72	27.97	2.25	167.11	110.50	218.42
Age (days)	154	231.73	92.99	7.49	244.00	122.00	404.00
ADG (kg)	154	0.70	0.09	0.007	0.71	0.46	0.94

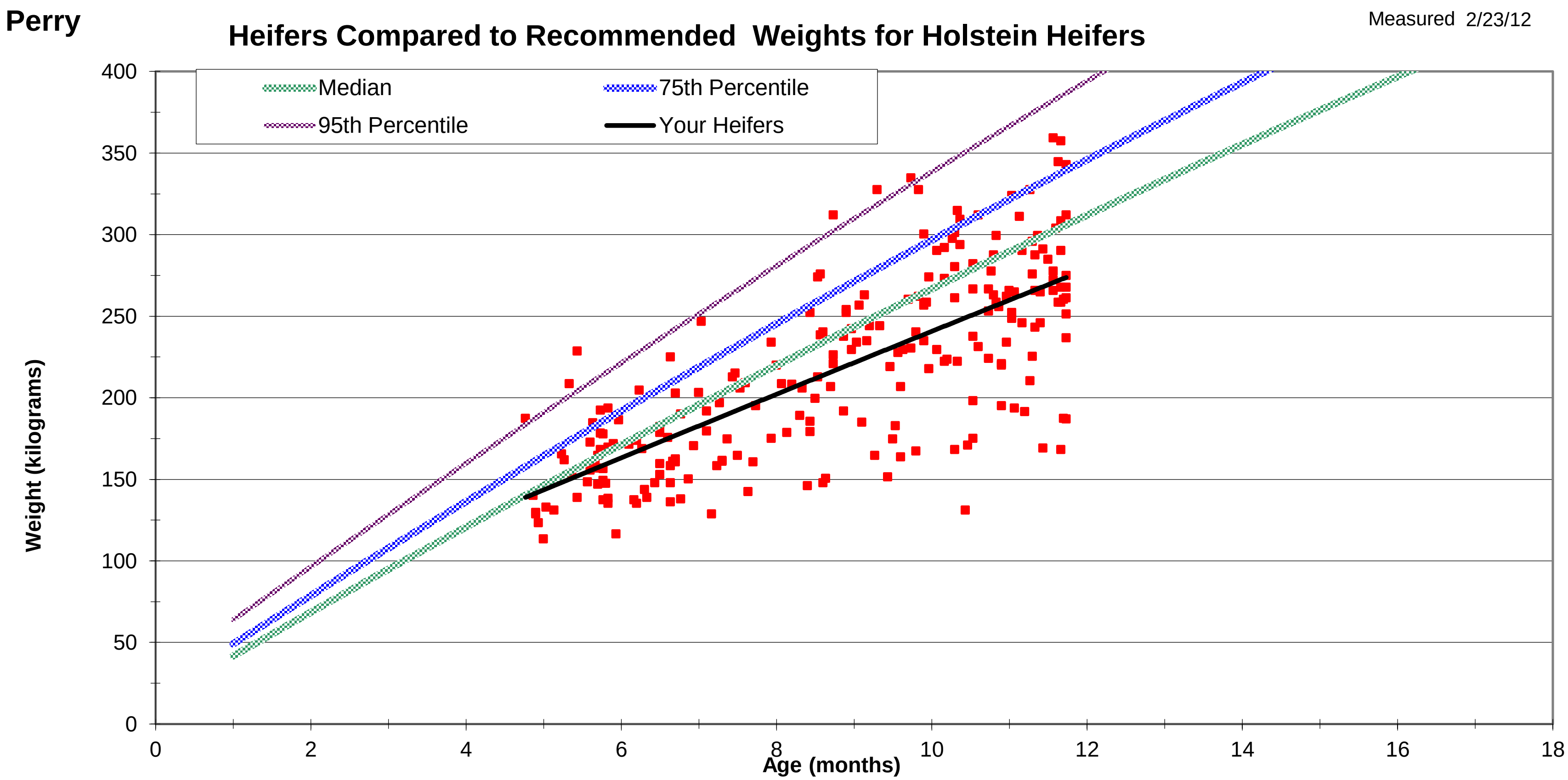
Appendix 9: Spearman Correlation Coefficients Method for Non-show heifers unranked Farm 3. The number in the first row is the correlation coefficient and the number in the second row is the p-value.

Spearman Correlation Coefficients Method – Non-Show Heifers Unranked Farm 3									
	Weight (kg)	**Head Length (cm)**	**Wither Height (cm)**	**Hip Height (cm)**	**Thurl Width (cm)**	**Tail Length (cm)**	**HMI**	**Age (days)**	**ADG (kg)**
Weight (kg)	1.00	0.95 <.0001	0.95 <.0001	0.94 <.0001	0.92 <.0001	0.91 <.0001	0.91 <.0001	0.93 <.0001	0.72 <.0001
Head Length (cm)	0.95 <.0001	1.00	0.94 <.0001	0.93 <.0001	0.90 <.0001	0.90 <.0001	0.85 <.0001	0.92 <.0001	0.61 <.0001
Wither Height (cm)	0.95 <.0001	0.94 <.0001	1.00	0.97 <.0001	0.91 <.0001	0.91 <.0001	0.80 <.0001	0.91 <.0001	0.62 <.0001
Hip Height (cm)	0.94 <.0001	0.93 <.0001	0.97 <.0001	1.00	0.90 <.0001	0.90 <.0001	0.77 <.0001	0.91 <.0001	0.60 <.0001
Thurl Width (cm)	0.92 <.0001	0.90 <.0001	0.91 <.0001	0.90 <.0001	1.00	0.90 <.0001	0.85 <.0001	0.90 <.0001	0.58 <.0001
Tail Length (cm)	0.91 <.0001	0.90 <.0001	0.91 <.0001	0.90 <.0001	0.90 <.0001	1.00	0.82 <.0001	0.88 <.0001	0.57 <.0001
HMI	0.91 <.0001	0.85 <.0001	0.80 <.0001	0.77 <.0001	0.85 <.0001	0.82 <.0001	1.00	0.84 <.0001	0.69 <.0001
Age (days)	0.93 <.0001	0.92 <.0001	0.91 <.0001	0.91 <.0001	0.90 <.0001	0.88 <.0001	0.84 <.0001	1.00	0.45 <.0001
ADG (kg)	0.72 <.0001	0.61 <.0001	0.62 <.0001	0.60 <.0001	0.58 <.0001	0.57 <.0001	0.69 <.0001	0.45 <.0001	1.00

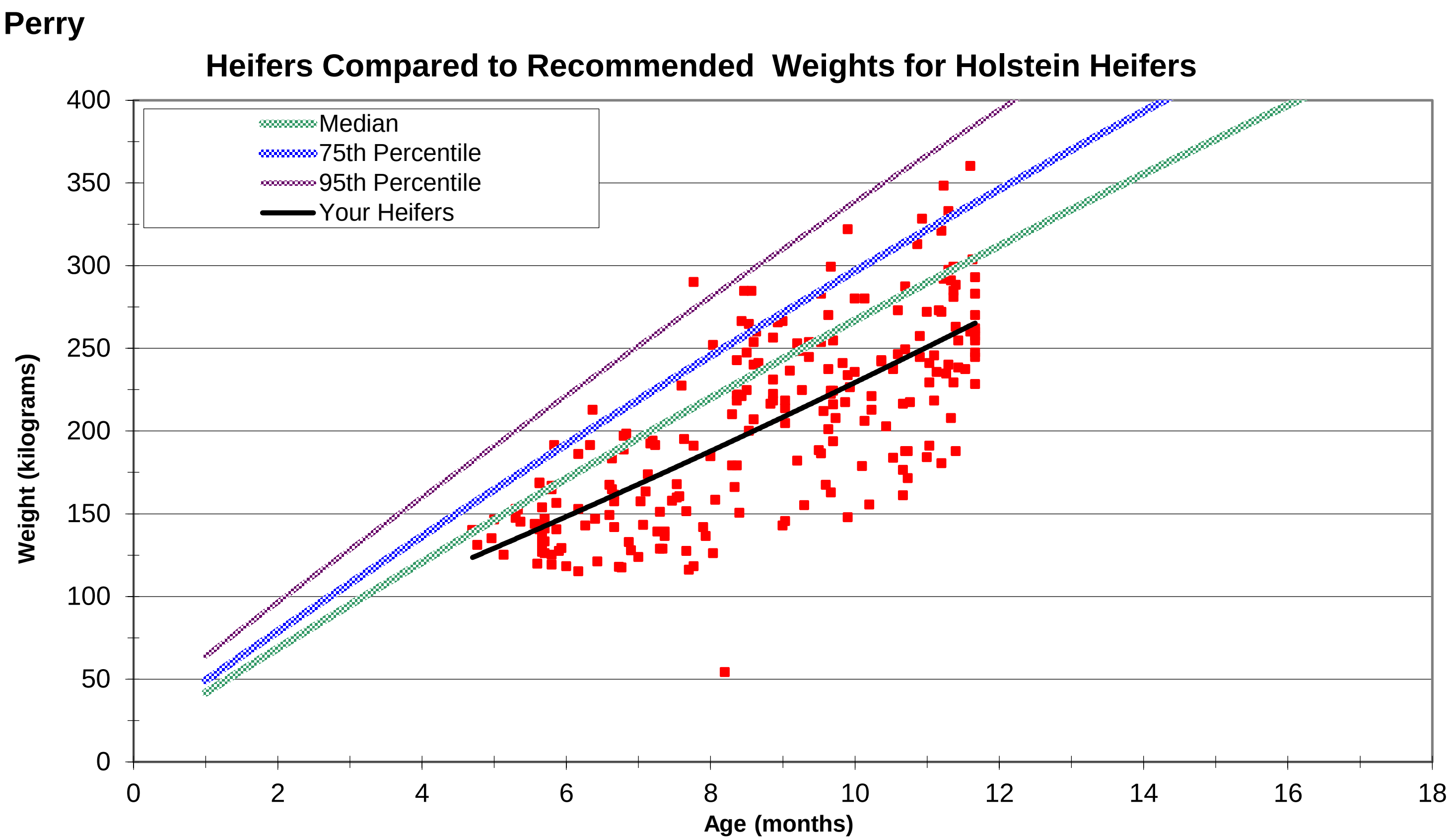
Appendix 10: breakdown of the number and percent of underweight show heifers and non-show heifers not growing to industry guidelines and the number and percent of show heifers and non-show heifers that are growing to industry guidelines according to the Penn State Graph

Underweight Heifers					
Heifer Origin	**Total Sample Size**	**Number of Heifers not Growing to Industry Guidelines**	**Percent of Heifers not Growing to Industry Guidelines**	**Number of Heifers Growing to Industry Guidelines**	**Percent of Heifers Growing to Industry Guidelines**
Show Heifers	454	329	72.47	125	25.53
Non-Show Heifers Farm 1	35	11	31.43	24	68.57
Non-Show Heifers Farm 2	104	59	56.73	45	43.27
Non-Show Heifers Farm 3	154	57	37.01	97	62.99
Non-Show Heifers Combined	293	127	43.34	166	56.66

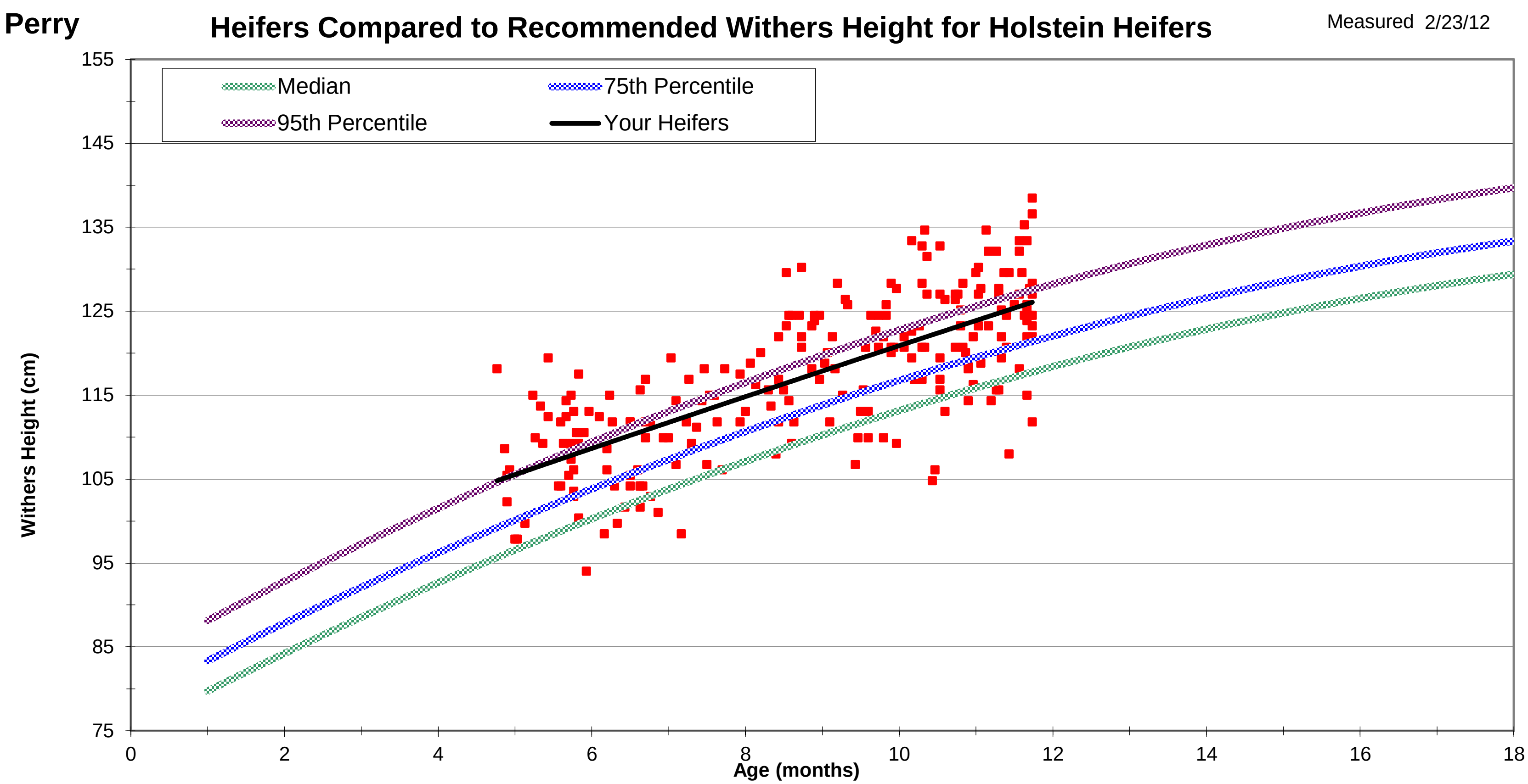
Appendix 11: Weight of show heifers from year 1 compared to recommended weights for Holstein heifers (Pennsylvania State University)



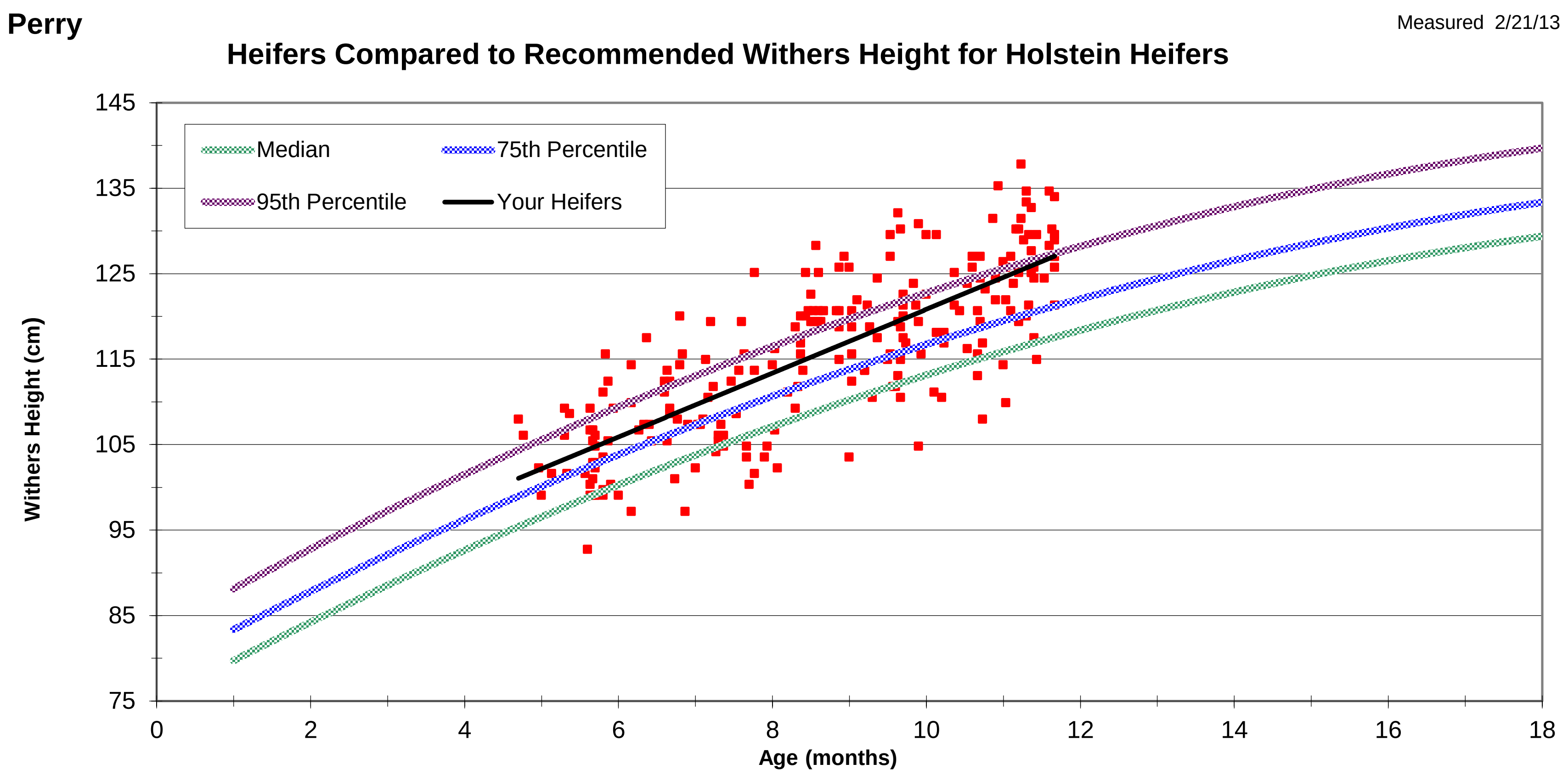
Appendix 12: Weight of show heifers from year 2 compared to recommended weights for Holstein heifers (Pennsylvania State University)



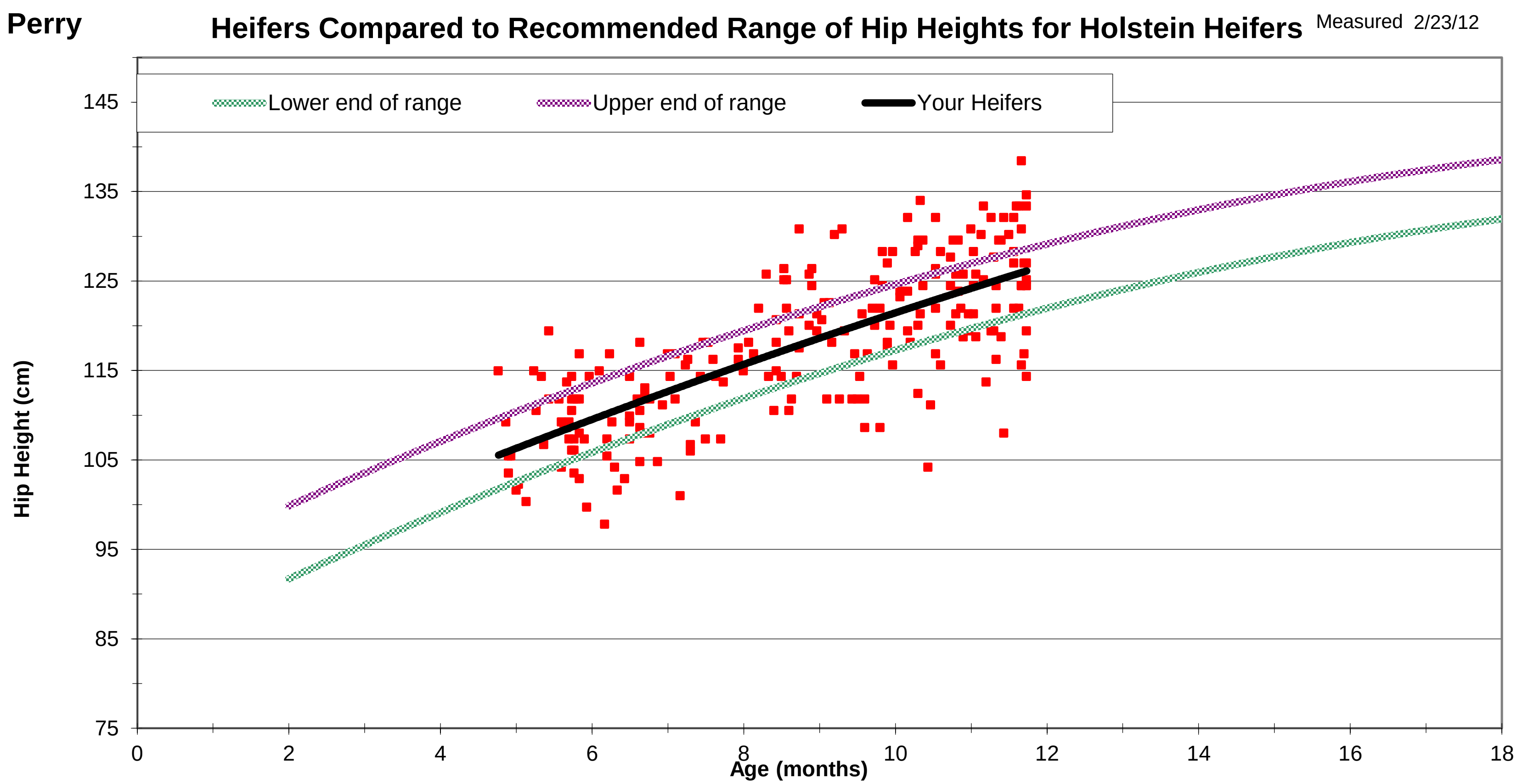
Appendix 13: Wither height of show heifers from year 1 compared to recommended wither height for Holstein heifers (Pennsylvania State University)



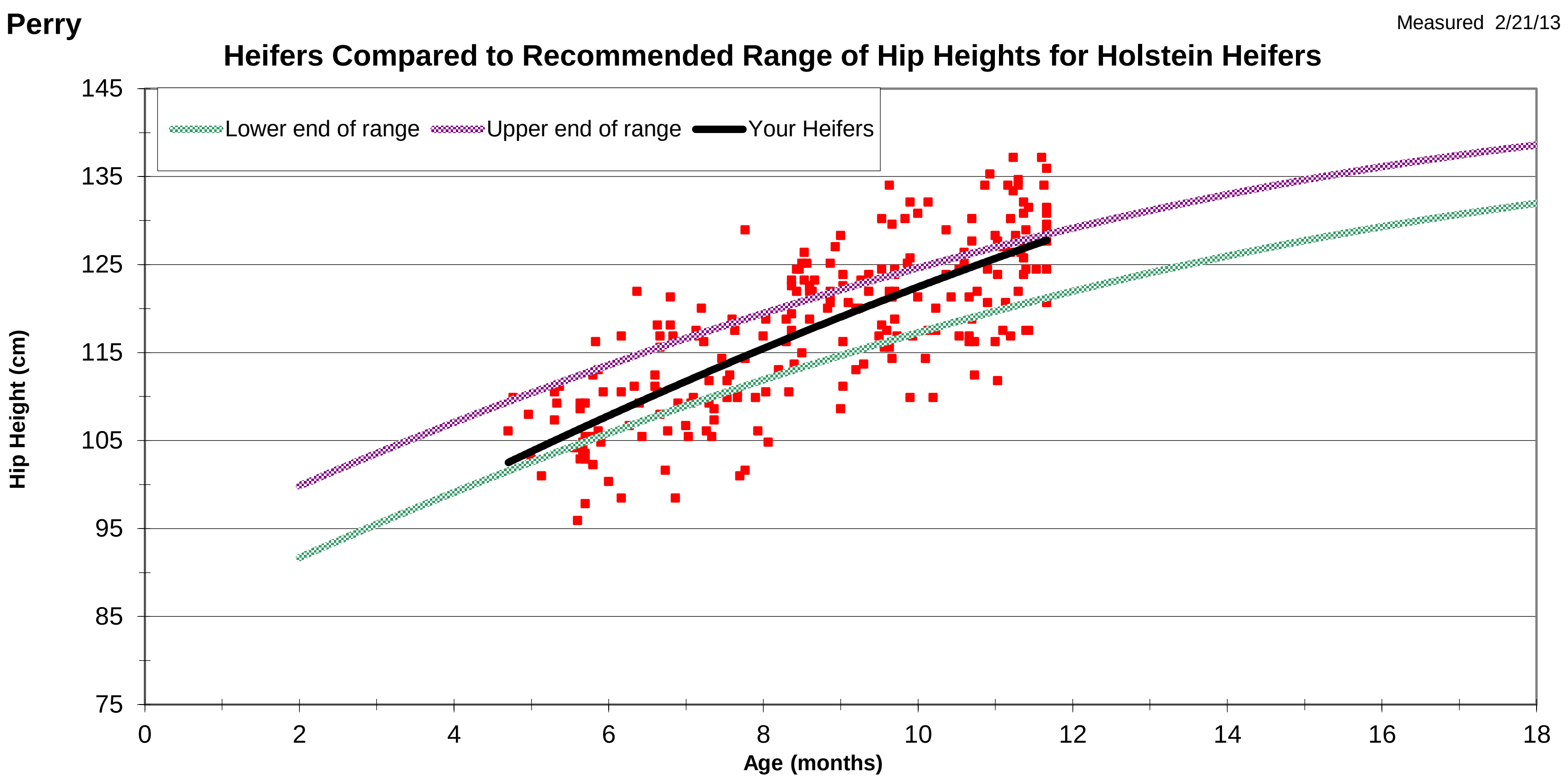
Appendix 14: Wither height of show heifers from year 2 compared to recommended wither height for Holstein heifers (Pennsylvania State University)



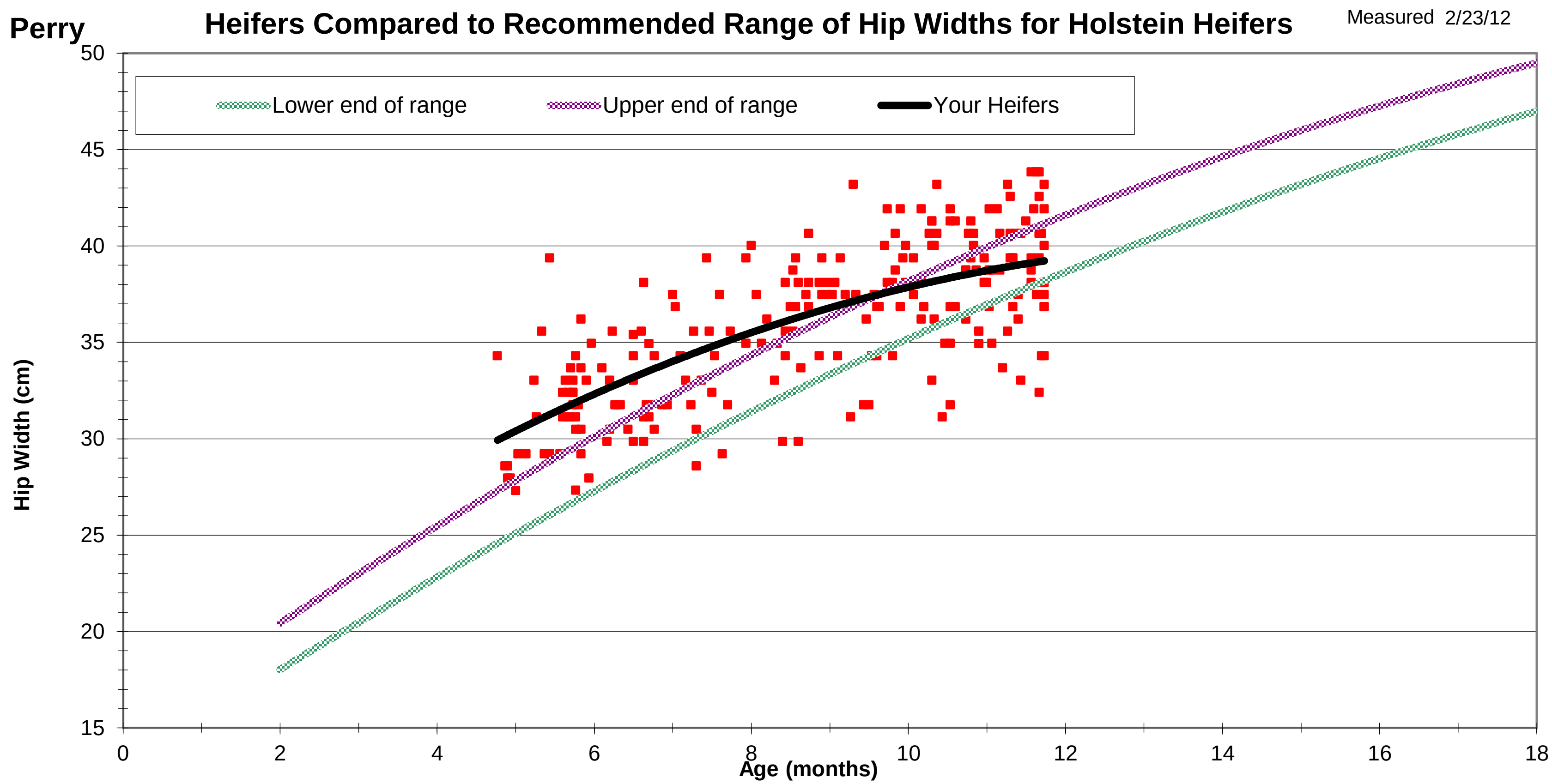
Appendix 15: Hip Height of show heifers from year 1 compared to recommended range of hip height for Holstein heifers (Pennsylvania State University)



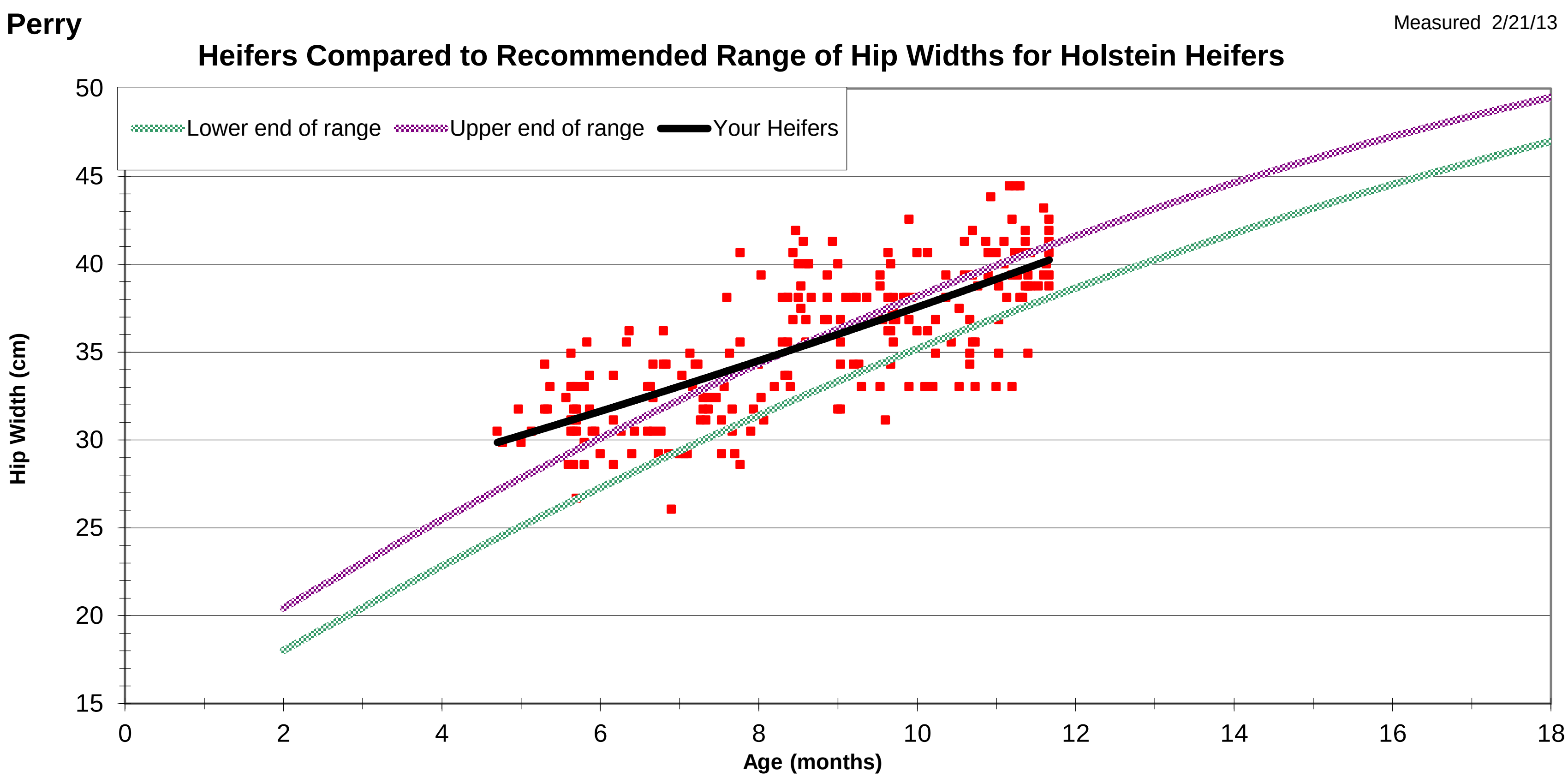
Appendix 16: Hip height of show heifers from year 2 compared to recommended range of hip height for Holstein heifers (Pennsylvania State University)



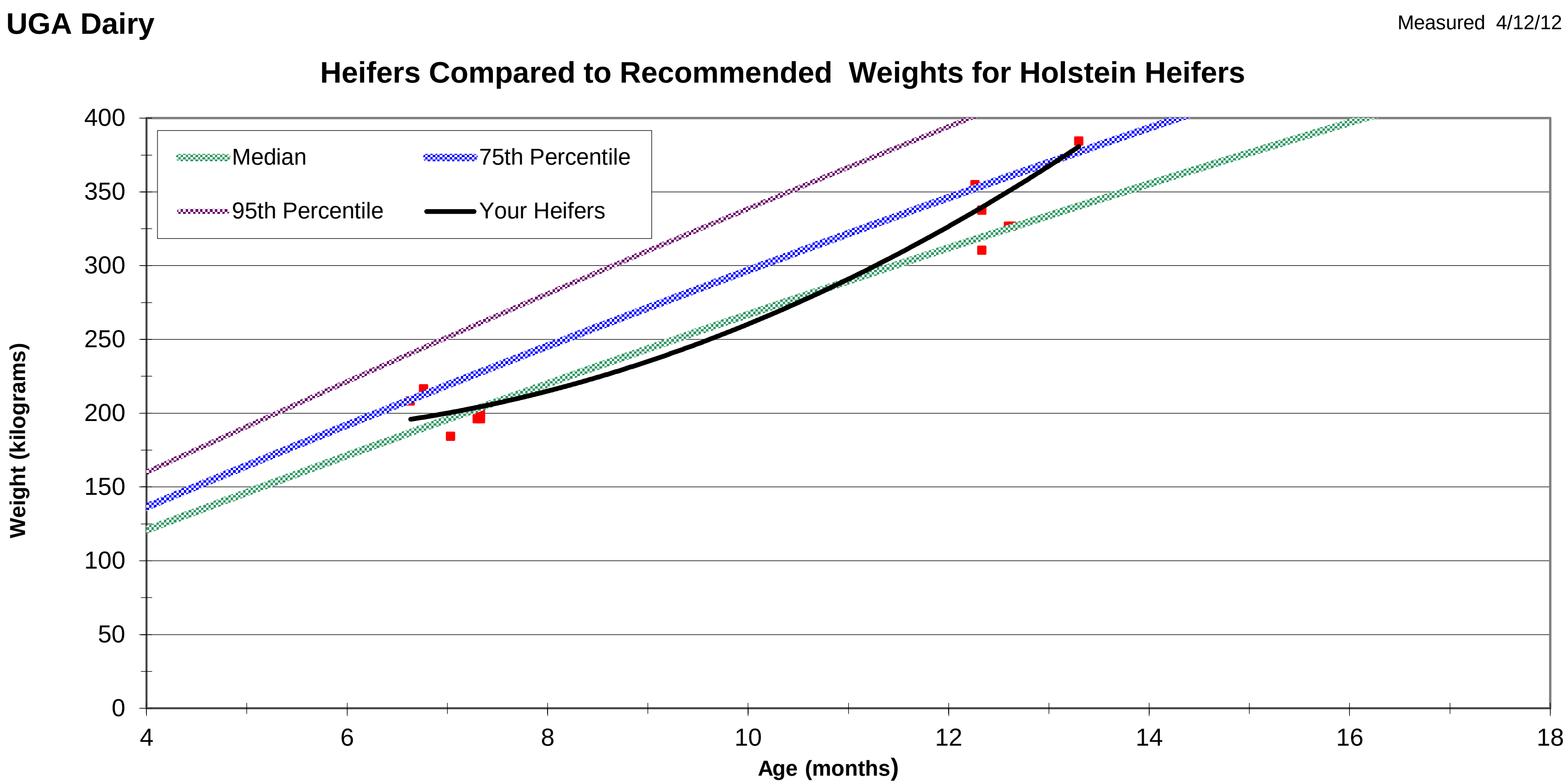
Appendix 17: Hip Width of show heifers from year 1 compared to recommended range of hip width for Holstein heifers (Pennsylvania State University)



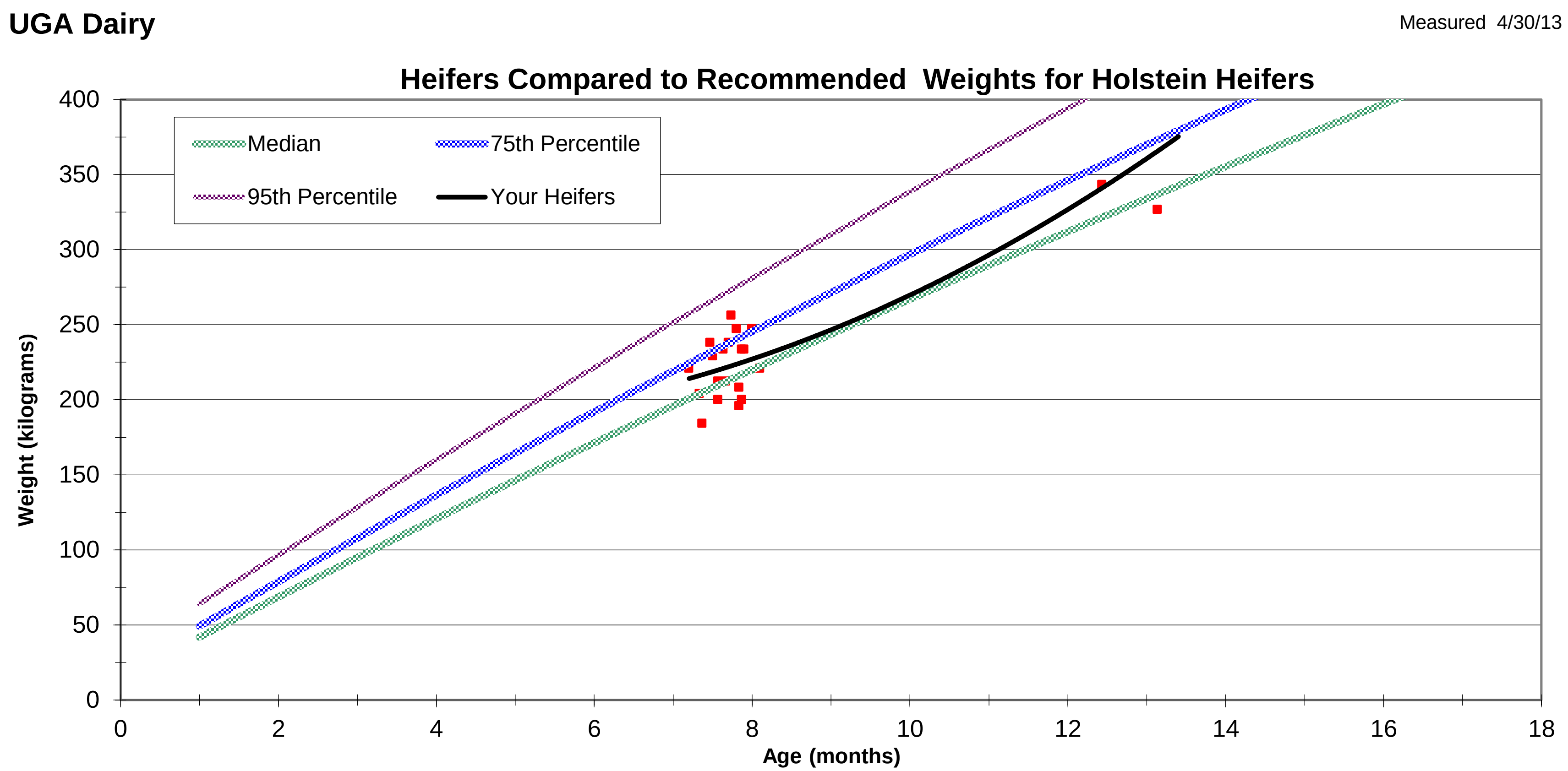
Appendix 18: Hip width of show heifers from year 2 compared to recommended range of hip widths for Holstein heifers (Pennsylvania State University)



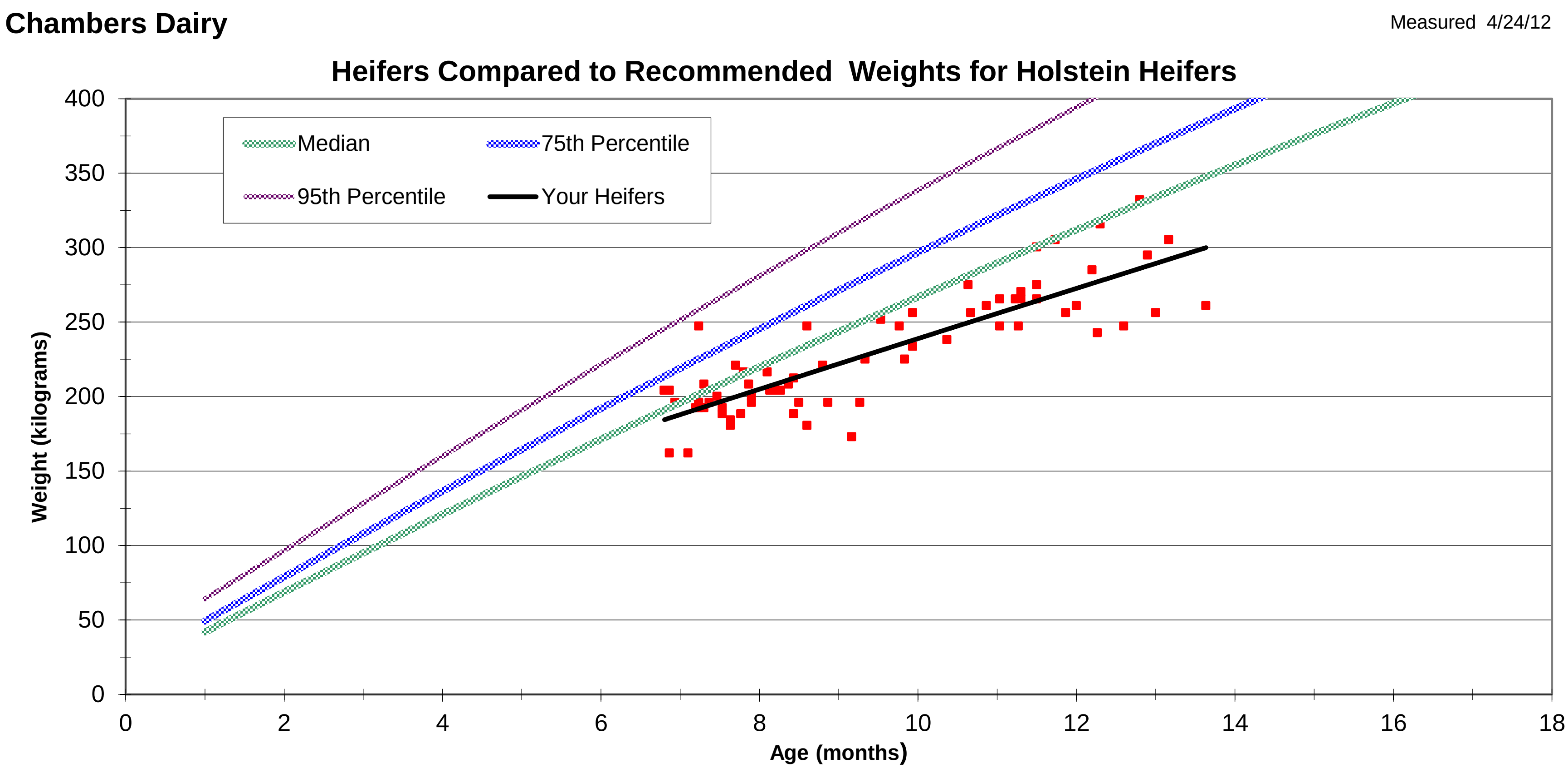
Appendix 19: Weight of farm 1 heifers from year 1 compared to recommended weights for Holstein heifers (Pennsylvania State University)



Appendix 20: Weight of farm 1 heifers from year 2 compared to recommended weights for Holstein heifers (Pennsylvania State University)



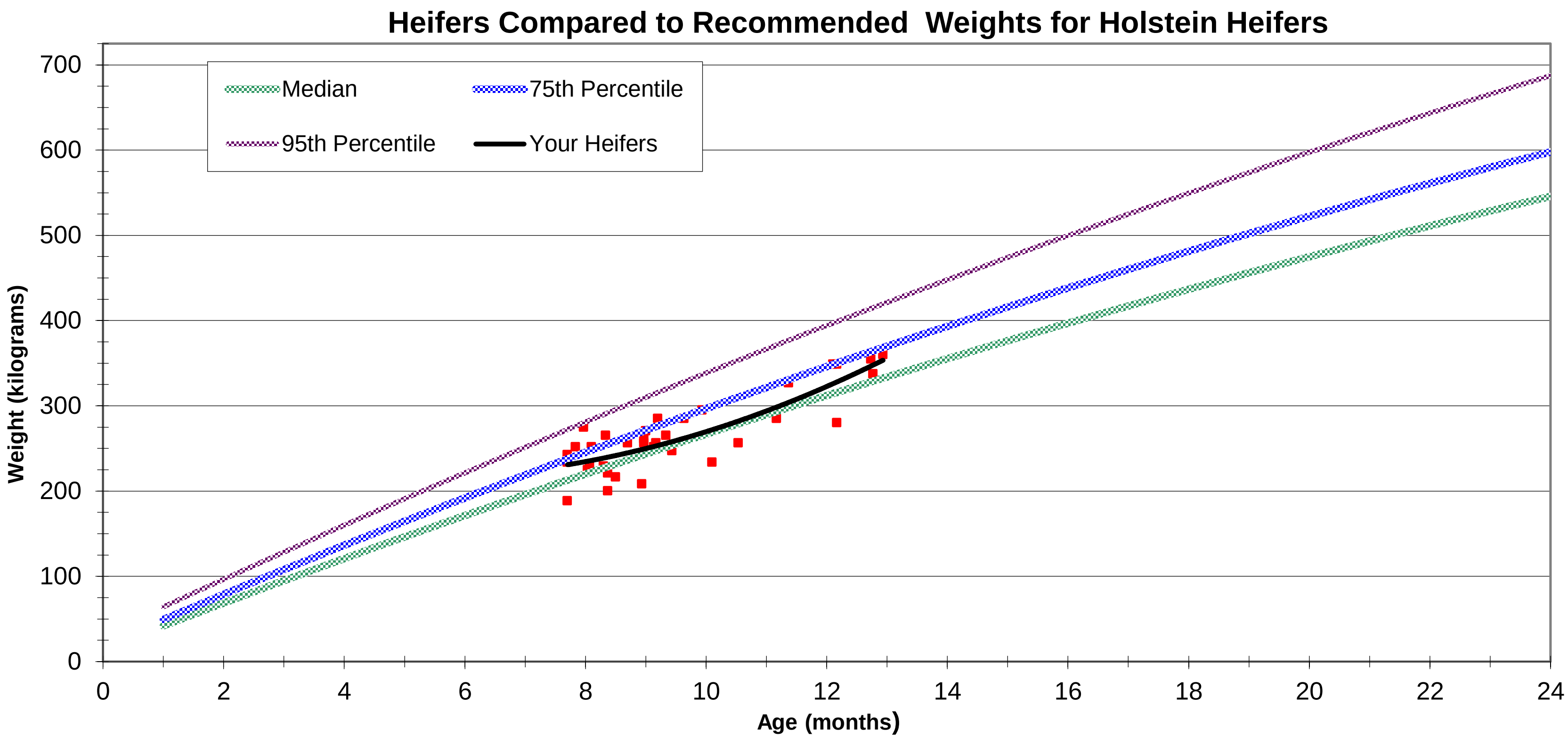
Appendix 21: Weights for farm 2 heifers from year 1 compared to recommended weights for Holstein heifers (Pennsylvania State University)



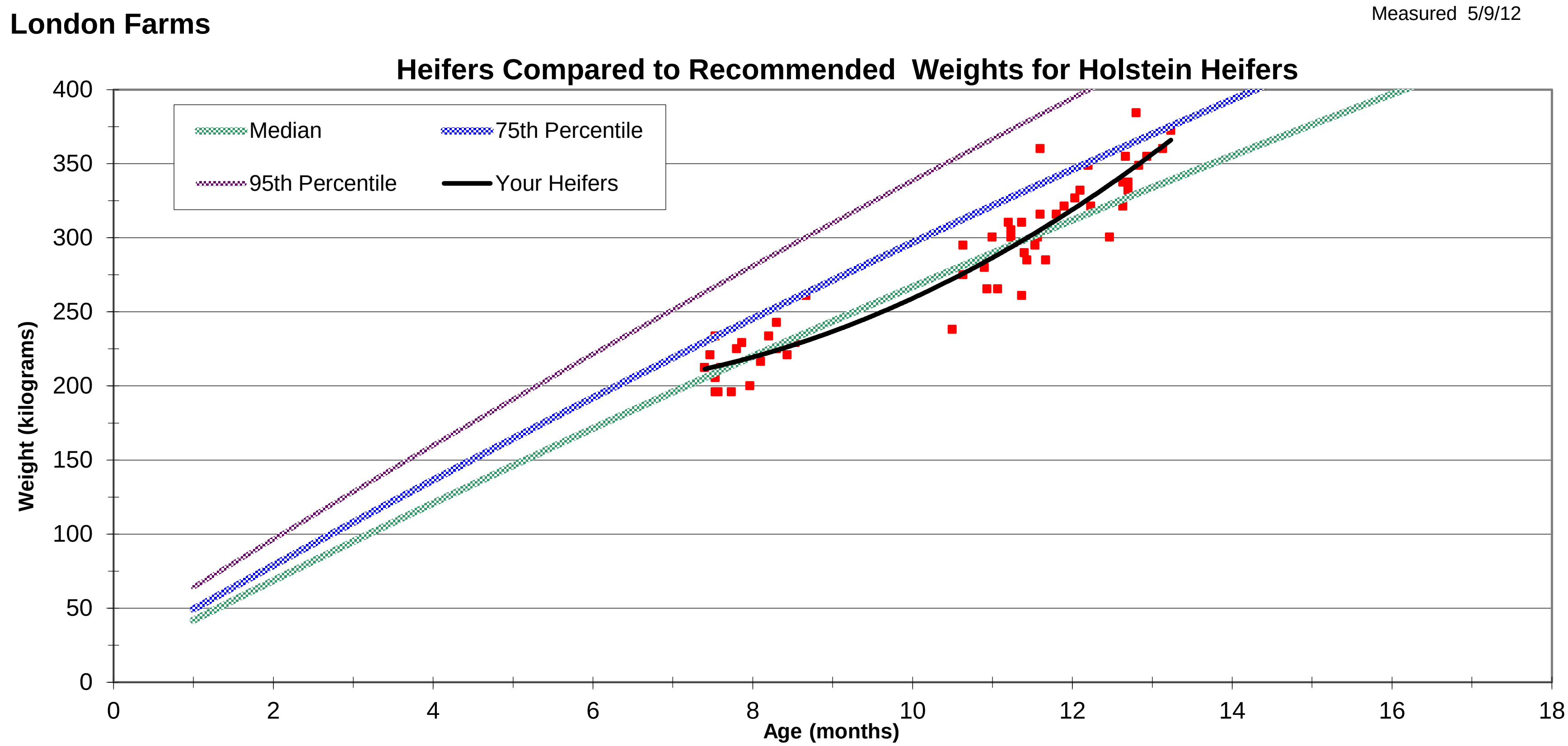
Appendix 22: Weights for farm 2 heifers from year 2 compared to recommended weights for Holstein heifers (Pennsylvania State University)

Chambers Dairy

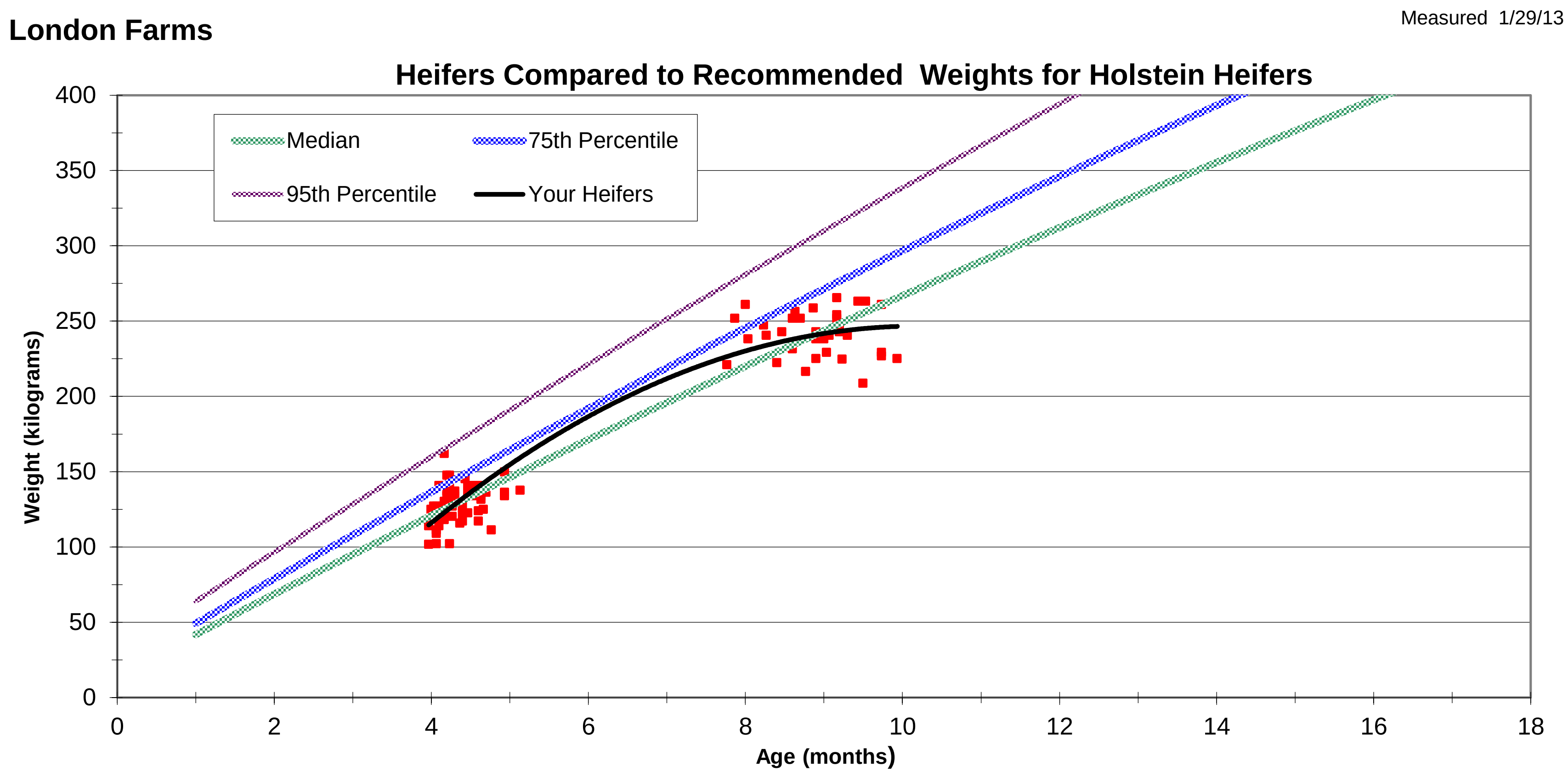
Measured 5/21/13



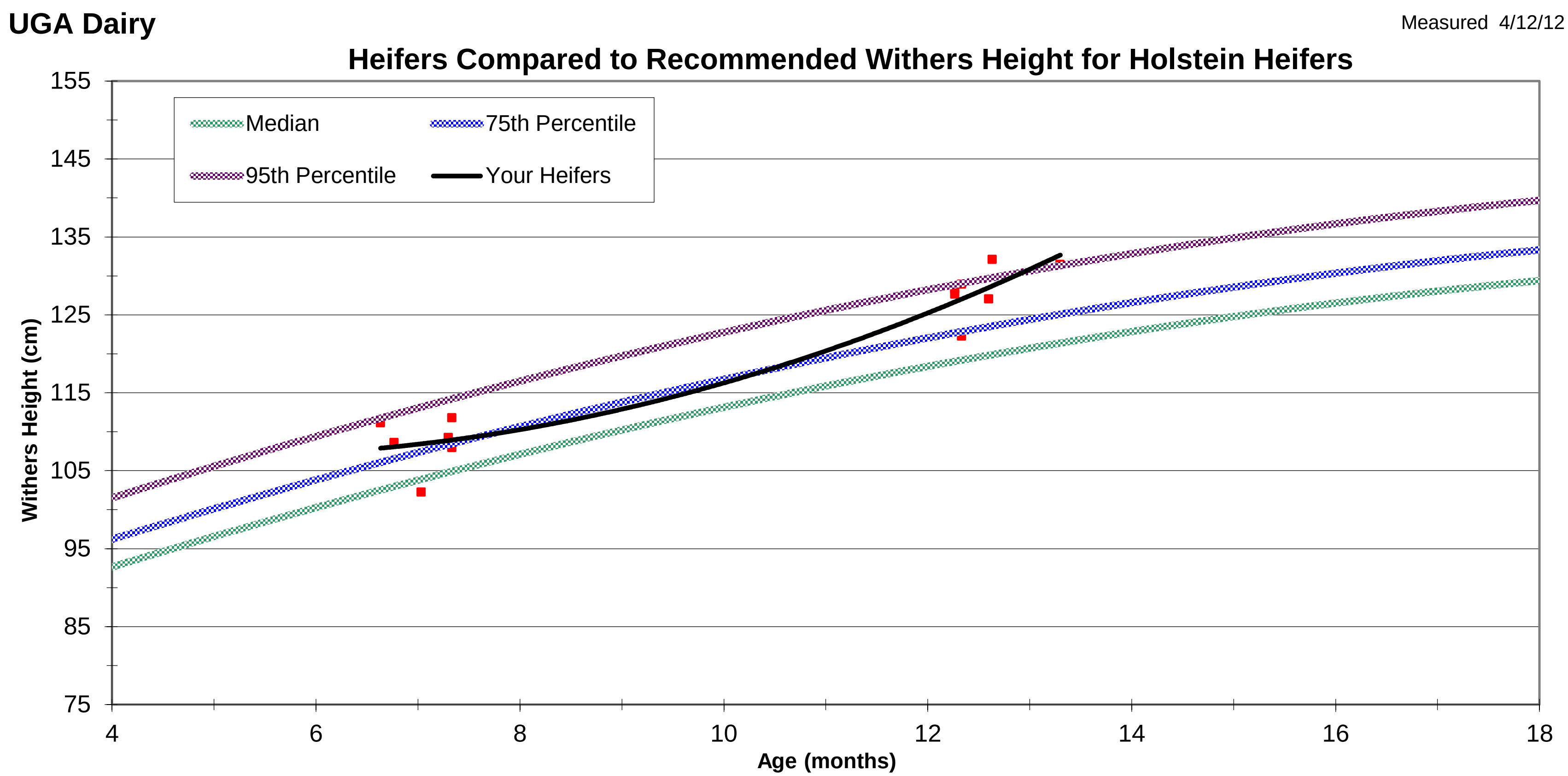
Appendix 23: Weight of farm 3 heifers from year 1 compared to recommended weights for Holstein heifers (Pennsylvania State University)



Appendix 24: Weight of farm 3 heifers from year 2 compared to recommended weights for Holstein heifers (Pennsylvania State University)

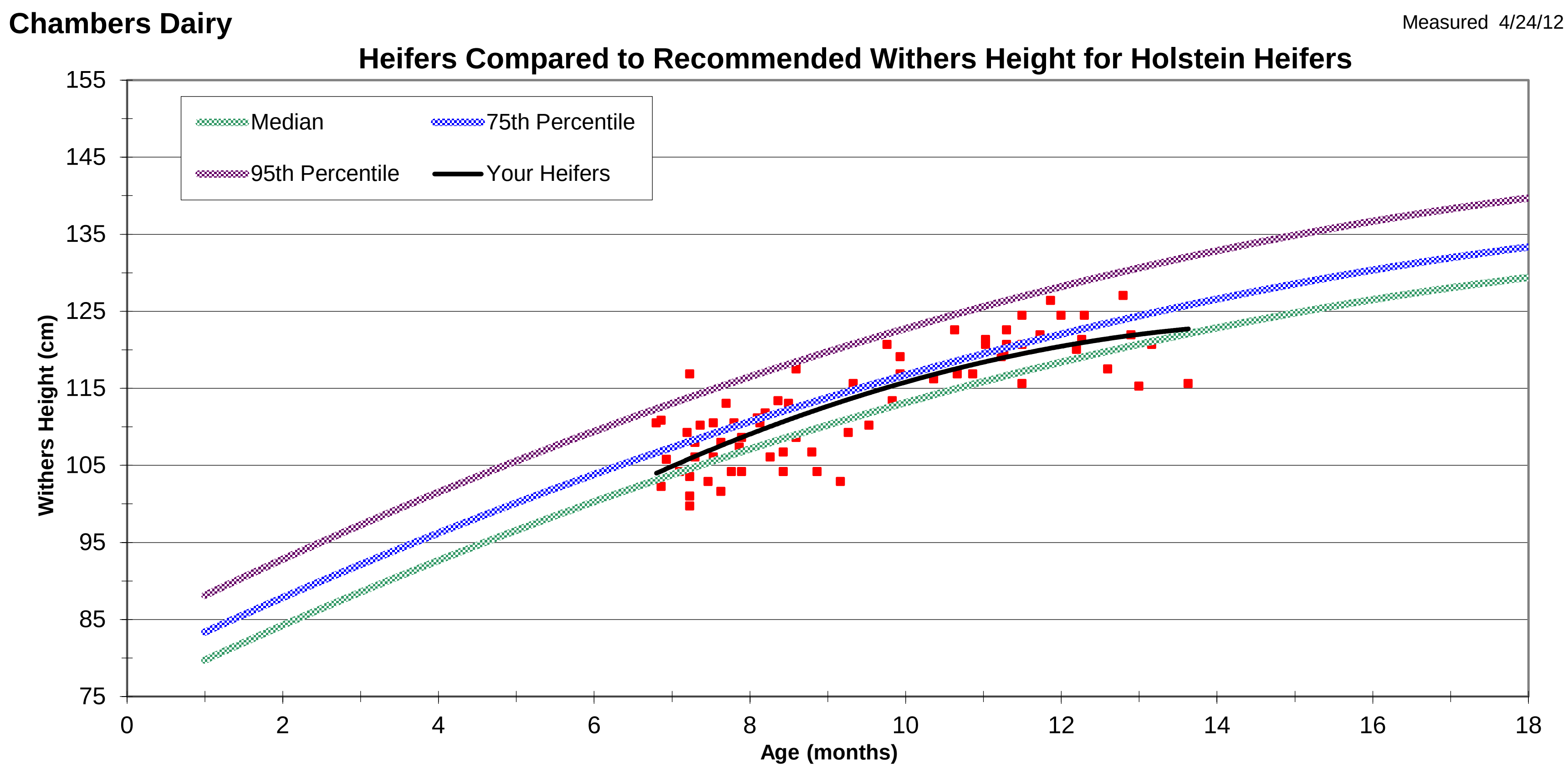


Appendix 25: Wither height of farm 1 heifers from year 1 compared to recommended wither height for Holstein heifers (Pennsylvania State University)

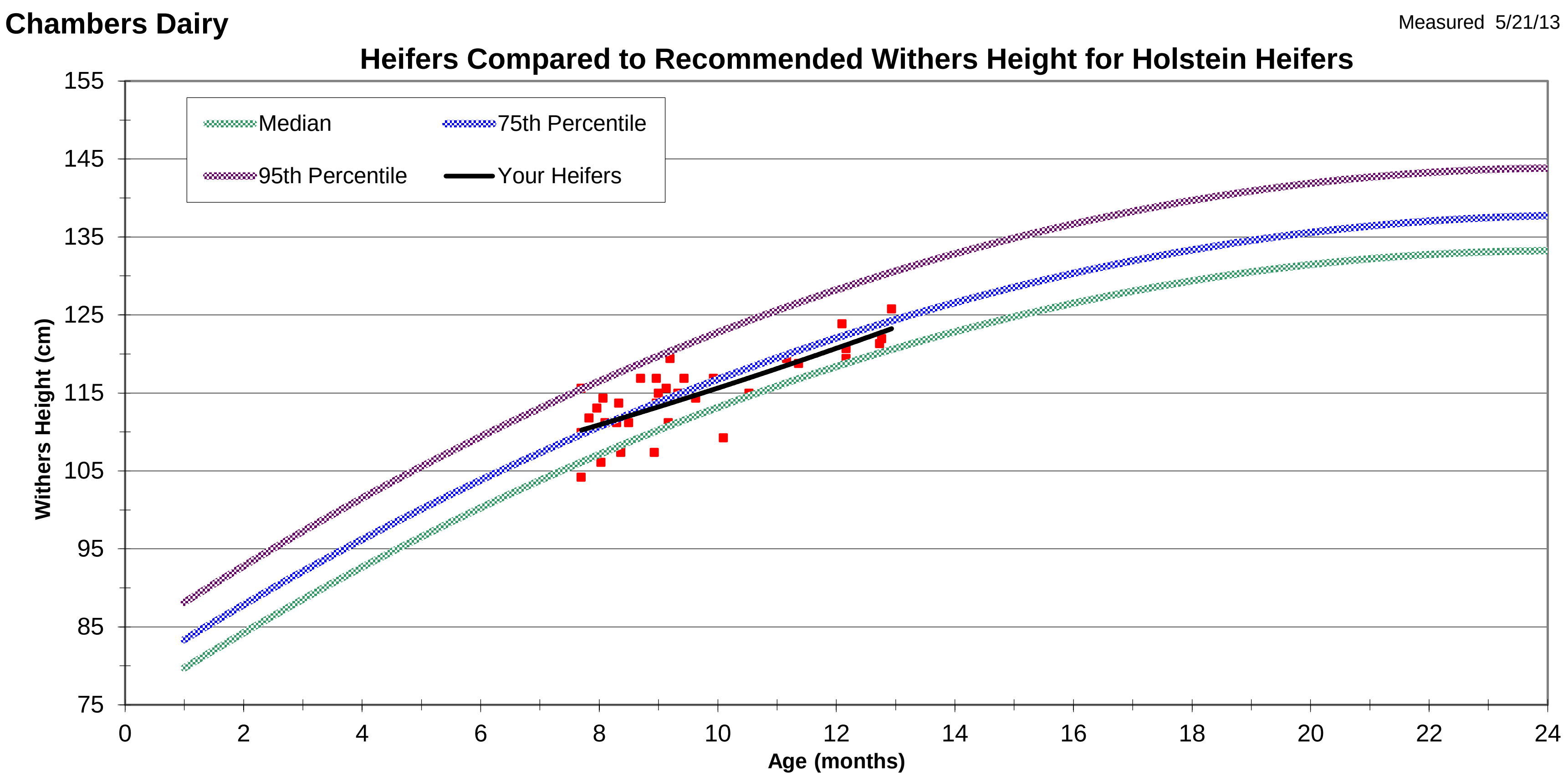


Appendix 26: Wither height for farm 1 heifers from year 2 compared to recommended wither height for Holstein heifers (Pennsylvania State University)

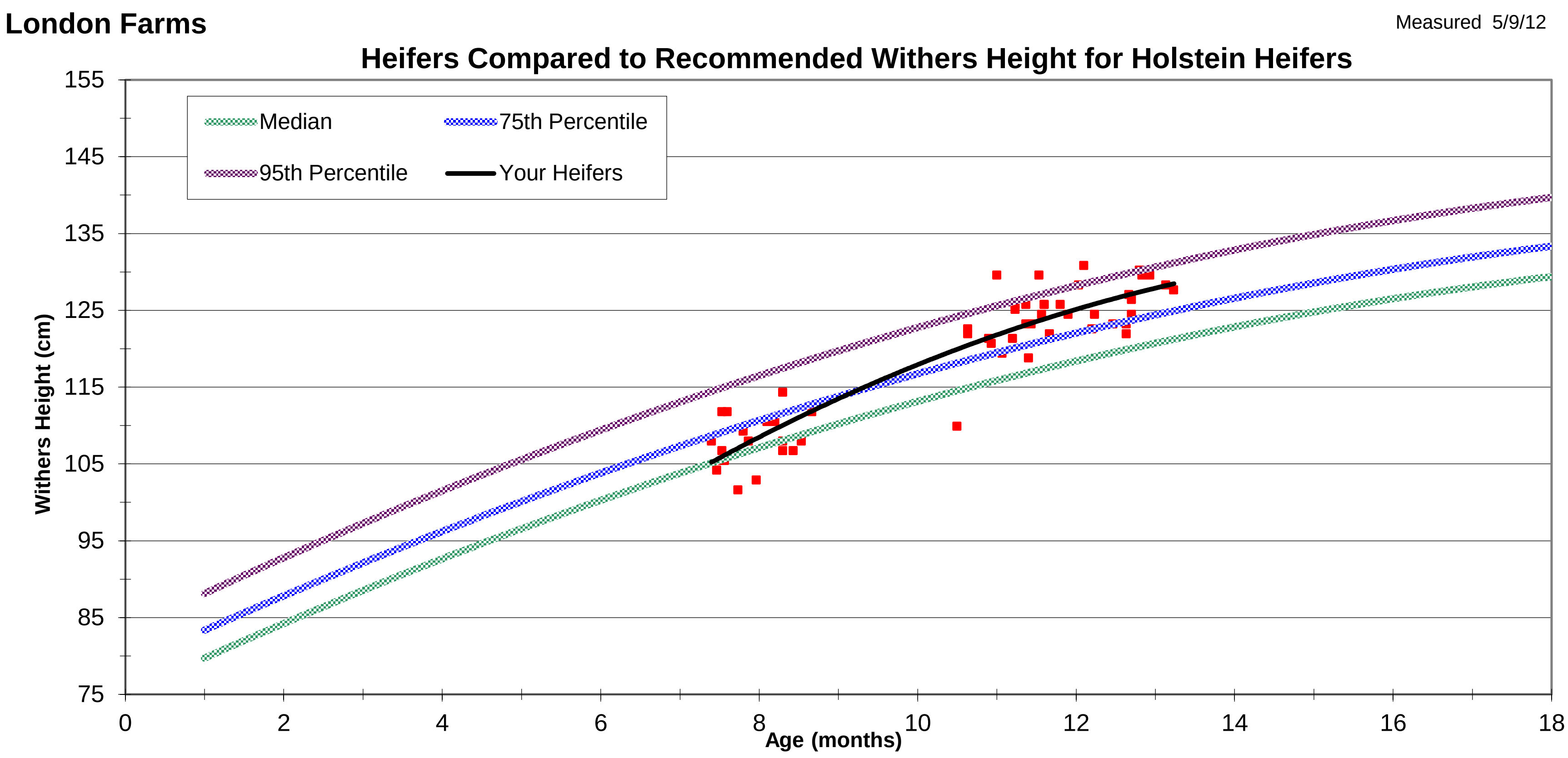
Appendix 27: Wither height for farm 2 heifers from year 1 compared to recommended wither height for Holstein heifers (Pennsylvania State University)



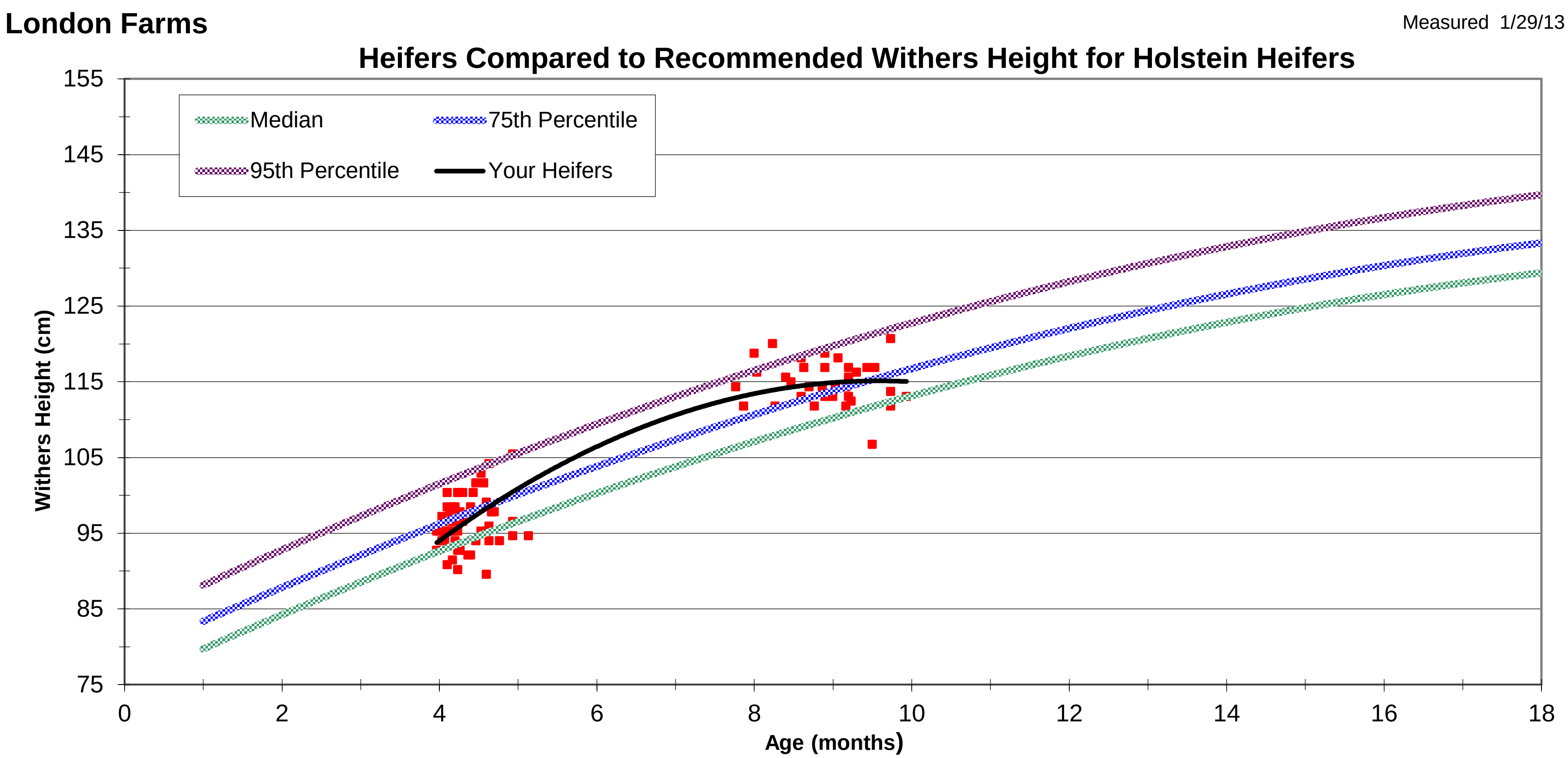
Appendix 28: Wither height for farm 2 heifers from year 2 compared to recommended wither height for Holstein heifers (Pennsylvania State University)



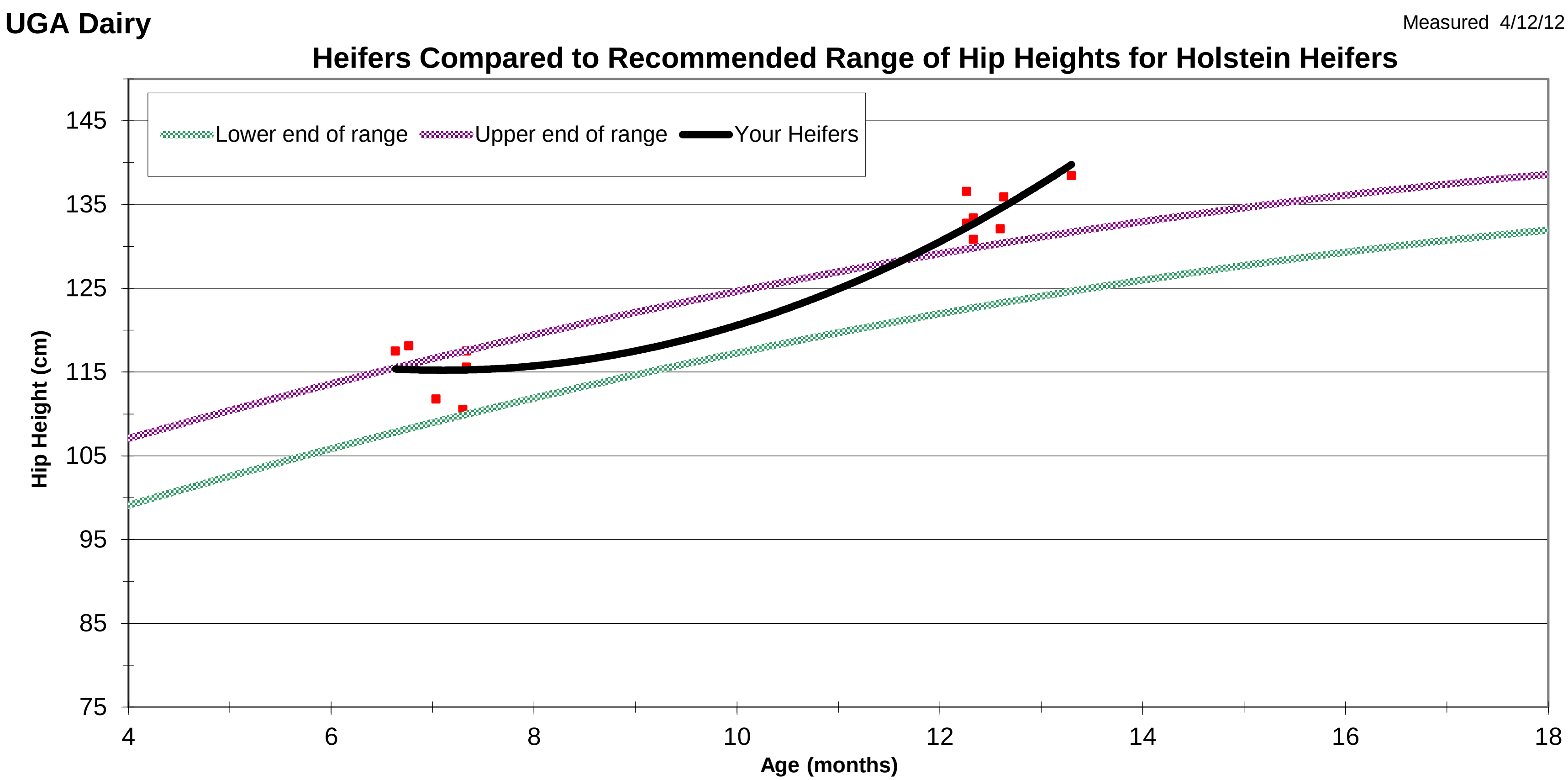
Appendix 29: Wither height for farm 3 heifers from year 1 compared to recommended wither height for Holstein heifers (Pennsylvania State University)



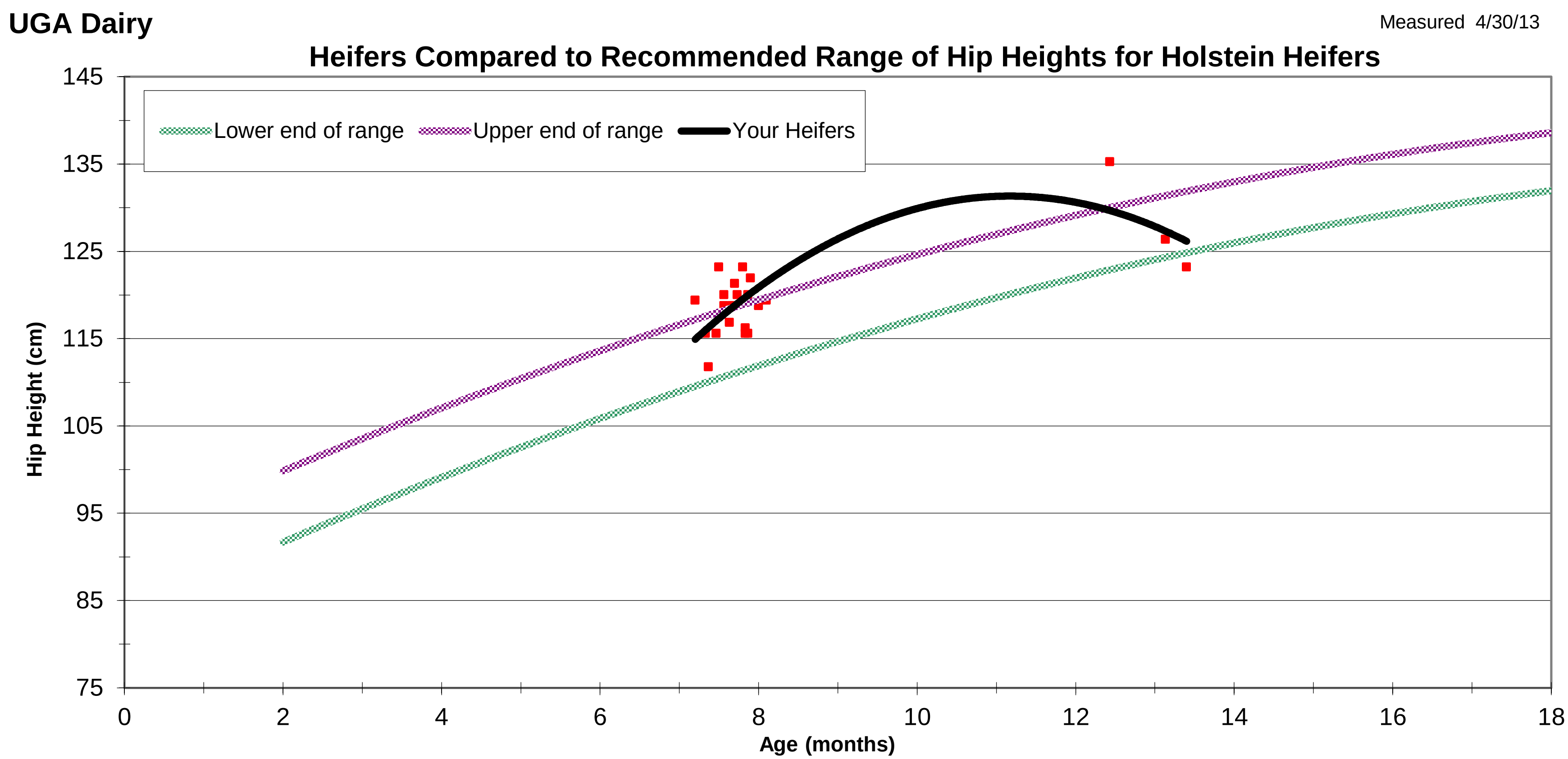
Appendix 30: Wither for farm 3 from year 2 compared to recommended wither heights for Holstein heifers (Pennsylvania State University)



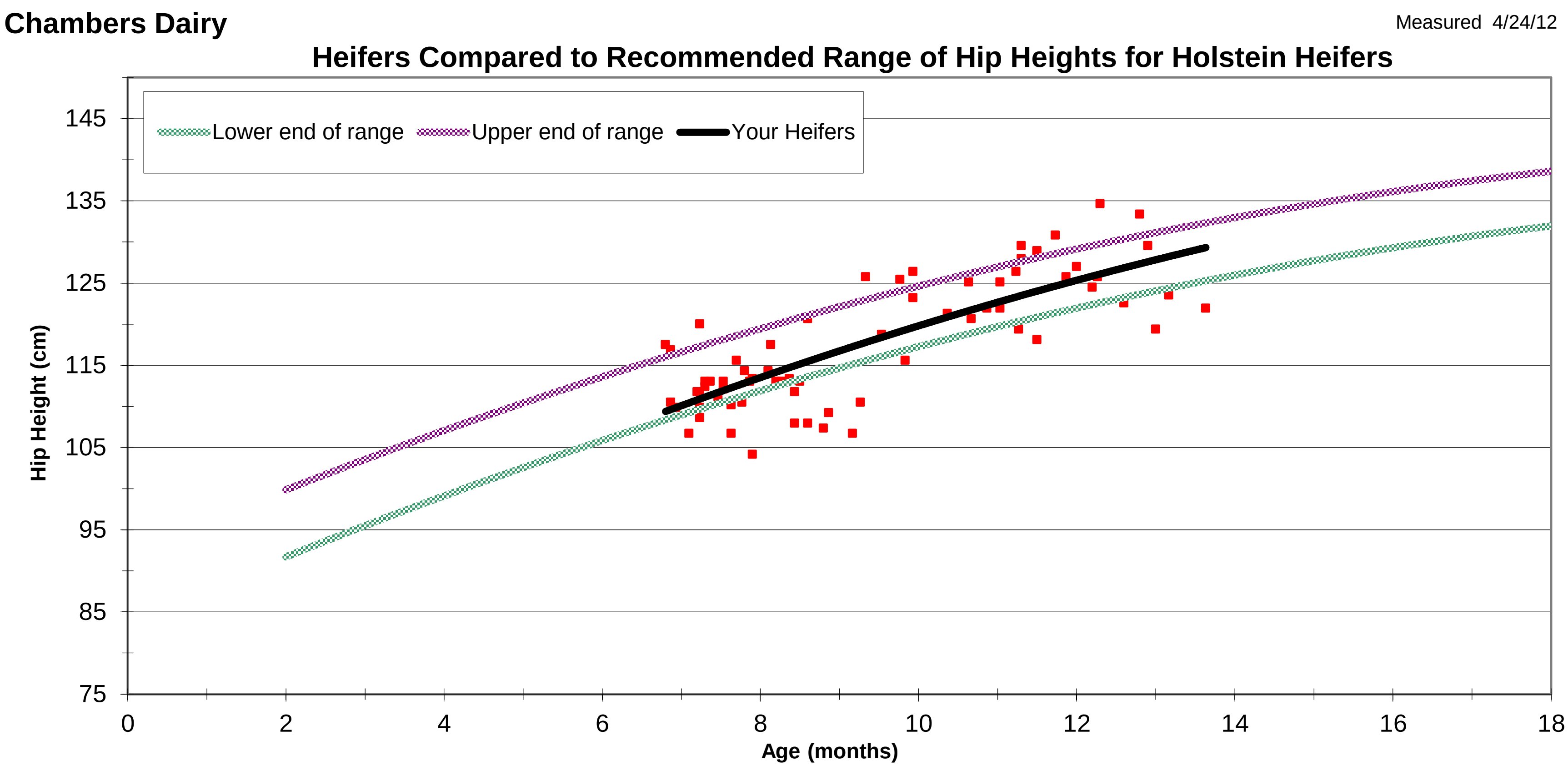
Appendix 31: Hip height for farm 1 from year 1 compared to recommended hip heights for Holstein heifers (Pennsylvania State University)



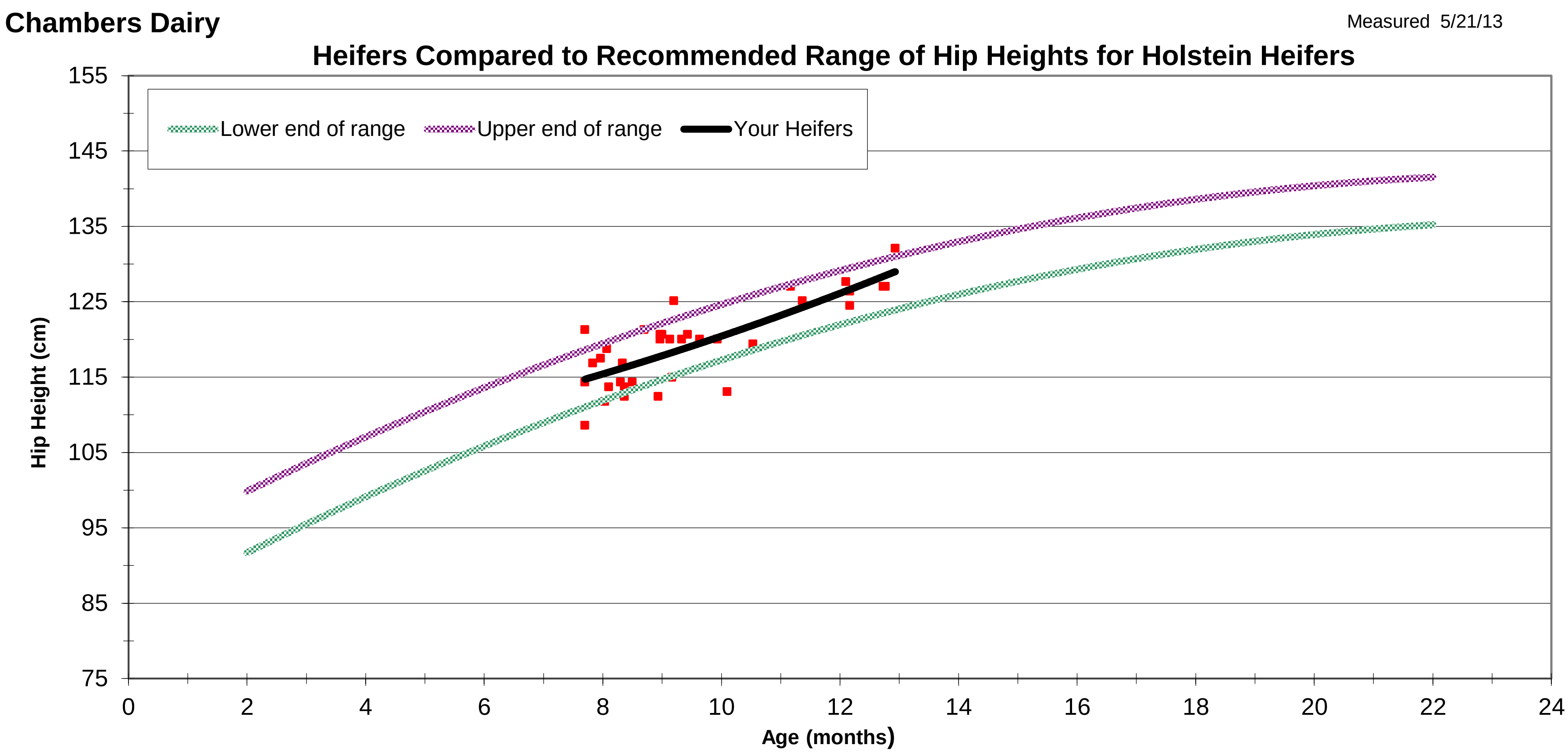
Appendix 32: Hip height for farm 1 from year 2 compared to recommended hip heights for Holstein heifers (Pennsylvania State University)



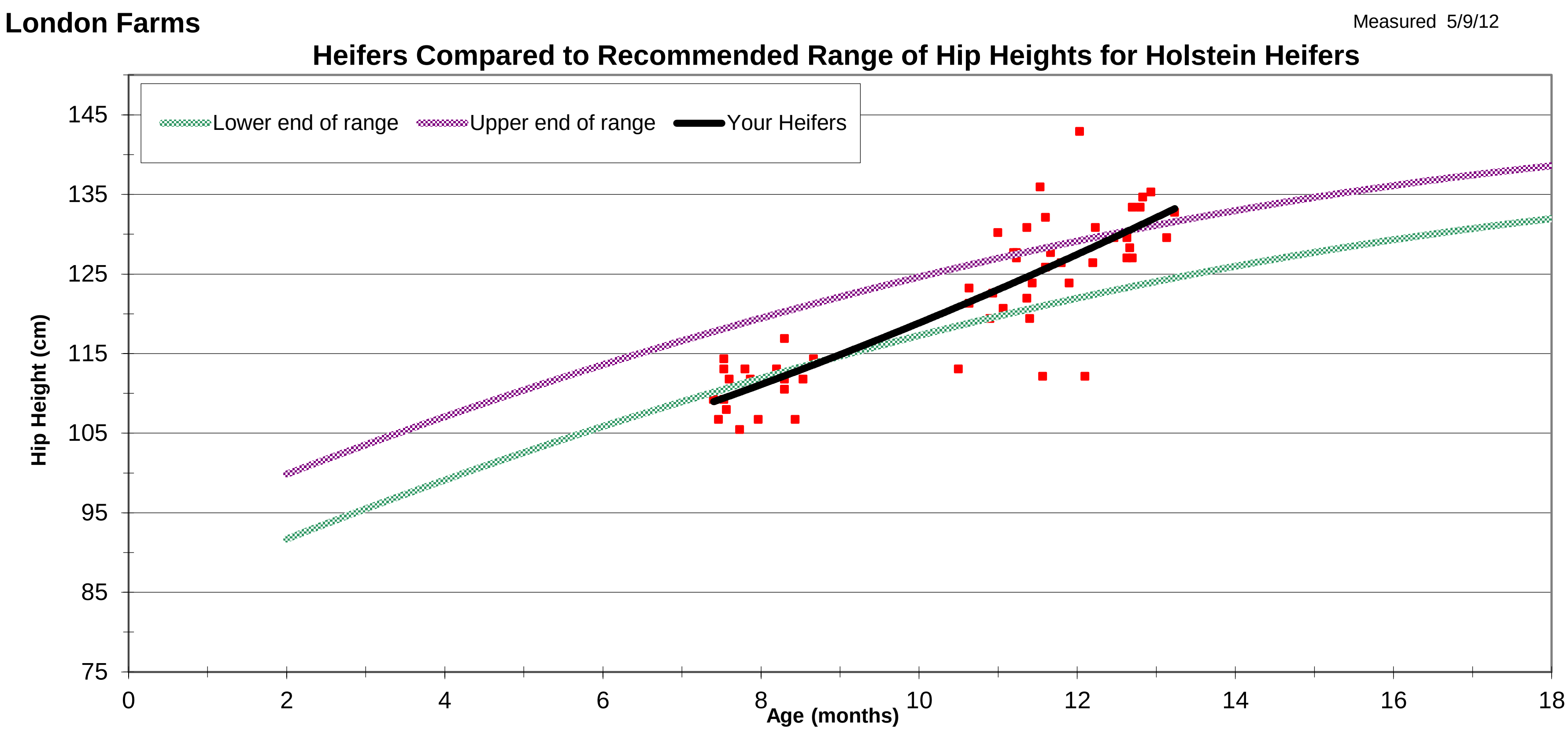
Appendix 33: Hip heights for farm 2 from year 1 compared to the recommended range of hip heights for Holstein heifers (Pennsylvania State University)



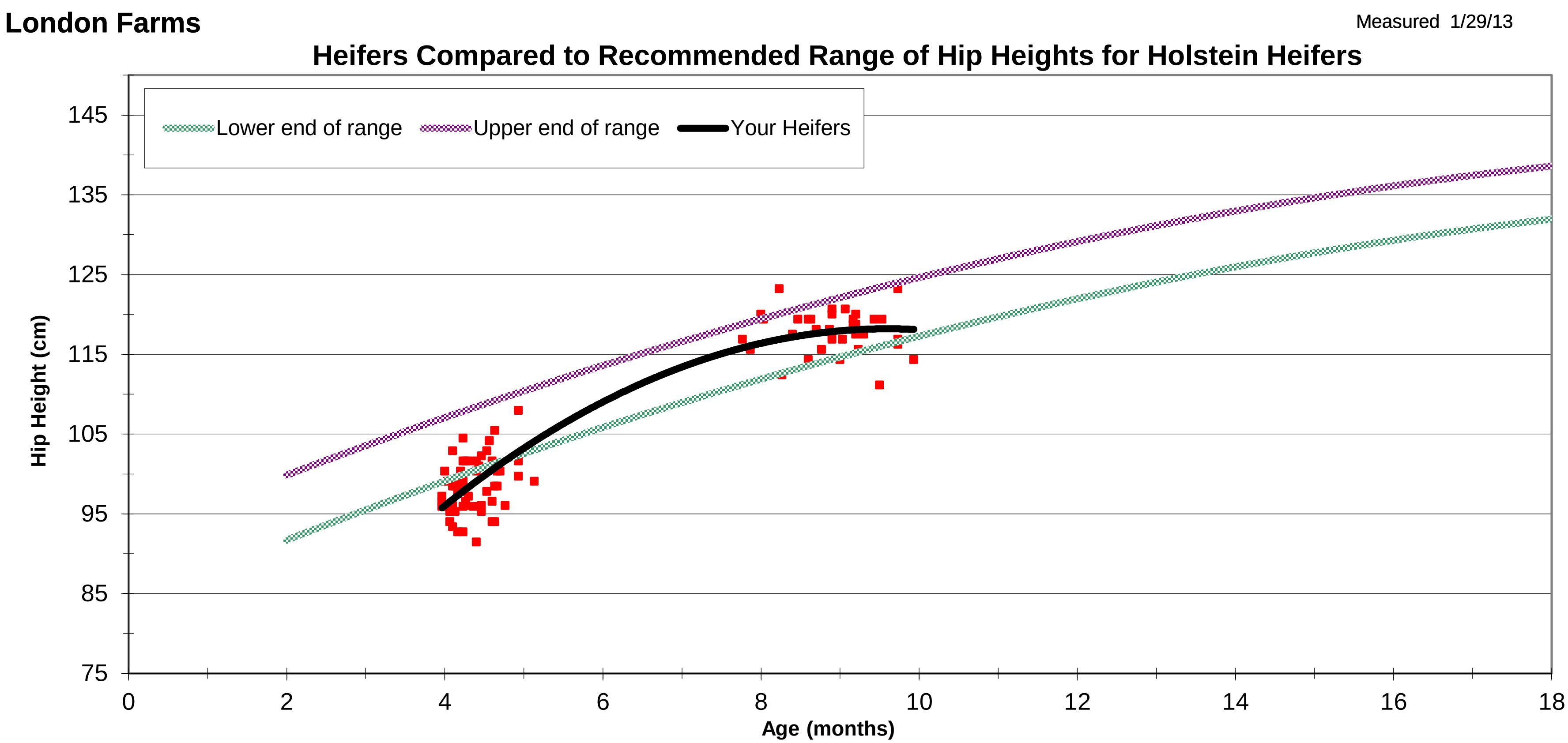
Appendix 34: Hip height for farm 2 from year 2 compared to the recommended range of hip heights for Holstein heifers (Pennsylvania State University)



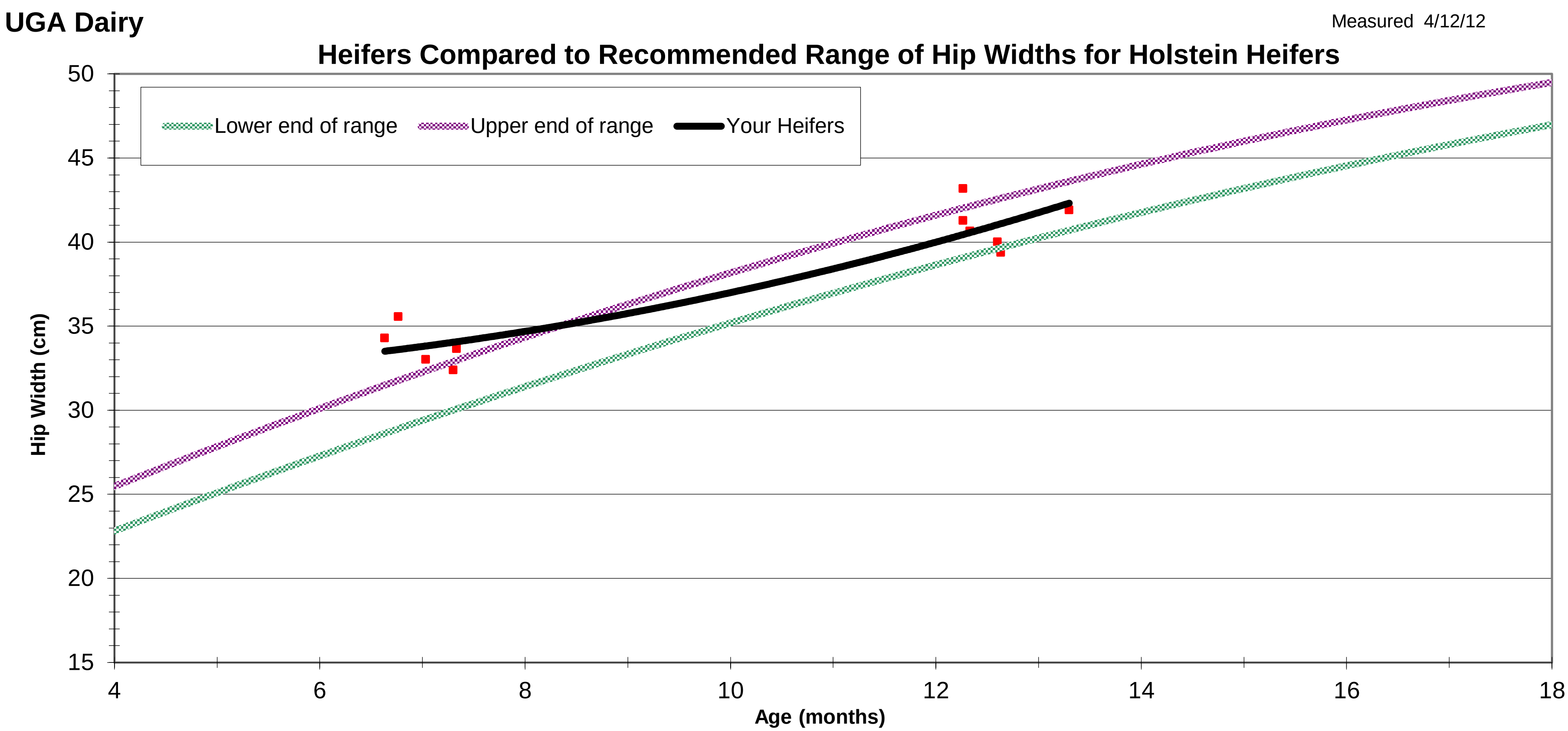
Appendix 35: Hip height for farm 3 from year 1 compared to the recommended range of hip heights for Holstein heifers (Pennsylvania State University)



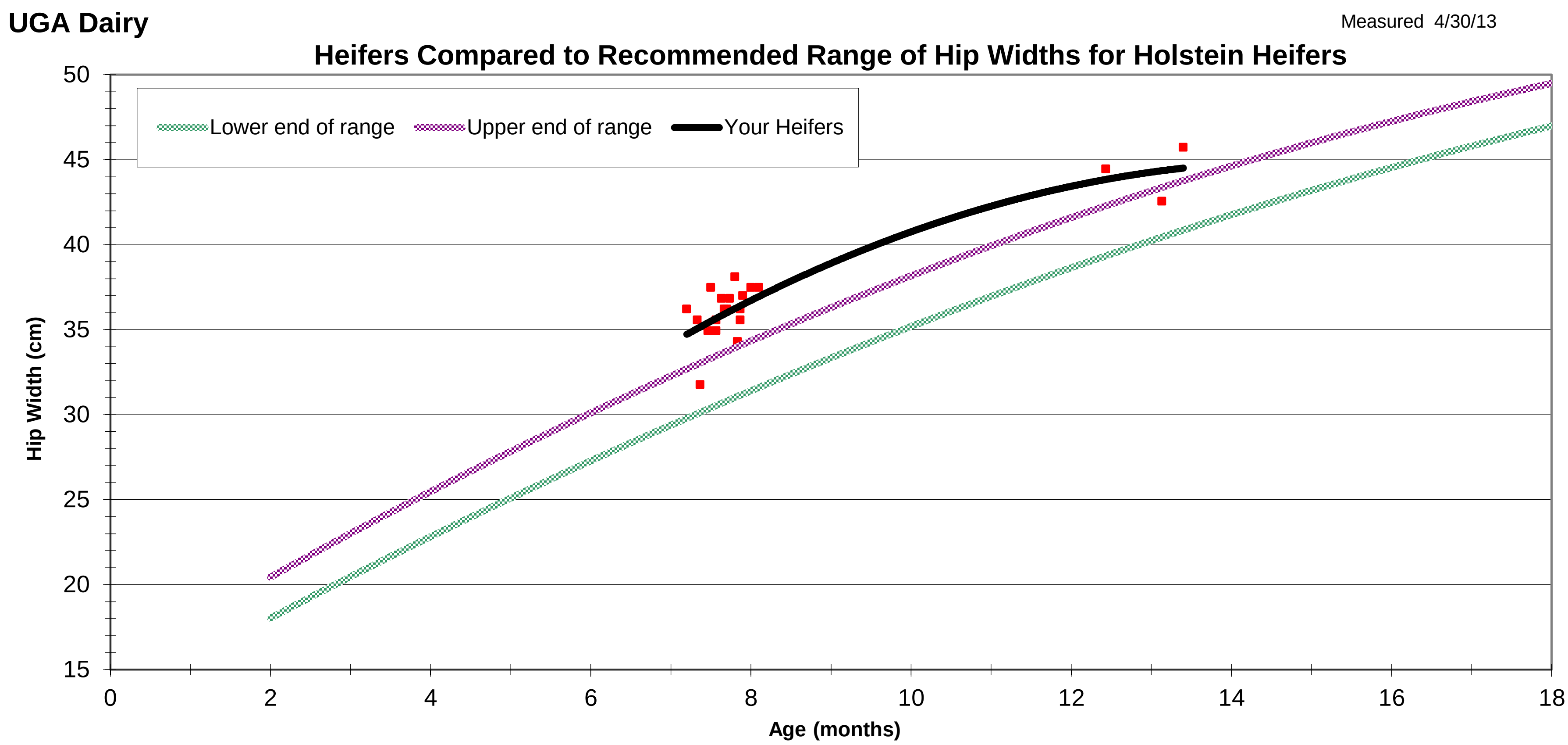
Appendix 36: Hip heights for farm 3 from year 2 compared to the recommended range of hip heights for Holstein heifers (Pennsylvania State University)



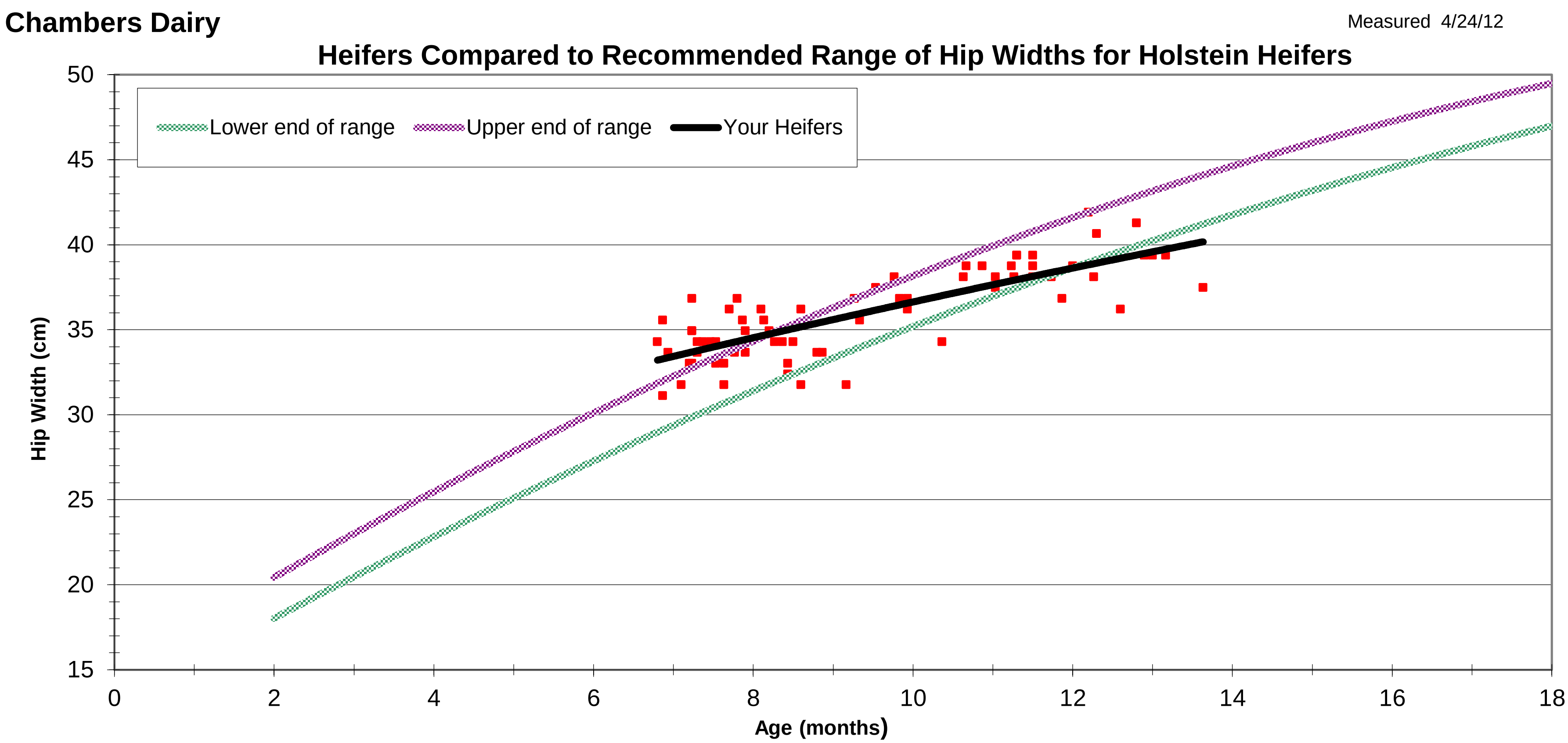
Appendix 37: Hip width for farm 1 from year 1 compared to the recommended range of hip widths for Holstein heifers (Pennsylvania State University)



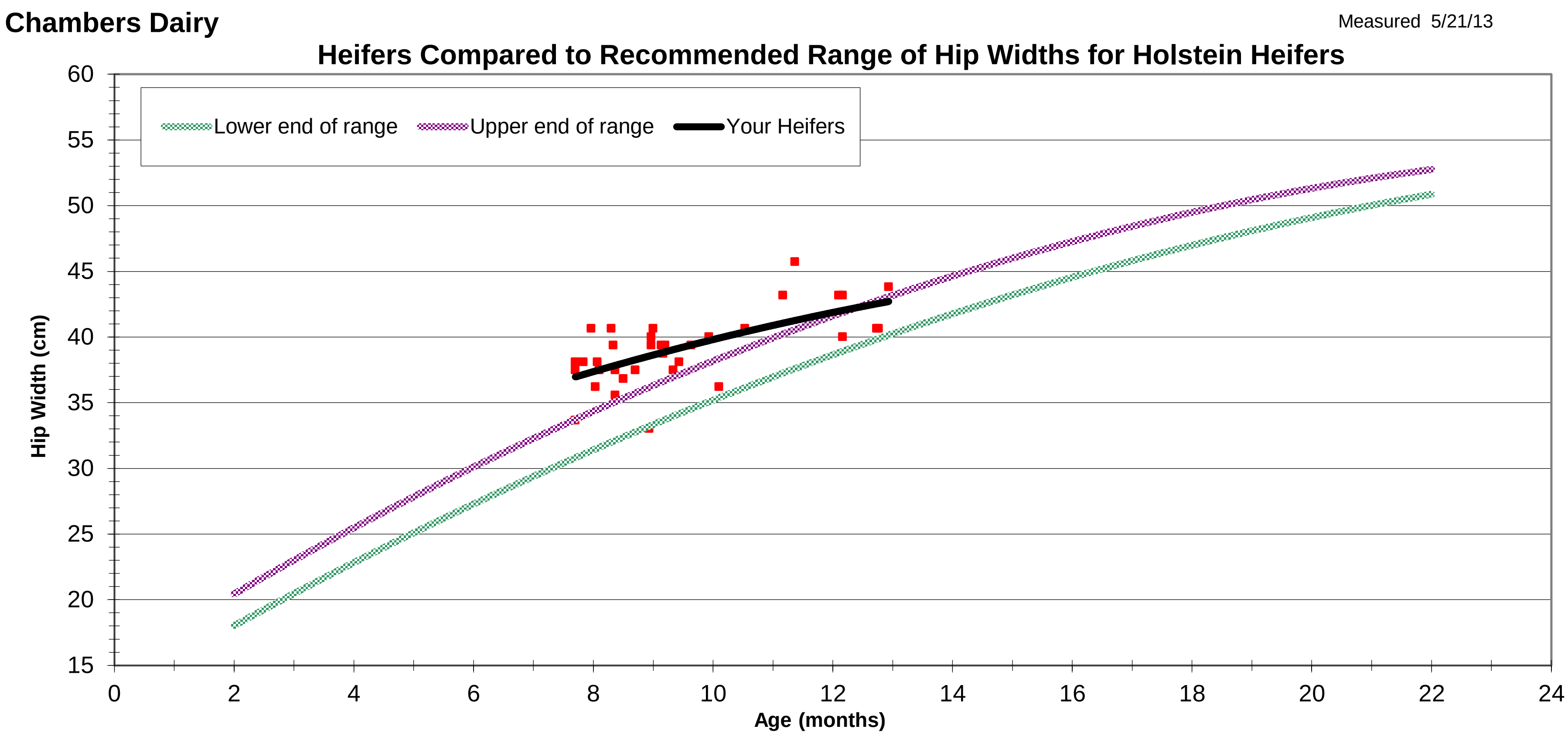
Appendix 38: Hip widths for farm 1 from year 2 compared to the recommended range of hip widths for Holstein heifers (Pennsylvania State University)



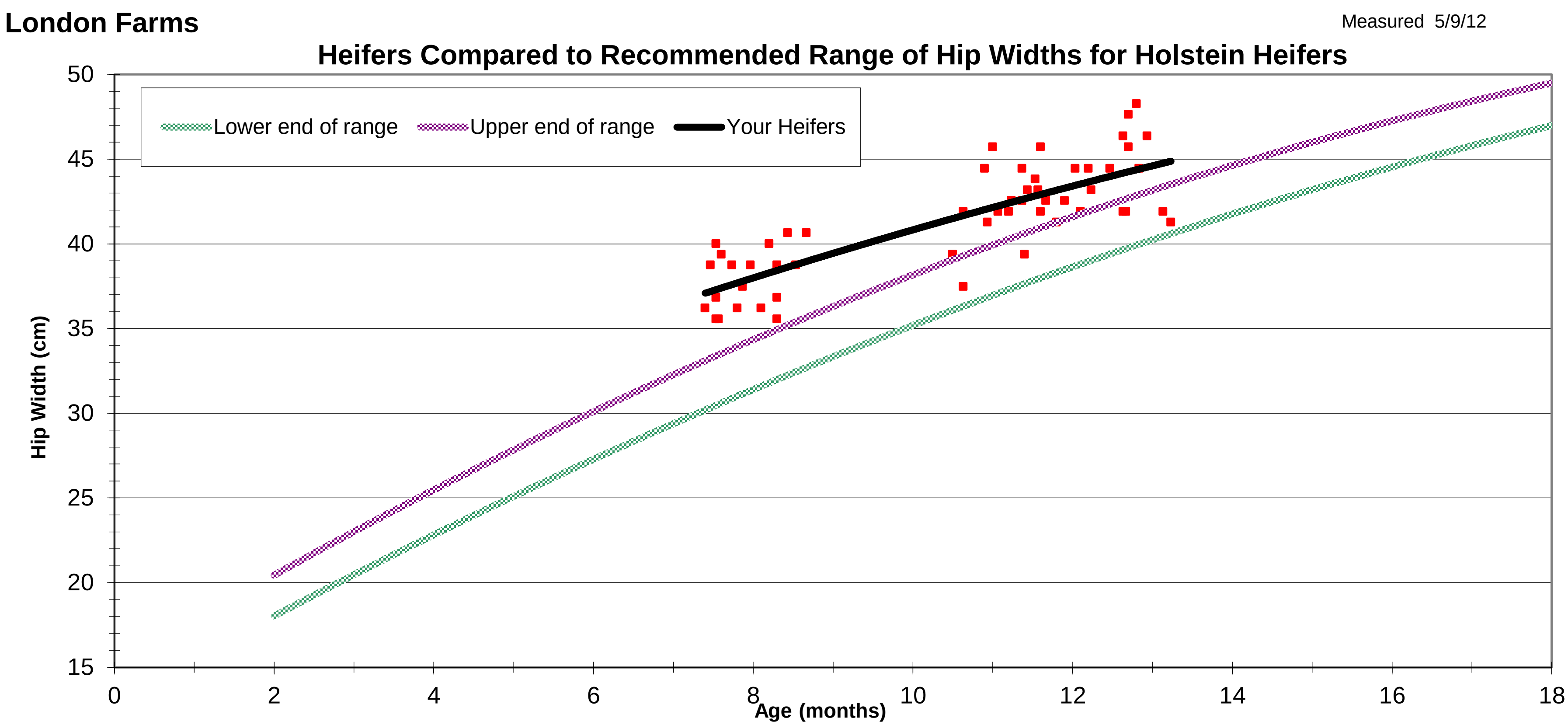
Appendix 39: Hip widths for farm 2 from year 1 compared to the recommended range of hip widths for Holstein heifers (Pennsylvania State University)



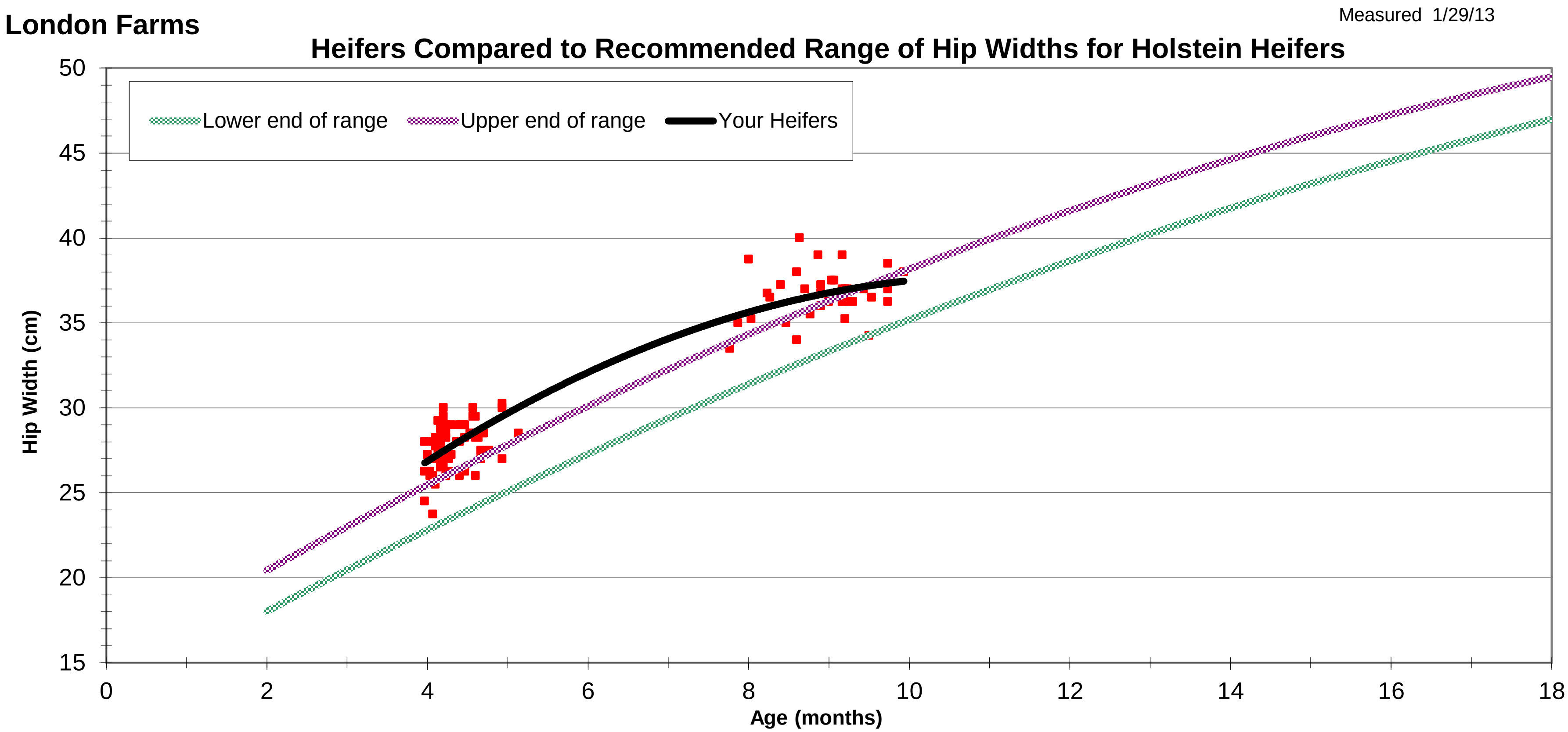
Appendix 40: Hip widths for farm 2 from year 1 compared to the recommended range of hip widths for Holstein heifers (Pennsylvania State University)



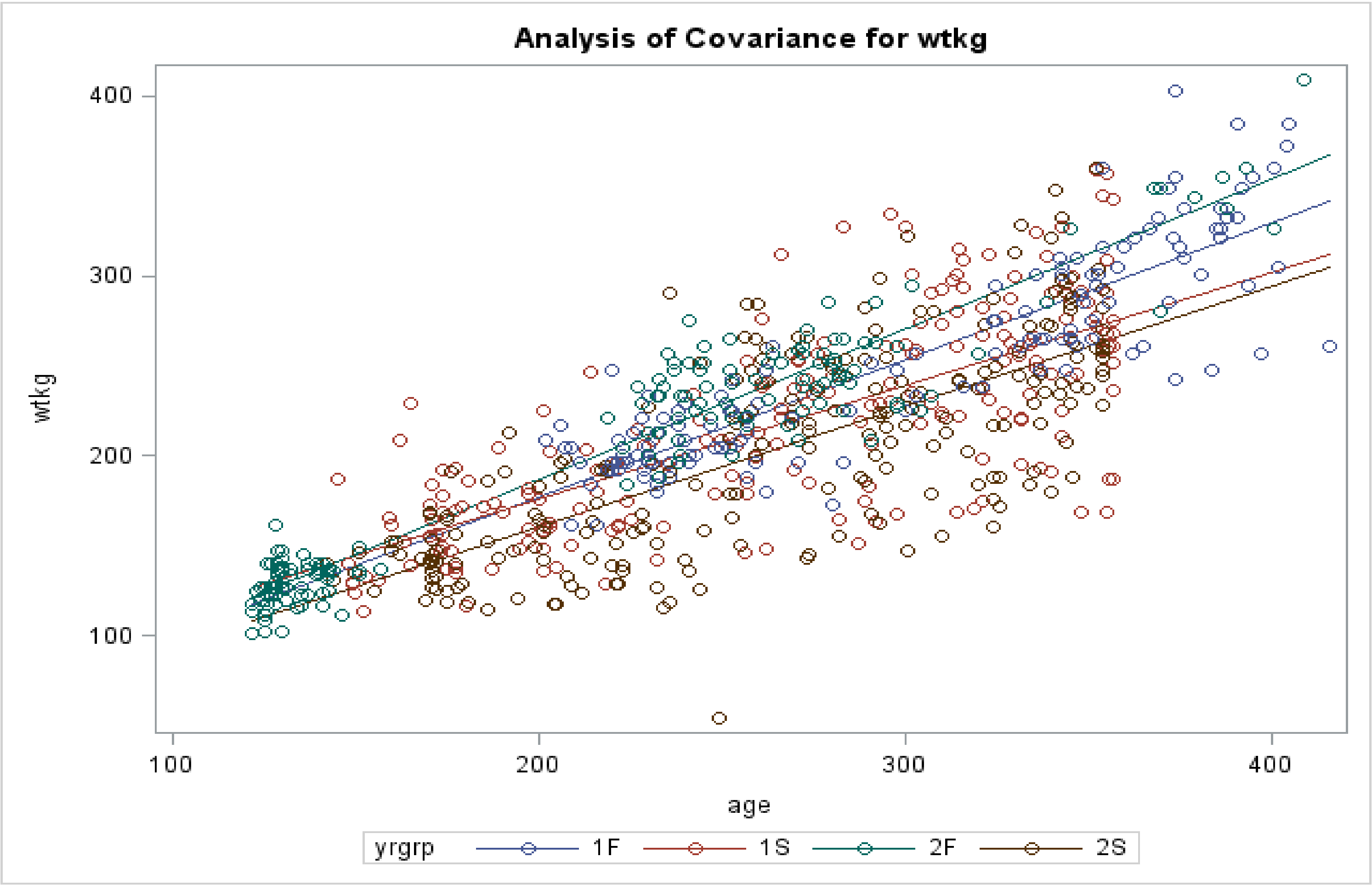
Appendix 41: Hip widths for farm 3 from year 1 compared to the recommended range of hip widths for Holstein heifers (Pennsylvania State University)



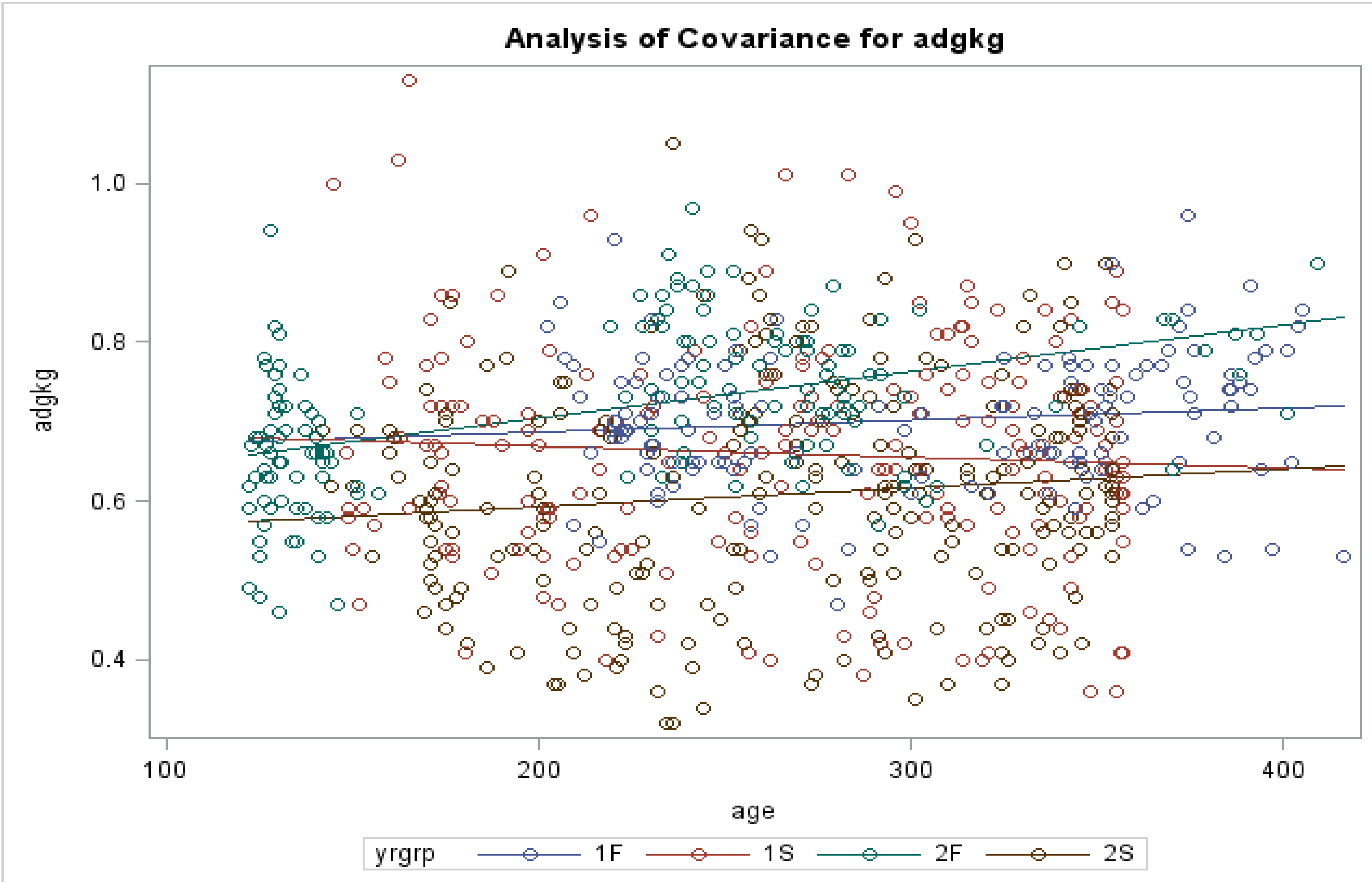
Appendix 42: Hip widths for farm 3 from year 2 compared to the recommended range of hip widths for Holstein heifers (Pennsylvania State University)



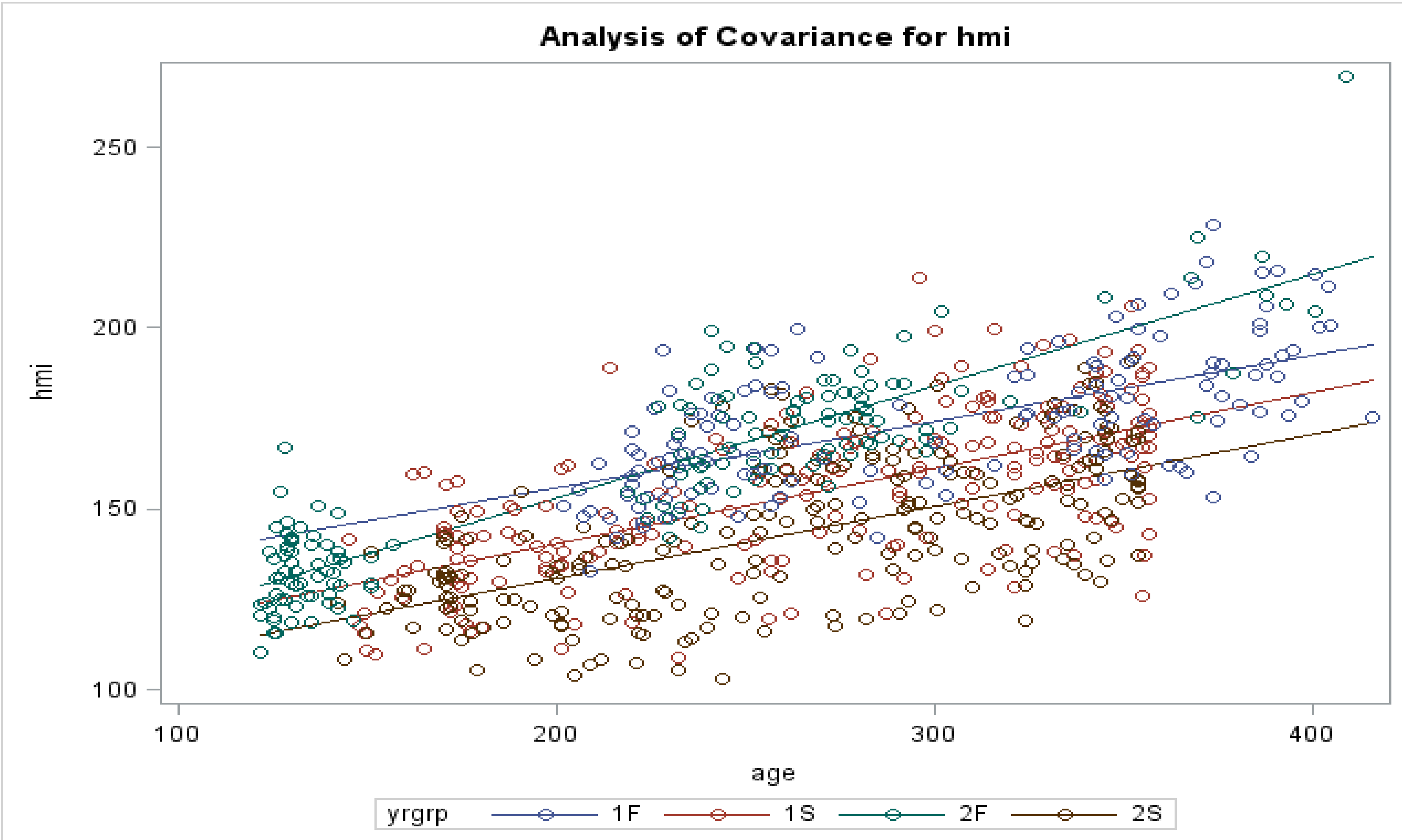
Appendix 43: Analysis of Covariance for weight (kg) comparing groups 1F(Farm year 1), 1S (Show year 1), 2F (Farm year 2) and 2S (Show year 2) (SAS Institute, 2008)



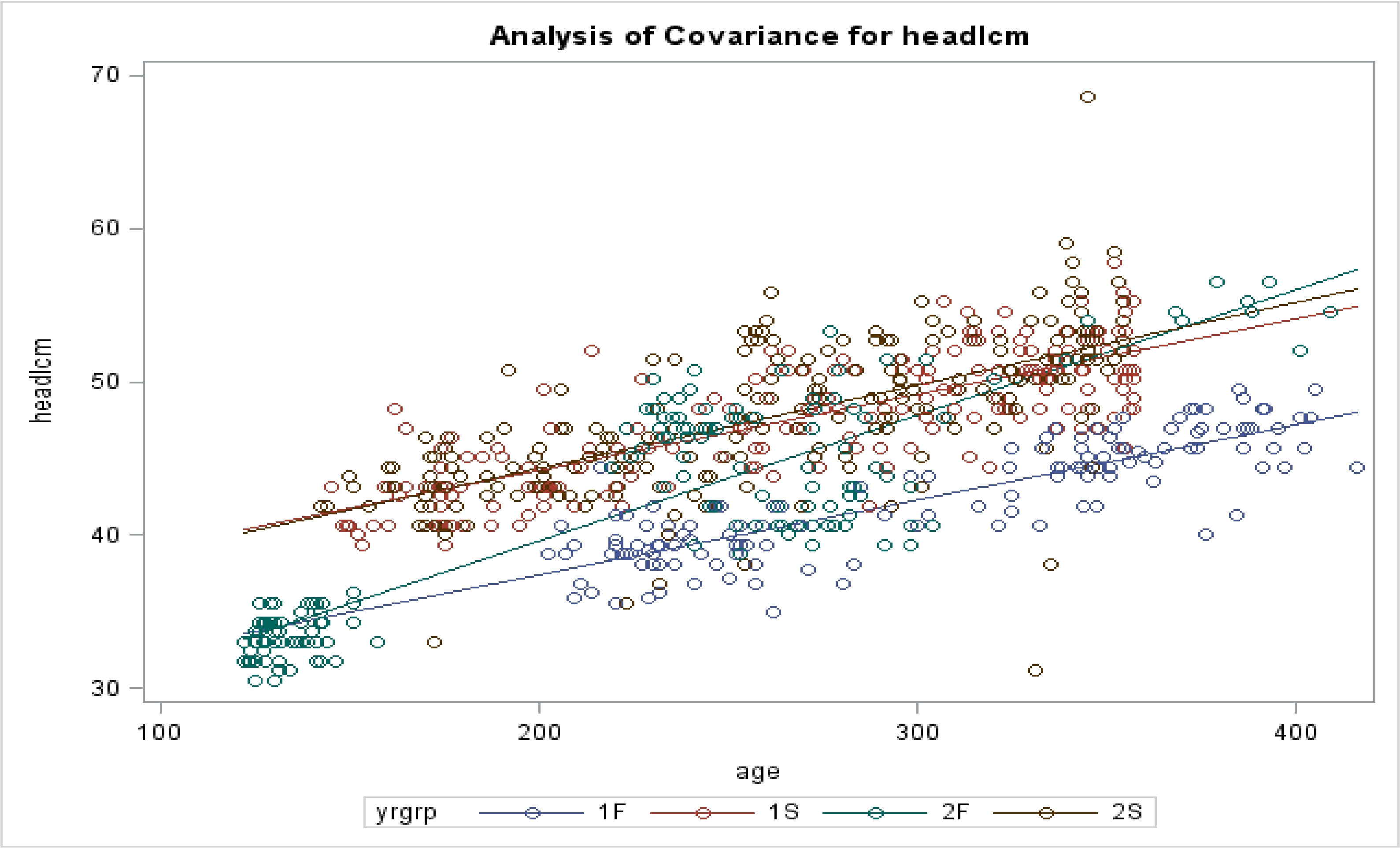
Appendix 44: Analysis of covariance for ADG comparing groups Farm year 1, Show year 1, Farm year 2 and Show year 2 (SAS Institute, 2008)



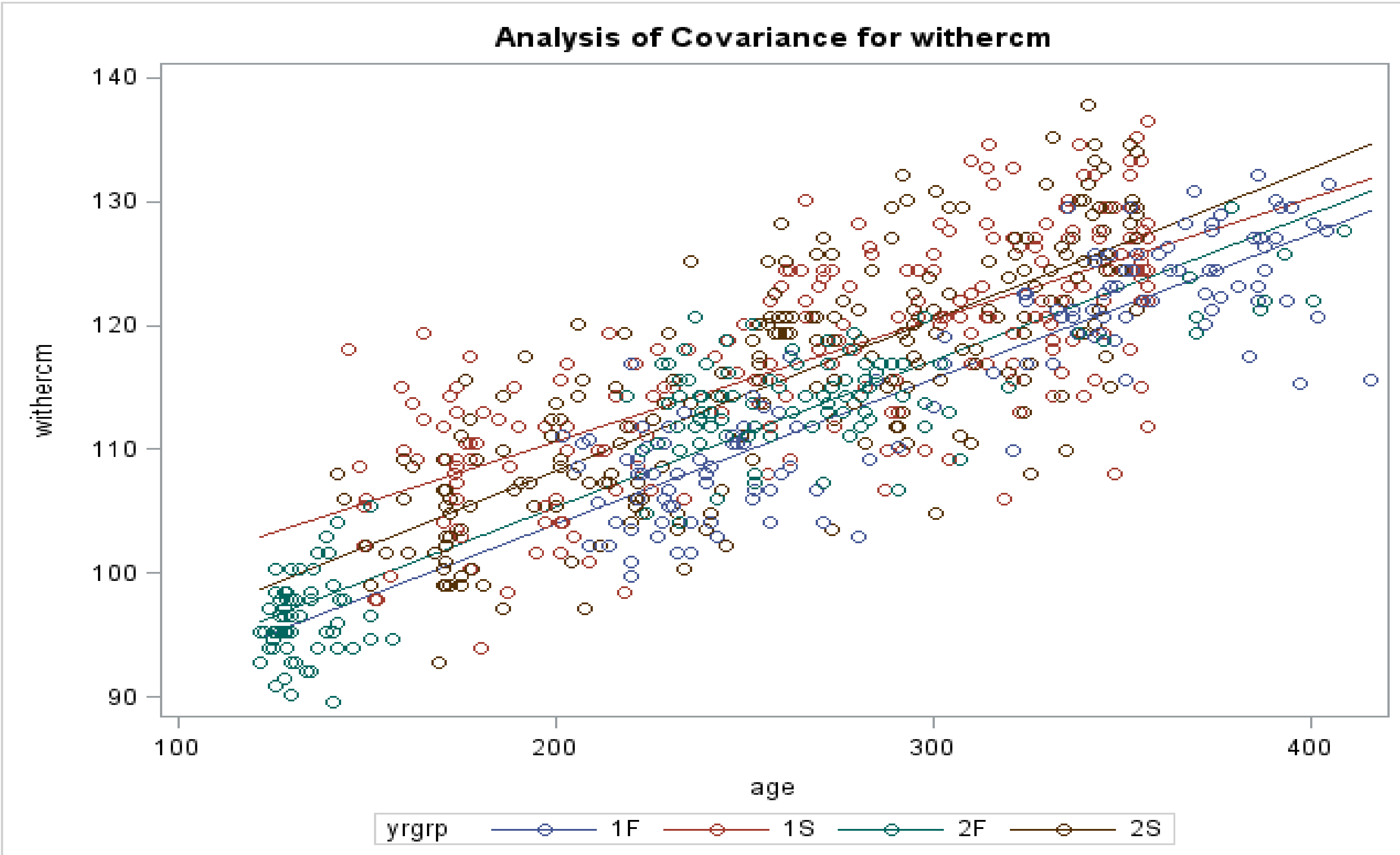
Appendix 45: Analysis of covariance for HMI comparing groups Farm year 1, Show year 1, Farm year 2 and Show year 2 (SAS Institute, 2008)



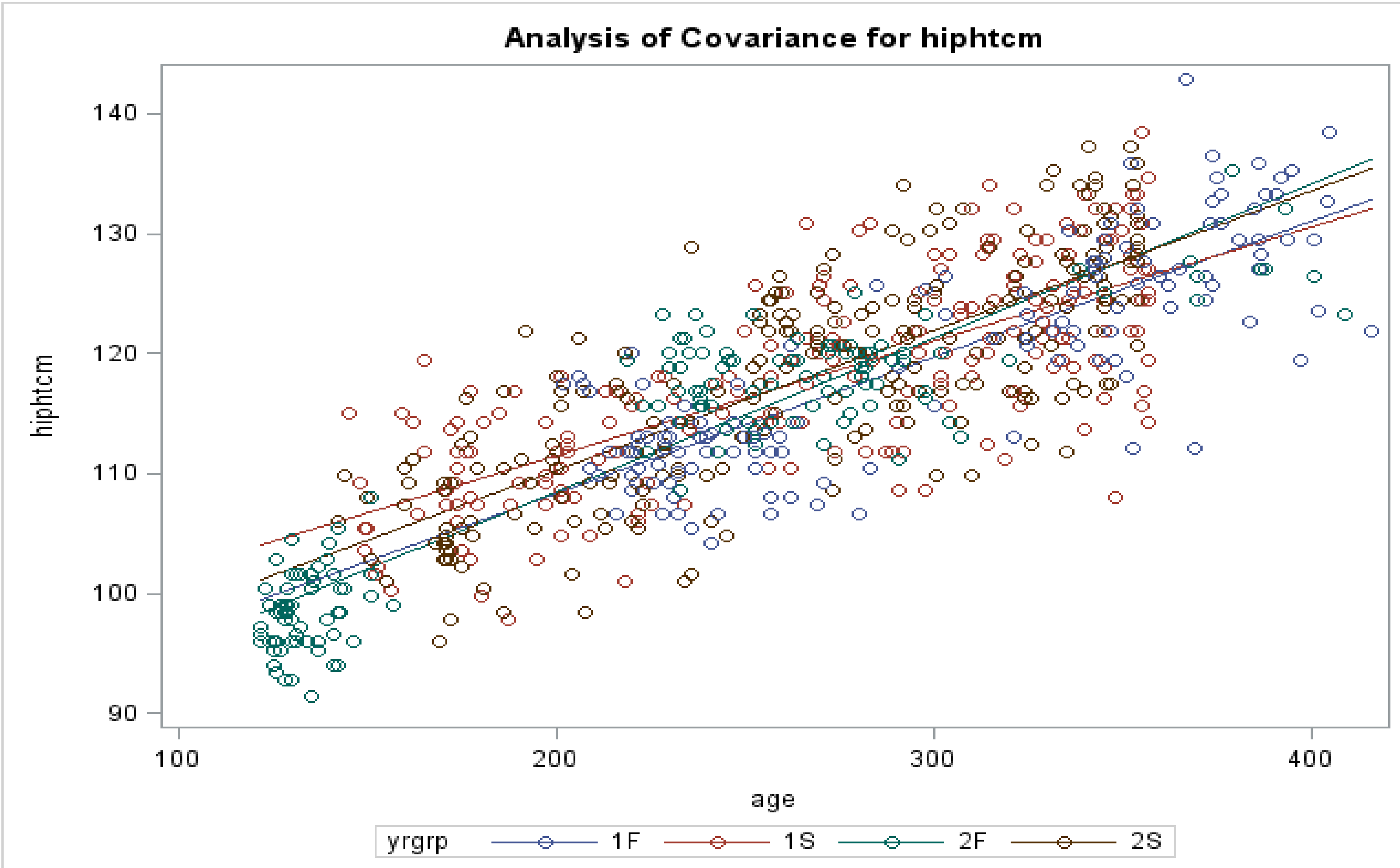
Appendix 46: Analysis of Covariance for head length comparing groups Farm year 1, Show year 1, Farm year 2 and Show year 2 (SAS Institute, 2008)



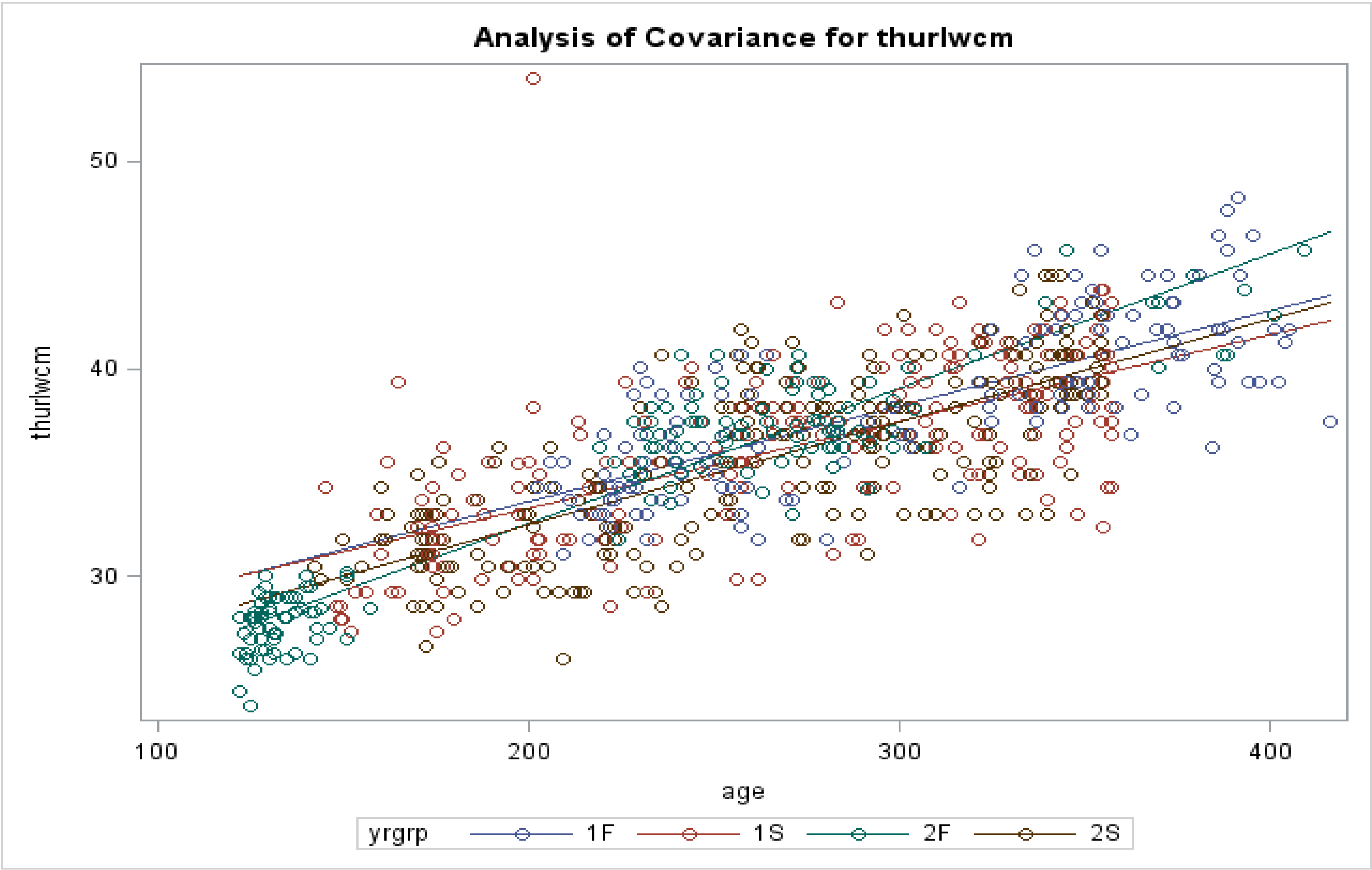
Appendix 47: Analysis of Covariance for wither height comparing Farm year 1, Show year 1, Farm year 2, Show year 2 (SAS Institute, 2008)



Appendix 48: Analysis of Covariance for hip height comparing Farm year 1, Show year 1, Farm year 2 and Show year 2 (SAS Institute, 2008)



Appendix 49: Analysis of Covariance for thurl width (hip width) comparing Farm year 1, Show year 1, Farm year 2, and Show year 2 (SAS Institute, 2008)



Appendix 50: Analysis of Covariance for tail length comparing Farm year 1, Show year 1, Farm year 2 and Show year 2 (SAS Institute, 2008)