1988

Breed and Heterosis Utilization in Rotational and Composite Crosses

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Introduction

Rotational crossbreeding systems breed heifers sired by one breed to bulls from another breed. Heifer offspring are then bred to the next breed in the rotation, etc. Composite systems result in a "new" breed consisting of fixed proportions of "old" breeds. Both systems produce their own replacement heifers rather than requiring the purchase of F₁ heifers or special matings. Both systems have potential advantages for producers of slaughter beef because a high level of heterosis (hybrid vigor) is present in cows and calves. High levels of heterosis increase efficiency and reduce the cost of producing beef.

The level of heterosis in rotational crossbreeding systems and composites increases as the number of breeds increases. All available breeds would be used if the level of heterosis was the only factor considered. However, not all breeds are equally efficient in a given beef production situation. A producer with a straightbred herd should use the most efficient breed. Likewise, the two breeds with highest efficiency would generally be used in a two-breed rotation or composite, the three best breeds in a three-breed rotation or composite, etc. Increasing the number of breeds has the advantage of increased heterosis, but at the cost of decreased average efficiency of the breeds in the rotations or composites.

Two problems may arise in adapting rotational crossbreeding systems to farm and ranch management. Bulls from all breeds in the rotation will need to be available each yr so that cows can be bred to the appropriate breed. Also, cows will need to be identified for their breed of sire so that the next breed they are bred to is known. These conditions are not too restrictive when artificial insemination is used. However, only one or two bulls may be needed by small herds using natural service sires. This makes it costly to maintain extra bulls and breeding pastures. In extensive production situations, identification and sorting of cows and having extra breeding pastures available can pose management problems, making it difficult to use rotational crossbreeding.

Results

Rotational and composite crossbreeding systems that use some breeds proportionately more than others were studied as a way of using higher percentages of genes from better breeds. Examples of the first ten generations of some of these types of rotations are shown in Table 1. The capital letters A, B, and C represent three arbitrary breeds. The shortest repeatable sequence, or cycle, of sire breeds is used to identify each of the rotations. For instance, AB and ABC identify conventional two- and three-breed rotations.

Illustrated in Figure 1 is the average level of heterosis for each of the rotations defined in Table 1 and the conventional two- and three-breed rotations. Also shown is the percentage of genes from each breed averaged over a cycle. It is easy to see that the avg percentage of genes from a breed can be varied from as little as 25 to as much as 75 in two-breed rotations, and from as little as 17 to as much as 60 in three-breed rotations. Of course, heterosis is greatest when each breed is used equally in conventional two- and three-breed (AB and ABC) rotations. Similarly, the amount of heterosis in a composite with the same breed percentages as the rotations is shown in Figure 1.

Increasing the percentage of genes from the best breed can sometimes be an advantage even though it results in less heterosis. Important reasons for deciding when to increase the use of a breed in a rotation or composite are (1) the differences between breeds in life-cycle efficiency of beef production, and (2) the effect of...

Table 1—Sire breed use by generation in rotations that use breeds unequally.

<table>
<thead>
<tr>
<th>Rotation designation</th>
<th>Generations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1  2  3  4  5  6  7  8  9  10  11  12</td>
</tr>
<tr>
<td>ABAC</td>
<td>A  B  A  C  *  A  B  A  C  *  A  B  A  C  *</td>
</tr>
<tr>
<td>ABACA</td>
<td>A  B  A  C  *  A  B  A  C  *  A  B  A  C  *  A  B</td>
</tr>
<tr>
<td>ABACAB</td>
<td>A  B  A  C  A  B  A  C  A  B  A  C  A  B</td>
</tr>
</tbody>
</table>

Figure 1—Average heterosis and breed percentages for several rotations and heterosis for a composite of the same breed percentages.

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heterosis on efficiency. The ratio of breed differences to heterosis effect for efficiency can be used to determine rules for selecting among the rotations. If this ratio is less than .6 for two breeds, then the best two-breed rotation is the conventional two-breed (AB) rotation. If this ratio falls between .6 and 1.2, then an ABA rotation (A being the better breed for efficiency) is best. An ABAA rotation is best if the ratio falls between 1.2 and 1.8. Straightbred A would be better than any of the two-breed rotations when the ratio exceeds 1.8. Similarly, only one set of breed percentages maximizes the efficiency of composites for any given set of breed differences. Figure 2 shows the relative differences among some two- and three-breed rotations and optimal composites for three sets of differences among the three breeds. When these differences are small, the best rotation uses the three breeds equally (ABC), and there are similar percentages of each breed in the optimal composite. As breed differences increase relative to heterosis, ABAC and ABACAB rotations and composites that reduce the percentages of the less efficient breeds (B and C) are more efficient than conventional rotations and composites.

Figure 2—Differences among two- and three-breed rotations and optimal composites relative to breeds A, B, and C. Heterosis is assumed equal to 20 and breed A is assumed equal to 100.

The previous results assume that cows were correctly identified for the breed of their sire and that cows were always mated to the next breed in the rotation. Small herd size and other management constraints often make this impossible for rotations, but not for composites. It does seem likely that the bull breed could be rotated regularly, ignoring the breed of the cows, in almost all management situations. In small herds, a convenient management scheme is to replace bulls after 2 yr of use. This prevents the occurrence of close inbreeding. Only rotating the breed of sire does not change the percentage of genes from each breed compared to a full rotation. However, heterosis will not be as high as a full rotation of sire and dam breeds. Figure 3 shows the amount of heterosis expected from a full rotation of bull and cow breeds compared with a rotation of sire breeds, and with composites of the same breed percentages. It is assumed that a bull in the sire-breed rotation is used for 2 yr and then replaced with a bull from the next breed in the rotation. Sire-breed rotations reduced heterosis by 3 to 13% compared to full rotations. This loss of heterosis needs to be weighed against the costs and feasibility of using a full rotation. In either case, substantial amounts of heterosis can be maintained by two- and three-breed rotations. Sire-breed rotations maintain more heterosis than composites of the same breed proportions. However, this comparison does not include the absence of heterosis in herds needed to produce purebred bulls for rotations.

Figure 3—Expected heterosis when a full rotation of bull and cow breeds is used, when only bull breeds are rotated, and for composites of the same breed percentages.

Rotations to produce replacement heifers combined with the use of a bull breed with high growth rate and desirable carcass qualities on older cows has previously been suggested as a method of increasing efficiency of producing beef. This method can combine desirable qualities from breeds with high growth rate and desirable carcass composition. The management of these systems can be simplified by rotating only the bull breed to produce the replacement heifer. Four breeds of bulls need to be available each yr to use a full three-breed rotation for replacement heifers and terminal breed to produce slaughter beef. Use of sire-breed rotations or composites to produce replacement heifers and mating excess cows to a terminal breed results in only two bull breeds needed each yr. Furthermore, replacement heifers only need to be identified by yr of birth if the terminal breed color or pattern marks their calves. This modification of the rotational-terminal crossbreeding system not only is simpler to use, but also allows the system to be used in smaller herds needing only two bulls. Figure 4 shows the percentages of heterosis for cows and calves in composite- or rotational-terminal systems breeding cows 5 yr and older to a terminal breed. Differences between full and sire-breed rotations range from 13 to 5% heterosis for cows and from 7 to 3% heterosis for calves. Differences between composites and full rotations range from 17 to 20% heterosis for cows and from 10 to 11% heterosis for calves.

Figure 4—Percentage of heterosis for cows and calves when full rotations, sire-breed rotations, or composites of two, three, or four breeds are used to produce replacement heifers and a terminal breed is mated to cows 5 or more yr of age.

Conclusions

Composites and rotations offer ways to make optimal use of breed differences and heterosis. When herd size or management practices make a full rotation unfeasible, sire-breeds and composites can still make good use of breed differences and heterosis to improve the efficiency of beef production.