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Review

Importance of hybrid vigor or heterosis for animal breeding

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ABSTRACT

The aim of this review is to compile the importance of heterosis for animal breeding. It should be thought that the heterosis observed in animal breeding is the increase in vigor that is seen in progenies of mattings of diverse individuals from different species, isolated populations, or selected strains within species or populations. Heterosis has been of immense economic value in agriculture and has important implications regarding the fitness and fecundity of individuals in natural populations. The amount of heterosis that is realized for a particular trait is inversely related to the heritability of the trait. This is logical since traits that are lowly heritable have a small additive component (proportionally speaking) and crossbreeding takes advantage of dominance and epistatic effects. There are three main types of heterosis including individual heterosis which are increased weaning weight, yearling weight and carcass traits. The second one is maternal heterosis which is the advantage of the crossbred mother over the average of purebred mothers. Maternal heterosis comprises younger age at puberty, increased calving rate and survival of calf to weaning, pounds of calf produced in lifetime, higher weaning weights, greater longevity in the dam and other reproductive traits. The third one is paternal heterosis which is the advantage of a crossbred sire over the average of purebred sires. Similarly, there are three theories of heterosis: Dominant, Over Dominance and Epistasis theories. Dominance theories are the dominance hypothesis attributes the superiority of hybrids to the suppression of undesirable recessive alleles from one parent by dominant alleles from the other. On the other hand, Over Dominance is the interaction between genes and it results in the heterozygous individuals being superior to the best homozygous parent. Epistasis is the effect of genes resulting from the new combination of genes from different loci.

Keywords: Cross-breeding, heterosis, dominance, epistatic, hybrid vigor, importance.

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INTRODUCTION

Selection and breeding are two major tools in breeder's hand to move their herd or flock towards desired direction. For an animal breeder, selection means choosing superior animals for generate the next generations that accumulates more and more of desired genes and genotypes in his cattle (herd) (Vandana et al., 2018). The crossing of unrelated individuals often results in offspring with increased vigor. This is called heterosis or hybrid vigor that is one of the objectives of cross breeding strategy (Mingroni, 2007).

Shull (1914) coined the term heterosis to refer in an increase in the vigor or other agriculturally related traits (which are usually components of fitness such as yield). While the basic concept of heterosis is straight-forward, it can be defined a number of different ways, depending on what reference population is used (Lamkey and Edwards, 1999). Heterosis or hybrid vigor refers to the superiority in performance of the crossbred animal compared to the average of the straightbred parents (Scott, 2009). In Genetic explanation, heterosis is the additive gene action affects the character the mean of F_1 progeny is exactly same as the mean of the parents if environment deviations are not taken into account; hence, this type of gene action is not responsible for heterosis. The mean of the F_1 progeny differ from the mean of the parents, if non-additive gene action is important. In this case, the mean of the F_1 may even be higher than the better parents and lower than the inferior parents. When F_1 exceed the better parent, it is called useful heterosis, and it is due to the different effects of genes (Vandana et al., 2018).

There are two general modes in which heterosis are expressed. The first is an increase in size or number of parts. It is the result of greater cell activity or greater number of cells. The second way is by an increase in biological efficiency such as reproductive rate or survix-a1ability. In addition to this, there may be a reduction of growth and/or survival rate. That is, hybrid weakness, reversed, or negative heterosis. This is not common; however, it does occur (Jones and Donald, 1952). Stern (1948) has found one example of negative heterosis in Drosophilla, hemizygotes and homozygotes for a series of position alleles R+ and +3 possess normal venation. Therefore, the objective of this review is to assess the importance of hybrid vigor or heterosis for animal breeding.

HETEROSIS: CONCEPTS

Heterosis is nothing more than an unexpected and often beneficial deviation from the average of the two parental lines. Hybrid vigor can also be thought of as the 'anti-inbreeding'. Inbreeding increases uniformity by increasing homozygosity but also creates 'inbreeding depression' or a general decrease in survival and reproductive traits that can be caused by a decrease in heterozygosity. Percent heterosis can be calculated as (Matthew and Spangler, 2017):

% Heterosis = [(crossbred average - straightbred average) / straightbred average] × 100%

A simple example would be the percent heterosis realized in the average weaning weight from breeding a herd of Breed a cow to a group of Breed B bulls. Let 525 pounds be the average weaning weight of the F_1 calves, 450 be the average weaning weight of the Breed a population, and 550 be the average weaning weight of the sire s population. The pounds of heterosis would be:

Pounds of heterosis = 525 - [(450 + 550) / 2] = 25 pounds

And the percent of heterosis would be:

% heterosis = 25 / [(450 + 550) / 2] = 0.05 or 5%

The amount of heterosis that is realized for a particular trait is inversely related to the heritability of the trait. This is logical since traits that are lowly heritable have a small additive component (proportionally speaking) and crossbreeding takes advantage of dominance and epistatic effects. With that in mind, traits of low heritability (reproductive traits) generally benefit from heterosis the most (Matthew and Spangler, 2017). They generally have a heritability of less than 10% and can be improved through the adequate use of crossbreeding systems. End-product traits on the other hand that benefit from heritability in the moderate to high range benefit less from heterosis (Matthew and Spangler, 2017).

Type of heterosis

There are three main types of heterosis:

1. Individual heterosis: The improvement in performance by the individual crossbred animal above average of its parents. Examples of individual heterosis are increased weaning weight, yearling weight and carcass traits (Bennet, 2017).

2. Maternal heterosis: Maternal heterosis is the advantage of the crossbred mother over the average of purebred mothers. Examples of maternal heterosis are younger age at puberty, increased calving rate, increased survival of her calf to weaning, pounds of calf produced in her lifetime higher weaning weights, greater longevity in the dam and other reproductive traits. The offspring of a F1 female will benefit from maternal heterosis. Most commonly thought of as realized heterosis of milk production (Matthew and Spangler, 2017).

3. Paternal heterosis: Paternal heterosis is the advantage of a crossbred sire over the average of purebred sires (Bennet, 2017). It is the improvement in productive and reproductive characteristics of the bull. Examples of paternal heterosis are reduced age at puberty, improvements in scrotal circumference, improved sperm concentration, increased pregnancy rate and weaning rate when mated to cows (Matthew and Spangler, 2017).

Genetic explanation of heterosis

Heterosis occurs in different reasons also there are three theories of heterosis: Dominant theory, over dominance theory and epistasis theory.

Dominance

The dominance hypothesis attributes the superiority of hybrids to the suppression of undesirable recessive alleles from one parent by dominant alleles from the other. Heterosis is directly proportional to the number of dominant genes contributed by each parent. Thus the performance of the hybrid offspring will exceed to that of the parents and sometimes exceed to that of the better parent It attributes the poor performance of inbred strains to loss of genetic diversity, with the strains becoming purely homozygous at many loci. The dominance hypothesis was first expressed in 1908 by the geneticist Charles davenport under the dominance hypothesis; deleterious alleles are expected to be maintained in a random-mating population at a selection mutation balance that would depend on the rate of mutation, the effect of the alleles and the degree to which alleles are expressed in heterozygotes (Carr and Dudash, 2003).

Over dominance

The over dominance is the interactions between genes and it results in the heterozygous individuals being superior to the best homozygous parent. Superiority of heterozygote may arise due to production of superior hybrid substance in heterozygote and cumulative action of divergent alleles (Shull, 1980). The over dominance hypothesis was developed independently by East (1908) and Shull (1980). Genetic variation at an over dominant locus is expected to be maintained by balancing selection. The high fitness of heterozygous genotypes favors the persistence of an allelic polymorphism in the population (Carr and Dudash, 2003). More divergent alleles will exhibit more heterosis than less divergent ones. The cross breeding result in superior animals if over dominance is important for the reason that the animal produced by crossbreeding has maximum number of heterozygous loci (Li et al., 2008).

Epistasis

The epistasis is the effect of genes resulting from the new combination of genes from different loci. The different genes coming together in the hybrid interact with each other and produce greater effect than when they are in different parents (Vandana et al., 2018).

Advantages of heterosis

The reason for crossbreeding is to increase the dairy cattle production through new combinations of genes in different breeds (Simm, 2000). Heterosis is a result of the non-additive gene effect, dominance and epitasis along with differences in the frequencies of the different alleles at each locus (Rajesh et al., 2015). Heterosis arises from favorable gene combinations. Gene combinations are not equally important to all traits in dairy cattle or other species. Furthermore, more genetically divergent breeds are more likely to generate more heterosis than breeds with more similar genetic backgrounds (Bennet, 2017). Rebecka (2015) described offspring from parents with greater genetic diversity are more profitable from heterosis effect than offspring of parents with less diversity.

Hybrid vigor results in high performance in cross breed animals. A cross breeding between Danish Red (DR), Danish Holstein (DH) and Danish Jersey (DJ) breeds shows a significant heterosis in all traits of different sire and dam breed combination (Clasen et al., 2017). This indicates crossbreeding can be a beneficial tool for increasing the heterosis effect and improving production and reproduction traits. Also Another study indicated that the cross breeding between Swedish Holstein (SH) and Swedish Red (SRB) indicates that the F_1 crosses produced significantly more fat during first and second lactation than pure breeds. Also, the F_1 crossbreds were superior in survival as compared with both purebred SH and purebred SRB also Calving difficulties were significantly lower in first and second lactation for all other breed groups when comparing estimates with purebred SH. So the Relative Heterosis Effect (RHE) for production traits ranged between 1.3 to 4.5%, and was favorable and significant for F_1 crosses in all lactations (Rebecka, 2015).

The benefits of heterosis occur to beef herd quality and consequently profitability (Anderson, 1990) and herd management programs (Brown, 2010). Heterosis achieved through continuous crossbreeding can be used to increase weight of calf weaned per cow exposed to breeding by 20% (Gregory and Cundiff, 1980). Heterosis can also increase longevity of cows by 1.3 year and can increase the total calf weight weaned per cow by 30 % over the life span of a dam (Cundiff et al., 1992). Heterosis has been utilized in beef production to enhance fertility, longevity, growth and meat quality traits in commercial herds through various cross-breeding systems. Application of crossing systems such as three or four breed crosses would be very difficult, so rotational crossbreeding systems are required to exploit breed and heterotic effects (Rajesh et al., 2015).

Direct heterosis is the benefit observed in a crossbred calf. On average, these advantages include a 4% increase in calf survival, a 5% increase in weaning weight and a 6% increase in post-weaning gain (Vandana et al., 2018). However, these effects are greatly influenced by breed. More hybrid vigor is better but maximum hybrid vigor is only obtainable in F_1 the first cross of unrelated populations. To sustain F1 vigor in herd, a commercial breeder must avoid backcrossing entirely, and that is not always an easy or practical thing to do. Most cross breeding systems do not achieve 100% of F_1 vigor, but maintain acceptable levels of hybrid vigor by limiting back crossing in a way that is manageable and economical

(Vandana et al., 2018).

CONCLUSIONS

Heterosis is valuable tool which can be used by animal producers. Also crossbreeding schemes are most profitable breeding strategies can assist improve growth, reproduction, production and maternal traits, health and overall fitness by taking advantage of heterosis, which results when animals from diverse backgrounds are crossed. However, heterosis alone will not guarantee success in a crossbreeding program. Much of the success from crossbreeding will result from selection on PTAs of sires for different traits. Traits of low heritability such as fertility, milk yield and longevity are difficult to enhance through pure breeding but are greatly enhanced through crossbreeding leading to improvements in survival, reproductive efficiency and growth rates. The genetic merit of purebreds and of the animals within those breeds for economically important traits need to be known and utilized to the producer's advantage. Heterosis arises from favorable gene combinations. Gene combinations are not equally important to all traits in dairy cattle or other species. Furthermore, more genetically divergent breeds are more likely to generate more heterosis than breeds with more similar genetic backgrounds. Traits subject to small amounts of inbreeding depression (perhaps somatic cell score is one such example) are expected to show less heterosis, as inbreeding depression results from the breakdown of favorable gene combinations.

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