Useable Crossbreeding Systems for Small and Large Sheep Flocks

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Introduction

The practice of crossbreeding is a well accepted practice among sheep producers in the U.S. as evidenced by the fact that the majority of lambs marketed each year are crossbreds. Crossbreeding is used in order to take advantage of the different and complementary strong points of two or more breeds and to utilize hybrid vigor. However, much of the crossbreeding in the sheep industry is haphazard, does not utilize systems that optimize the advantages of crossbreeding, and are not sustainable over several years.

Characteristics of a good crossbreeding system are:

1. Easy to implement and maintain – The KISS (Keep It Simple, Stupid) approach applies here. If the system requires too much record-keeping, greatly increased labor in flock management, or breeds or crossbreds that are in short supply or very expensive, it will not be sustainable and may not result in increased net income.
2. Properly utilize the strong points of different breeds (complementarity) – Different breeds of sheep excel for different economically important traits. A well designed crossbreeding system utilizes these breed differences in a strategic manner to improve the efficiency of meat, wool, and milk production over purebreeding.
3. Optimize the amount of hybrid vigor – The amount of hybrid vigor is maximized in the offspring of a ram and ewe of two unrelated breeds. It is not possible to maintain the maximum amount of hybrid vigor in all systems, but a good crossbreeding system will be able to maintain high levels of hybrid vigor.
4. Produce a uniform product – For ease of management and acceptance in the market, the commercial products from your flock (feeder lambs, market lambs, wool, milk) should be as uniform as possible. A haphazard crossbreeding system can result in large variations in the appearance, size, performance, and quality of your products while a well designed system will minimize this variation.

As with most things in life, deciding on the best crossbreeding system for your flock is an exercise in compromises. One system may result in higher hybrid vigor but poorer breed complementarity and less uniform products whereas another system may be easy to maintain, have more uniform products, make good use of breed complementarity, but maintain lower amounts of hybrid vigor. A producer needs to weigh the pros and cons of several crossbreeding systems and pick the one that is best for his/her particular conditions.

Utilizing Breed Differences – Complementarity

The most recent edition of the Sheep Production Handbook lists 49 recognized breeds of sheep in the U.S., and there are some recent imports (and perhaps some other breeds) that are not on the list (e.g. Lacaune, a dairy breed of French origin). There is a large amount of variation among these 50 or so breeds for performance for economically important traits that can be exploited in well-designed crossbreeding programs.

The breeds of sheep can be broadly classified into three groups based on their level of performance for certain traits: ram breeds, ewe breeds, and general purpose breeds. Ram breeds should excel in one or more of the traits of growth, feed efficiency, carcass merit, and lamb survival. Ewe breeds should have superior levels of performance for one or more of the traits of adaptability to the production environment, small to moderate body size for lower maintenance costs, non-seasonal breeding, litter size, milk production, mothering ability, wool production, and fleece quality. General purpose breeds have good levels of performance for some ram breed and some ewe breed traits. From the standpoint of breed complementarity, the ideal crossbreeding system would have all market lambs sired by purebred or crossbred rams of the ram breeds and all ewes in the flock would be crossbred ewes of the ewe breeds.

Most commercial flocks purchase purebred rams and raise their own replacement ewes. Since a large proportion (20 to 30%) of available ewe lambs are kept for replacements and minimal production records generally are available on these ewe lambs, very little flock genetic improvement results from ewe selection. The vast majority of the genetic improvement in the flock comes through the purchased rams. Therefore, the purchased rams must be from breeds with high average genetic merit and the individual rams should be of high genetic merit within the breed. In addition, it is preferable that the rams are of relatively common breeds that are available in large numbers so they can be easily obtained at reasonable prices.

Ideally, breed choice should be based upon the results of research trials that have fairly compared several breeds. Well-designed experimental comparisons of the various breeds of sheep were begun about 50 years ago at the U.S.D.A. stations at Dubois, Idaho and Beltsville, Maryland and about 35 years ago at the U.S. Meat Animal Research Station, Clay Center, Nebraska. During this same period of time, various State Land Grant Universities conducted numerous breed evaluation studies. Unfortunately, many of the breeds of sheep in the U.S. have not been evaluated in a single comparative trial. Producers wishing to use one of these non-evaluated breeds must rely on their own observations of the performance of the breed in other flocks or on the biased claims of the breed association or breeders of the breed. I wrote a paper with a ranking of breeds for a few traits compiled from comparative research trials published through 1996, and it can be found at: <http://www.uwex.edu/ces/animalscience/sheep/wisline_03/index.html>. The results of a few new studies evaluating additional breeds have been published since this paper was written, but many of the breeds still have not been evaluated in comparative studies.

Once a superior breed has been selected for a crossbreeding system, rams of superior genetic merit of that breed should be purchased. The breed should be enrolled in a national performance recording program (such as the National Sheep Improvement Program (NSIP) or LambPlan) that allows for comparison of estimated genetic merit of individuals across flocks so accurate selection decisions among rams in several flocks can be made. Unfortunately few breeds, and few flocks within these breeds, are enrolled in such national performance recording programs. At a minimum, the flocks that rams are purchased from must have some type of within flock performance recording system that allows for the ranking of animals within the flock for estimated genetic merit.

Table 1 presents the breeds of sheep that are numerically common in the U.S. based upon the number of purebred registrations in 2004 and some less numerically common breeds that I feel may be important for commercial lamb production. Also included in Table 1 is the classification of the breed as a ram, ewe, or general purpose breed, those breeds that have been evaluated recently in at least one comparative breed evaluation study, and those breeds participating in NSIP or LambPlan.

Table 1. Some breeds for consideration in a crossbreeding system for lamb production

Breed	No. of animals registered in 2004[a]	Classification	Evaluated in a research trial	Participation in an across flock genetic evaluation program
Top ten breeds listed in order by number of 2004 registrations:				
Suffolk	14,230	Ram	Yes	NSIP, LambPlan
Dorset	9,743	Ewe, General	Yes	NSIP
Hampshire	9,104	Ram	Yes	NSIP (recent)
Dorper	6,050	Ram, General	Yes	LambPlan
Southdown	5,742	Ram	No	No
Katahdin	4,209	Ewe	Yes	NSIP
Rambouillet	3,967	Ewe	Yes	NSIP (recent)
Columbia	3,000	General	Yes	NSIP (recent)
Shropshire	2,613	Ram	No	No
Montadale	2,211	General	Yes	No
Less numerically common breeds that may be important in crossbreeding systems for lamb production (not a complete list):				
East Friesian	no association	Ewe	Yes	No
Finnsheep	371	Ewe	Yes	No
Oxford	1,087	Ram	Yes	No
Polypay	1,366	Ewe	Yes	NSIP
Romanov	?	Ewe	Yes	No
Romney	1,800	Ewe	Yes	NSIP (recent)
St. Croix	446	Ewe	Yes	No
Targhee	922	Ewe	Yes	NSIP
Texel	534	Ram	Yes	No

[a]The Banner Sheep Magazine. 2005. 28(2):20.

The majority of the breeds listed in Table 1 have been compared with other breeds in one or more research trials. A review of these research trials will provide some information on the average genetic merit of that breed relative to some other breeds and will allow a producer to make an informed choice on which breeds to include in his/her crossbreeding system. However, only six of the breeds (Suffolk, Dorset, Dorper, Katahdin, Polypay, and Targhee) currently have a large enough number of animals enrolled in a national performance testing program to allow commercial producers the opportunity to compare a significant number of rams across flocks for estimates of genetic merit before a purchasing decision is made. Therefore, many rams will be purchased on the basis of some type of within flock records.

Putting a list of breeds together that does not include all breeds will always be controversial because someone will have had good experience with a breed that is not listed and take issue with the list. Table 1 is not meant to be a complete list of all breeds that may be useful in a crossbreeding system, and producers should use breeds not listed if there are sound reasons to do so.

Hybrid Vigor

It is a well established fact that crossbreds often perform at a higher level than the average performance of the purebreds that make up the crossbred. This increased performance of crossbreds is called hybrid vigor or heterosis. The following example demonstrates the calculation of hybrid vigor.

Calculation of Hybrid Vigor

A flock of sheep was composed of purebred Suffolk and Dorset ewes and rams. The rams and ewes were mated in all possible combinations so that purebred (Suffolk and Dorset) and crossbred (Suffolk x Dorset and Dorset x Suffolk; sire breed listed first) lambs were produced.

Adjusted 60 day weaning weights of the lambs were:
Suffolk = 62 lb.
Dorset = 52 lb.
Suffolk x Dorset = 61 lb.
Dorset x Suffolk = 59 lb.

Hybrid vigor (HV) = average of crossbreds – average of purebreds
HV = (61+59)/2 - (62+52)/2 = 60 - 57 = 3 lb.

% HV = ((average of crossbreds – average of purebreds)/average of purebreds) * 100
% HV = (3/57) * 100 = 5.3 %

In the above example, hybrid vigor for lamb 60 day weight was 3 lb.; on average, crossbred lambs were 3 lb. heavier than purebred lambs. Hybrid vigor is often expressed as a percentage of the purebred average. In this example, crossbred lambs had 5.3% heavier weights than purebred lambs.

In this example, purebred Suffolk lambs had the heaviest weights but hybrid vigor still existed. The existence of hybrid vigor does not necessarily imply that the crossbreds are superior to the best purebred; the existence of hybrid vigor means that the crossbreds are superior to the average of the purebreds. If 60 day weaning weight was the single most important trait influencing profit in this flock, the producer should not be crossbreeding, but instead, she should be raising purebred Suffolk lambs. In practice, however, the crossbreds are superior to the best purebred for many important traits, and crossbreeding is the logical choice of a mating system.

The hybrid vigor demonstrated in the above example is called Individual Hybrid Vigor (HV_I); increased performance of an individual due the individual being a crossbred. An individual can also benefit from HV if its dam is a crossbred versus a purebred. Crossbred dams express HV for milk production and mothering ability, which results in the offspring of crossbred dams having greater performance than the offspring of purebred dams. This type of HV is called Maternal Hybrid Vigor (HV_M). Both HV_I and HV_M can influence the performance of a lamb as indicated below:

Suffolk sire x Suffolk dam => Suffolk lamb, The Suffolk lamb does not exhibit any HV_I or HV_M because both the lamb and dam are purebred.

Suffolk sire x Dorset dam => Suffolk x Dorset lamb, The Suffolk x Dorset lamb exhibits HV_I because it is a crossbred but no HV_M because its dam is a purebred.

Suffolk sire x (Finnsheep x Dorset) dam => Suffolk x (Finnsheep x Dorset) lamb, The Suffolk x (Finnsheep x Dorset) lamb exhibits HV_I because it is a crossbred and HV_M because its dam is a crossbred.

Paternal Hybrid Vigor (HV_P), the increased performance of lambs from crossbred sires compared to purebred sires, also exists for some traits, but it is generally much smaller than either HV_I or HV_M. This discussion will assume that HV_P is not important in determining performance in a crossbreeding system. Estimates of HV_I and HV_M for some sheep production traits are presented in Table 2.

Table 2. Expected individual (HV_I) and maternal (HV_M) hybrid vigor for lamb production traits

Trait	HV_I, %	HV_M, %
Ewe conception rate	2.6 [a]	8.7
Ewe litter size	2.8 [a]	3.2
Lamb survival to weaning	9.8	2.7
Lamb weaning weight	5.0	6.3
No. of lambs weaned per ewe exposed	15.2 [a]	14.7
Weight of lamb weaned per ewe exposed	17.8 [a]	18.0

[a] Purebred ewes mated to a different breed of purebred ram to produce crossbred lambs.

Table 2 shows the dramatic effect that utilization of HV can have on increasing lamb production. A purebred ewe mated to produce crossbred lambs is expected to wean 17.8% more weight of lamb than a purebred ewe mated to produce a purebred lamb – the HV_I effect. If we use crossbred ewes to produce crossbred lambs, we get an additional 18.0% increase in performance from HV_M, or a total increase of 39% over production of purebred lambs (1.178 HV_I x 1.180 HV_M = 1.390).

The above calculations assume that there are no breeds in common between the sires and dams that produced the lambs or the dams. If the sire and dam have some breeding in common, we obtain something less that the HV values presented in Table 2. For example:

Suffolk sire x (Finnsheep x Dorset) dam => Suffolk x (Finnsheep x Dorset) lamb, The Suffolk x (Finnsheep x Dorset) lamb exhibits 100% of the HV_I values in Table 2 because the lamb's sire and dam had no breeds in common and 100% of the HV_M values in Table 2 because the sire and dam of the lamb's dam had no breeds in common.

Suffolk sire x (Suffolk x Dorset) dam => Suffolk x (Suffolk x Dorset) lamb, The Suffolk x (Suffolk x Dorset) lamb exhibits 50% of the HV_I values in Table 2 because the lamb's sire and dam had the Suffolk breed in common but 100% of the HV_M values in Table 2 because the sire and dam of the lamb's dam had no breeds in common.

The general formula for calculating the proportion of maximum retained HV_I and HV_M in various crosses is presented in the Sheep Production Handbook, but it will not be presented here. Just be aware that less than maximum HV vigor will be expressed if the sire and dam have a breed or breeds in common, and the greater the amount of breeding they have in common, the greater the loss in HV.

Crossbreeding Systems

A crossbreeding system that maximizes HV and breed complementarity is a 3-breed terminal system (Fig. 1).

T sires (ram breed) x AxB crossbred ewes (ewe breeds)

↓

Tx(AxB) lambs (all males and females to market)

Figure 1. Three-breed terminal crossbreeding system – purchase replacement ewes.

All lambs are crossbreds with no breeds in common between their sires and dams, and the lamb's dams are crossbreds with no breeds in common between their sires and dams, so HV_I and HV_M are maximized. All lambs are sired by rams of the ram breeds, and all dams are of ewe breeds, so maximum use is made of breed complementarity. Every market lamb is of the same 3-breed cross, so they will be uniform in appearance and performance. The system is easy to manage because all ewes on the farm get bred to the same breed of ram; only one breeding group is needed.

The only possible problem with the system is in regards to replacement ewes. Where will you obtain the crossbred AxB ewes? They could be purchased from a specialized producer of crossbred replacement ewes. This is a good option if such ewes are available at a reasonable cost. However, specialized producers of crossbred replacement ewes are not common, and even if they were, many commercial producers do not wish to purchase large numbers of ewes on a continuing basis for fear of introducing disease into their flock. The alternative to purchasing the replacement ewes is to produce them within the flock (Fig. 2).

The system in Fig. 2 is definitely more complicated than the one in Fig. 1. We now have three breeds of sire on the farm (A, B, and T), two types of ewes (B and AxB), and at least three breeding groups are required. About 25% of the ewes are purebred B ewes, and their lambs will not benefit from HV_M. About 10% of the lambs will be purebred B lambs, and they will not benefit from HV_I. Three different types of lambs will be marketed (B, AxB, and Tx(AxB)) so it may appear at first that there will be large variation in the performance and appearance of the market lambs. However, this is not a big concern because about 90% of the market lambs will be from the T sires (Tx(AxB) lambs).

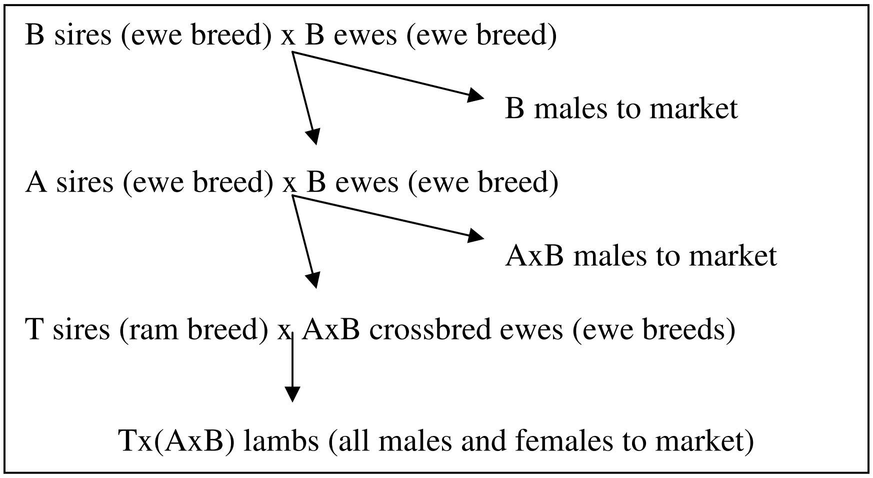

Figure 2. Three-breed terminal crossbreeding system – replacement ewes produced within the system.

Even with some loss of HV_I and HV_M in the system from some purebred lambs and purebred ewes, this system is still the most productive crossbreeding system possible when ewe replacements must be produced from within the system.

The 3-breed terminal crossbreeding system can be simplified somewhat by producing the A-B crossbred ewes in a rotation (Fig. 3). This system is often called a roto-terminal crossbreeding system. The A-B crossbred ewes are produced by rotating between A and B sires; any ewe in the rotation sired by a B sire is mated to an A sire, and any ewe in the rotation sired by an A sire is mated to a B sire. Once the system stabilizes, the ewes will be 67%A,33%B or 33%A,67%B.

Only the number of A-B ewes needed to generate flock replacement ewes are kept in the rotational portion of the system – about 25% of the ewes. The other 75% of the A-B ewes are mated to terminal sires.

The advantages of this system over the 3-breed terminal system in Fig. 2 are:

1. All lambs in the system are crossbred; A-B lambs exhibit 67% of maximum HV_I, and Tx(A-B) lambs exhibit 100% of maximum HV_I.
2. Slightly more ewes can be mated to terminal sires since a few less ewes are required to produce replacements.
3. Market lambs are somewhat less variable in appearance and performance.

The major disadvantage of this system is that market lambs exhibit only 67% of maximum HV_M compared to approximately 90% of maximum HV_M for market lambs in the 3-breed terminal system. This is because all the dams of market lambs in the roto-terminal system are backcross ewes whereas about 90% of the market lambs in the 3-breed terminal system have dams who are first cross ewes.

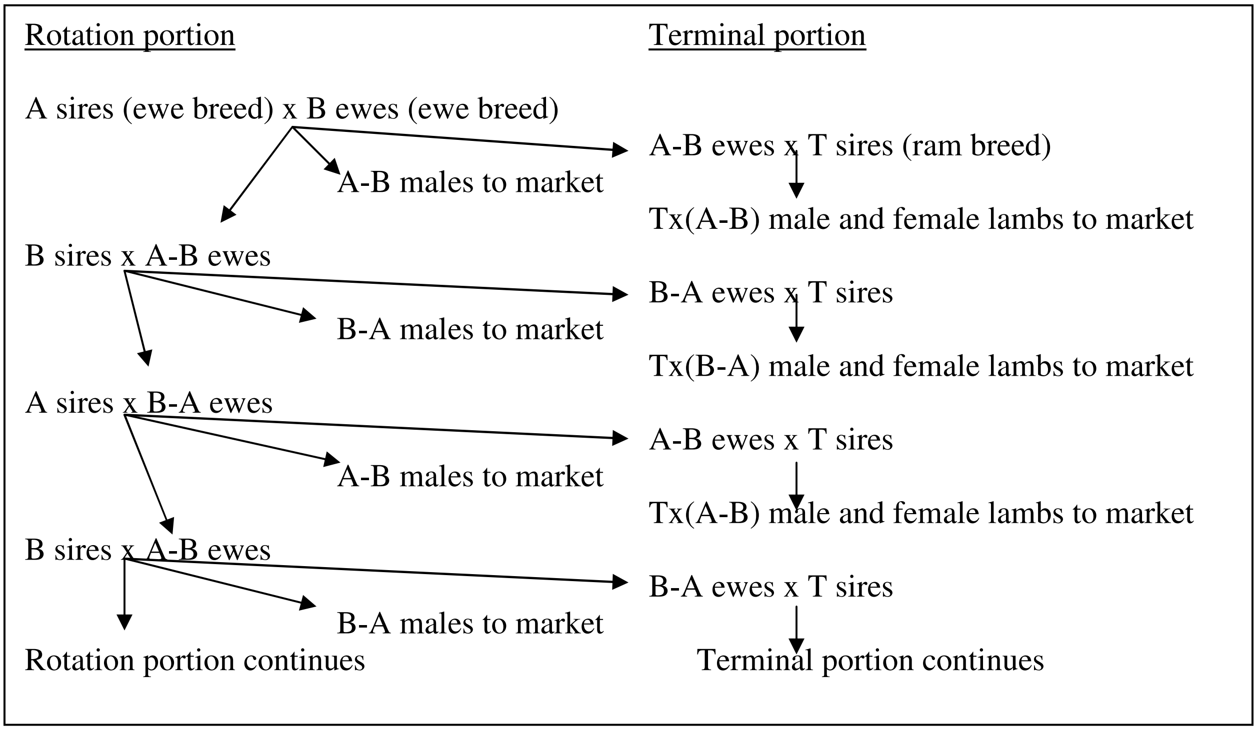

Figure 3. Roto-Terminal crossbreeding system.

The roto-terminal system still has the disadvantage of three different breeds of sire on the farm requiring three breeding groups. Incorporation of a two-breed composite for the two-breed rotation for the production of replacement ewes would eliminate one breed of sire from the system (Fig. 4).

A composite is a new breed created by initial crossing of two or more existing breeds and then treating the new crossbred as a pure breed. The Polypay breed (25% Rambouillet, 25% Targhee, 25% Dorset, 25% Finnsheep) is a relatively recent composite breed developed in the U.S. Other older composite breeds are the Columbia, Corriedale, Targhee, and Montadale. If composites are developed from a wide genetic base, are regenerated occasionally from the parent breeds, and/or avoid inbreeding, they retain a constant proportion of their HV_I and HV_M in successive generations. A two-breed composite (50% A, 50% B) retains 50% of HV_I and HV_M, a three-breed composite (50% A, 25% B, 25% C) retains 62.5% of HV_I and HV_M, and a four breed composite, like the Polypay, retains 75% HV_I and HV_M. Composites offer the simplicity of purebreeding with the retention of some HV.

The composite-terminal system is somewhat simpler because only AB_C rams and T rams are needed requiring only two breeding groups, and the AB_C market lambs will be somewhat more uniform than the A-B and B-A rotationally produced market lambs. The major disadvantage with the system is that only 50% of maximum HV_M will be expressed for all market lambs because all dams are a 2-breed composite, and AB_C market lambs will exhibit only 50% HV_I.

Of course, the success of the composite-terminal system is dependent upon the availability of a productive composite breed. Most flocks are too small to produce and maintain their own composite breed. Composite breed formation and maintenance requires a very large flock or several breeders working together.

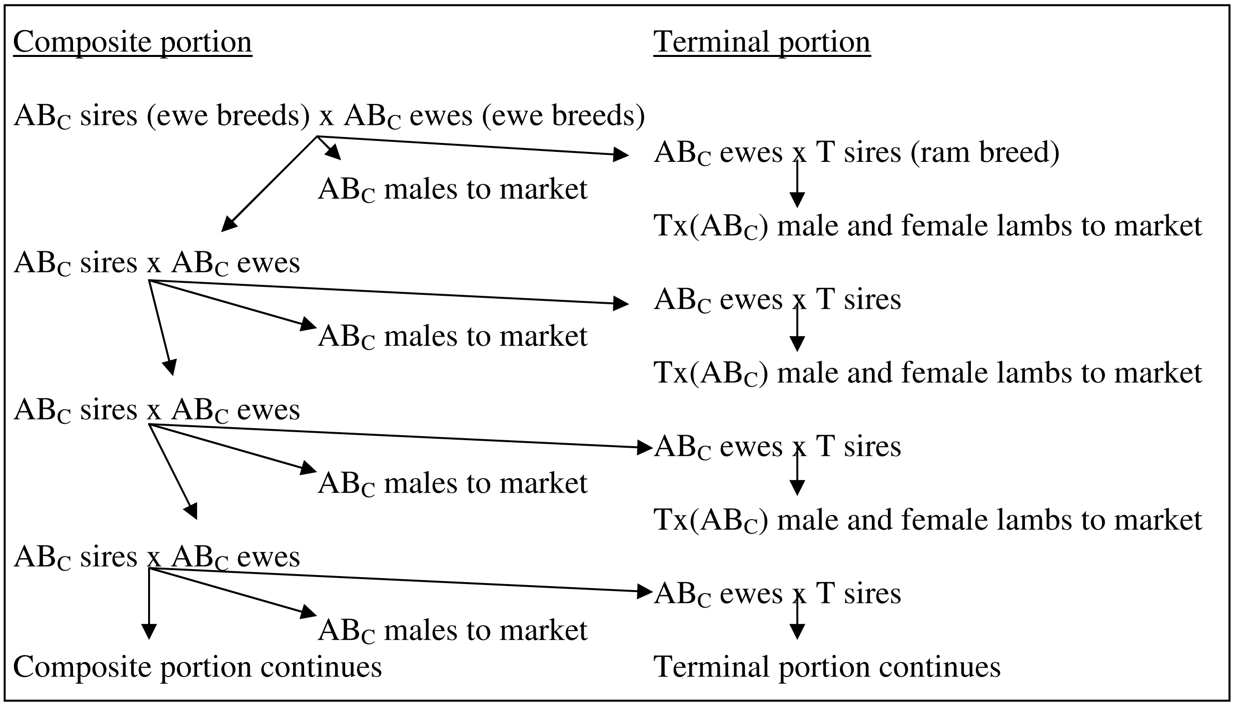

Figure 4. Composite-Terminal crossbreeding system.

Table 3 presents the expected productivity of alternative crossbreeding systems. This information was developed by Dr. Kreg Leymaster, U.S. Meat Animal Research Center, Clay Center, NE and can be viewed in the recent edition of the Sheep Production Handbook or online at < http://www.uwex.edu/ces/animalscience/sheep/wisline_02/index.html > or < http://www.ars.usda.gov/SP2UserFiles/Place/54380000/onlineinfo/MARCCrossbreeding.pdf >.

The assumptions used in the construction of the information in Table 4 were:

1. A flock of 400 ewes is maintained.
2. 20% of ewes are replaced each year.
3. All ewe replacements are produced within the system, and all rams are purchased.
4. Purebred ewes raise 1.4 lambs per ewe exposed (A and B ewes).
5. There is 15% HV_I for lambs reared per ewe exposed.
6. There is 15% HV_M for lambs reared per ewe exposed.
7. Purebred lambs weigh 50 pounds at weaning.
8. There is 5% HV_I for lamb weaning weight.
9. There is 6% HV_M for lamb weaning weight.
10. There is a 5% increase in weaning weight for lambs sired by terminal ram breed sires (T breed rams).

Since the A and B breeds have the same level of performance, any differences among purebreeding, two-breed crossing, rotational crossing, and composite breeds in Table 3 are due to different amounts of HV (HV_I and HV_M) expressed in the systems. Compared with purebreeding, these three systems were estimated to produce 18 to 34% more weight of weaned lamb just due to increased HV. When a terminal sire was added to the systems, productivity was increased 22 to 50% over purebreeding. This advantage was due to improved breed complementarity, increased HV_I, and in some cases, increased HV_M.

Table 3. Lamb production of alternative crossbreeding systems

System	Mating type	% ewes needed to produce replacement ewes	No. lambs weaned[a]	Pounds lamb weaned[a]	Pounds of lamb weaned relative to purebreeding
Purebreeding	A	29%	476	23,800	100
Two-breed X	A x B	29%	539	28,115	118
Rotational	AB_R	24%	592	31,780	134
Composite	AB_C	25%	564	29,752	125
Terminal	T x A	29%	536	29,080	122
	T x (AxB)	26%	620	35,608	150
	T x AB_R	24%	612	34,728	146
	T x AB_C	25%	596	33,472	141

[a]No. of lambs and pounds of lamb weaned do not include ewe lambs kept for replacements.

Recommendations for Flock Owners

Very small flocks – up to 30 ewes

The most efficient system for these very small flocks is a terminal system where ram and ewe replacements are purchased (Fig. 1), and all lambs are marketed. An example of such a system would be to mate Suffolk rams to Romanov x Dorset ewes. Sourcing of replacement ewes will be the greatest problem. Ideally, the small flock owner would be located close to a larger flock that was a specialized producer of these crossbred ewes or to a large flock involved in a 3-breed terminal (Fig. 2) or roto-terminal (Fig. 3) system where some of the excess replacement ewes from the large flock could be purchased.

Composite breeds are an easy way for small flocks to take advantage of the benefits of crossbreeding. The flock owner could purchase composite breed ewes created from ewe breeds, such as the Polypay, mate them to ram breed terminal sires, such as the Suffolk or Hampshire, and market all the lambs.

Very small flock owners that want to produce all their own replacements should consider raising a composite breed as a purebred. This allows the breeder to take advantage of HV, but does not result in good use of breed complementarity.

Small flocks – 30 to 80 ewes

Small flocks of 30 to 80 ewes generally require 2 rams each breeding season. They can utilize the same crossbreeding systems recommended for the very small flocks. In addition, they could utilize the composite-terminal crossbreeding system (Fig. 4) or the two-breed cross (Table 3).

A possible choice of breeds for the composite-terminal system would be Polypay and Hampshire. In a flock of 60 Polypay ewes, about 15 (25%) of the Polypay ewes would be mated each year to produce replacement ewe lambs and some Polypay market lambs. The remaining 45 (75%) of the Polypay ewes would be mated to the Hampshire ram, and all Hampshire-sired lambs would be marketed.

A possible choice of breeds for the two-breed cross system would be Dorset and Suffolk. A flock of Dorset ewes would be maintained with about 25% bred to Dorset rams to produce replacement ewes and about 75% bred to Suffolk rams to produce terminal market lambs. The main disadvantage of this system is that all the ewes are purebred so no use is made of HV_M.

Medium to large flocks – over 80 ewes

Flocks of over 80 ewes generally will use 3 or more rams at breeding time, therefore, all of the crossbreeding systems discussed are possible options. The choice of the system will largely depend upon how much time and effort the producer wishes to put into management of the system. The system becomes more complicated as the number of different breeds and crossbred types of rams and ewes increases.

The most productive system is the 3-breed terminal system (Table 3) as diagrammed in Fig. 2. A possible system that may be well suited for intensive production systems in the upper Midwest would be one that used Targhee, Romanov, and Hampshire breeds. About 30% of the flock would be composed of Targhee ewes, and about 70% of the flock would be composed of Romanov x Targhee ewes. Each year, about 1/3 of the Targhee ewes (10% of all ewes in the flock) would be mated to Targhee rams in order to produce replacement ewes and a few Targhee market lambs. The other 2/3 of the Targhee ewes (20% of all ewes in the flock) would be mated to Romanov rams to produce replacement ewes for the Romanov x Targhee flock and a few Romanov x Targhee market lambs. The Romanov x Targhee ewes (70% of all ewes in the flock) would be mated to Hampshire rams, and all of the lambs produced from this mating would be marketed. This would be a very productive system. It makes good use of HV_I and HV_M and excellent use of the strong points of the three breeds.

If level of lamb production generated from the Romanov-cross ewes was too high for some less intensive management systems, breeds like the Polypay or Dorset could be substituted for the Romanov. If a producer wanted to have a flock of hair sheep ewes, the Katahdin and St. Croix breeds or the Katahdin and Dorper breeds could be substituted for the Targhee and Romanov breeds. There are many combinations of breeds that would result in productive systems.

Conclusion

Hybrid vigor (both individual and maternal) and breed complementarity are powerful tools to increase the productivity of commercial sheep flocks. Organized crossbreeding systems can optimize the use of both hybrid vigor and breed complimentarity and can be utilized by flocks of all sizes.

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