S. Afr. J. Anim. Sci. 2, 139–149 (1972)

LIVESTOCK PRODUCTION SYSTEMS FOR INCREASED YIELD ON RESOURCES

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I am a student of an animal agriculture that is oriented toward the conversion of a different mixture of production resources to those found in South Africa. Thus, I shall confine my presentation to principles that may be translated between the two environments, rather than to specific production equations that require an in-depth understanding of your livestock production resources. Furthermore, I shall give primary attention to considerations relating to research and education planning, implementation and execution. Also, as most of my personal research has been with beef cattle, much of the data that I will present will deal with this aspect.

The basic consideration underlying efforts to increase agricultural production is an understanding of the production resources and their capabilities. For greater intensification, primary efforts must be directed toward increased feed production per unit of land resource and increased animal products per animal unit. In an analysis of production resources, it is essential to identify both the opportunities and the problems or constraints. Further, it is necessary to separate the constraints over which some control can be gained from those that are unyielding. To me, intensification is the word that is most descriptive of the evolution of agriculture, i.e., the employment of increased increments of capital, labour, technology, etc., to increase productivity. The economic feasibility of employing different levels of these inputs and their optimum synchronization is determined by the basic resource situation relating particularly to soil and climate, and the relative value of the production.

"Intensive Animal Production," obviously must be viewed in a relative sense. It is most logical to orient a program toward the level of intensification that returns the maximum yield on the resources employed. This should be regarded, generally, as the optimum level of intensification. This requires adjusting or synchronizing the production variables to the basic resource situation, or obtaining an optimum balance among the biological, economic and physical variables involved in the development and utilization of the production resources.

I have observed that in some parts of the world animal production, particularly with ruminants, tends to be regarded as a no- or a low-input enterprise. In other words, it is assumed that the optimum level of intensification is low. This characterized the beef cattle industry in much of the western United States during the early stages of its evolution. While the optimum level of intensification for beef cattle production is still relatively low in many of our western states, economic feasibility has favoured the implementation of rather large amounts of technology to increase the utilization of, and the returns to, production resources. This has included programs to increase the feed production per unit of grazing land and to increase the productivity per animal unit. Generally, this has been a relatively slow rate of evolution, but the rate has increased appreciably during the last two to three decades.

Research and Education Programming

The primary objective of livestock production research and education programs is to generate and disseminate new technology that can be implemented into production programs that will result in the maximum conversion rate of the feed and other resources into palatable and nutritious animal products. This requires the identification of opportunities, as well as the problems or constraints, with maximum precision; assigning priorities to them on a systematic basis; and planning, organizing, implementing and executing programs that will provide solutions to production problems at the lowest cost. This is commonly referred to as mission oriented research and education and I think that the application of sound principles of business management to research and education programming is essential for maximizing the yield on research and education resources. My personal attitude is that this approach, when pursued on an imaginative and realistic basis, provides sufficient latitutde to satisfy the highest level of intellectual curiosity. Further, I believe that this organized approach (with a problem-solving orientation) is likely to contribute most effectively to intellectual growth of individual scientists and educators by keeping them continuously involved in viable projects and programs. I do not think that agricultural research scientists can afford the luxury of doing research that relates only to their personal interests and to the interests of other scientists – it must be relevant to solving the practical production problems involved in more effective utilization of production resources.

I do not know the extent to which your national planning for livestock production research and education has analyzed your opportunities and problems or constraints on a systematic basis, nor how you have organized your efforts to obtain maximum return on your livestock production research and education resources in regard to maximizing animal production per unit of production resource use in the Republic of South Africa.

The following items, relating generally to animal agriculture in the Republic of South Africa, are presented as an *example* of some of the considerations involved in making an analysis of opportunities and constraints. These specific items are subject to the error of my interpretation, and certainly they are not all inclusive. Be assured that I am not sufficiently naive to believe that I comprehend your situation at the level necessary to make an intelligent analysis.

These items are based primarily on my interpretations from Department of Agriculture and Technical Services Special Publication No. 4 (1963) and from Hirzel (1968). As stated, these items are presented only as an example of some of the basic considerations involved in making an analysis of opportunities and constraints. They reveal that:

(1) Approximately 6% of the land area is now cultivated with the maximum potential of arable land being not more than 15% – perhaps less.

(2) Approximately two-thirds of the land area receives less than 24 inches of rainfall annually.

(3) Approximately 85% of the land area receives a relatively high percentage of its annual precipitation during the growing season, i.e., summer.

(4) While I could not find specific information on either irrigation development or potential, my general impression is that both irrigation development and potential may be relatively low as a percentage of your total land resource.

(5) Approximately 35% of your population is engaged in agricultural production.

(6) Cattle and sheep numbers have been relatively stable in recent years – 12 to 13 million cattle and 38 to 40 million sheep. The pig population has been more variable, i.e., in the 1,1 to 1,4 million range.

(7) The relationship of beef, sheep and pigs as contributors to red meat supplies has been relatively constant – beef and veal 71%, mutton and lamb 21%, and pork 8%.

(8) About 17% of your beef supplies have been imported in recent years, but with little importation of sheep and pigs.

(9) The consuming public has shown an increasing preference for beef.

(10) While red meat production has been increasing, it has probably not kept pace with population increases, thus, the *per capita* consumption has been declining.

(11) Perhaps available technology has not been implemented as rapidly in meat production as has characterized other agricultural commodities.

(12) Animal health programs have been reasonably effective.

(13) Poisonous plants are a major problem in the utilization of some of your grassland areas.

(14) The nutritional status of a high percentage of your cattle and sheep populations may be relatively low during much of the year.

(15) Calving and lambing percentages are low, i.e., 60% estimated for cattle and 69% estimated for sheep.

(15) There seems to be an increasing tendency to slaughter cattle at relatively young ages and light weights.

(17) Percentage of national beef herd and sheep population represented by annual slaughter has been increasing, but is still relatively low.

(18) Like the United States, you export maize, yet you import meat.

(19) You have an unfavourable maize-to-meat price relationship in regard to favouring increased feeding of maize, but this seems to be changing. However, there are many who think that the rate of change is too slow.

(20) Last, but by no means irrelevant, you produce one-eighth of the world's diamonds and one-third of the world's gold.

Your basic resource situation would seem to favour opportunities for intensification in ruminant animal production. With your relatively high percentage of nonarable land, efforts to intensify would seemingly start with increasing the productivity of this major component of your land resource. This may involve not only procedures for increasing feed production on this component of your land resource, but perhaps consideration to the budgeting of an optimum percentage of the arable land for feed production to supplement and, thus, enhance the value of the feed production from your nonarable land. I recognize that perhaps changes in national agricultural policy may be involved here in regard to providing incentives.

In the United States, concentrates are an important component of the feed resources available for beef production. However, they probably do not contribute more than 15 to 20% of the nutrients required for the production of the nation's beef (adapted from Nutrient Requirements for Beef Cattle, National Research Council, 1970). Yet, this level of concentrates greatly enhances the production from our native ranges, improved pastures and forage crops in contributing to our total beef production. Certainly, new technology in feed grain production that has resulted in large quantities of relatively low cost concentrate feeds has had a great impact on the beef cattle industry in the United States.

I recognize that limitations on arable land and water are primary constraints to feed-grain production in the Republic of South Africa, but it seems that you likely do have an opportunity to appreciably increase your ruminant animal production by use of a higher percentage of your arable land for the production of feeds that would most effectively supplement the production of your nonarable land resource.

In regard to assigning priorities for research and education programs, I believe that a good case can be made for a balance of research and education resources between comprehensive and integrated, multidiscipline programs that give attention to all components, including feed production in basic production equations;and to specific thrusts directed toward gaining solutions of the more limiting problems, such as reproduction rate. The comprehensive efforts involving life cycle production systems must take cognizance of the primary biological, economic and physical variables within the framework of the relevant production resource situations. Particular emphasis should be given to the problem areas, or specific components of production equations that, when subjected to a cost-benefit ratio analysis, show promise of returning the greatest yield. Such a problem area in the United States is reproduction rate in all economic livestock, and I am particularly impressed by the relatively low reproduction rates that you report for cattle and sheep. The obvious reason why we emphasize integrated, multidiscipline approaches is that neither biological nor production systems are organized on a discipline basis. Biological phenomena are obviously characterized by many complex interactions and integrated, multidiscipline approaches seem to be the only logical means for gaining understanding of the interactions. Further, any production equation in any resource situation requires the synchronization of all of the biological, physical and economic variables. Thus, the basis situation favours involving the appropriate disciplines on both specific problems or components in a production equation as well as across all components of the equation.

Obviously, there are many interrelated factors affecting rate of reproduction. This rather complex situation favours attacking the problem area with an integrated multidiscipline approach. To achieve satisfactory levels of reproduction, it is essential to synchronize all other components in the production equation with the basis feed resource situation. We are suggesting the necessity for a balance among the biological variables in the production equation. This means synchronizing or adjusting the germ plasm capability to the economically feasible feed resource situation. For example, the mature size, milk level, growth curve, etc., need to be adjusted to the feed environments if high reproduction rates are to be achieved. The bigger a reproducing animal is and the more milk she gives, the greater the feed required for regular reproduction. When subjected to a cost-benefit ratio analysis, small changes in reproductive rate have a major effect on profit margin relative to changes in any other economic trait.

As a basis is for more effective research and education planning, the production-model approach is a tool that may be worth considering (Gregory, 1972). We are suggesting the use of comprehensive input-output equations that involve the identification and quantification of the components. This approach should provide a basis for gaining understanding of the effects of different inputs and the interactions among them on outputs. The production model approach should provide a systematic basis for inventorying production resources and identifying the gaps or voids in the biological and economic understanding that is necessary for maximizing returns to resources. This is the crux of more effective research and education planning. It is likely that this approach would give a more precise basis for budgeting research and education resources since the problems and constraints relating to more effective resource use can be brought into sharper focus and can be identified and quantified with greater accuracy.

While, in a loose sense, we do use this approach in research planning; perhaps our planning and execution could be more effective if we were more systematic in the identification and quantification of the inputs and the outputs within the framework of maximizing outputs per unit of resource use. Obviously, research planning and education is a continuous process that requires constant reappraisal of objectives and adjustments in procedures for achieving them. The production model approach should assist in keeping our programs relevant in terms of present and future problems and prevent the use of research resources for the solution of yesterday's problems – this is a hazard that we cannot ignore with the rate of technological and economic development that characterizes the late twentieth century.

A potential source of increased beef production in South Africa would seemingly be from your dairy industry. In some areas of the world, where the dairy and beef industries have been organized as separate entities, there seems to be great opportunity to expand beef production by the development of truly integrated dairy-beef enterprises. The relative value of the so-called "beef by-product" of the dairy industry has reached the level where it is worth serious consideration in the production system. Obviously, this involves an intensive production system. The dairy enterprise in the United States has been moving in this direction and I think that economic factors favour the continuation of this trend at an increasing rate.

Biological Engineering

Basic considerations to increasing the yield on resources through livestock production systems involves primary attention to animal health and feeding. I believe that these two factors determine both the opportunities and the constraints that relate to the optimum level of intensification. All the other components in the production equation must be synchronized or balanced with these basic elements. While my personal background is genetics, it has become increasingly apparent that the genetic capability, in regard to performance characteristics in different economic traits, must be in harmony with the feed situation. One needs very little knowledge of evolution and ecology to comprehend the relevance of feed supply and animal health in livestock production.

Selection

Natural selection has generally favoured the evolution of biological systems that are most efficient for a given environment. However, man can readily assist nature in increasing the rate of genetic change toward a more efficient biological system for the utilization of given resources. As economic feasibility favours an increasing rate of intensification, the environment may be adjusted to support a biological system with increased production rate. Thus, the objective is to inject a genetic component into the production or management system that is capable of giving maximum response to the improved environment. If the change in the environment is relatively slow,

Table 1

Heritability estimates of some economically important traits

Trait	Heritability
	%
Calving interval (fertility)	10
Birth weight	40
Weaning weight	30
Cow maternal ability	40
Feedlot gain	45
Pasture gain	30
Efficiency of gain	40
Final feedlot weight	60
Conformation score:	
Weaning	25
Slaughter	40
Carcass traits:	
Carcass grade	40
Rib-eye area	70
Tenderness	60
Fat thickness	45
Retail product, per cent	30
Retail product, pounds	65
Susceptibility to cancer eye	30

selection to the environment within a breed that is indigenous or generally adapted may be the most appropriate procedure for providing a biological system capable of maximum response. If, however, the rate of environmental improvement is great, selection among biological types for those with higher performance levels may be a more rapid procedure.

There is a logical analogy between biological systems and mechanical systems -- high performance units in both require "fuel ", in both quality and quantity, if they are to give a favourable response. In regard to biological systems in animals, the maximum and the optimum may not be the same, if the maximum has requirements more than that which the economically feasible environment will support. Selection, both within and among breeds, is a useful and necessary tool for providing more efficient biological systems for resource conversion in a given environment.

Table 1 provides estimates of heritability for a series of economic traits in beef cattle and table 2 provides estimates of selection response for specific traits within a breed based on these estimates of heritability and assumed selection differentials and generation interval (Gregory, 1969).

Figures 1, 2, 3 and 4 and tables 3 and 4 provide preliminary information on differences among breeds of

Table 2

Estimates of potential progress in 10 years when different intensities of mass selection are practiced for specific traits[a]

Trait		Percentage of bulls saved					Assumptions[b]
		1	10	20	50	70	
Weaning weight and							
No other traits	pounds	41,6	30,6	26,4	19,2	15,6	50% of heifers saved; h^2, 0,3 in both sexes; S.D., 40 lb in both sexes
1 other trait	do.	29,4	21,6	18,7	13,6	11,0	
2 other traits	do	24,0	17,7	15,2	11,1	9,0	
3 other traits	do	20,8	15,3	13,2	9,6	7,8	
Postweaning daily gains and							
No other traits	do	0,44	0,30	0,25	0,17	0,12	50% of heifers saved; h^2, 0,5 in bulls, 0,3 in heifers; S.D., 0,29 lb in bulls, 0,20 lb in heifers.
1 other trait	do	0,31	0,21	0,18	0,12	0,08	
2 other traits	do	0,25	0,17	0,14	0,10	0,07	
3 other traits	do	0,22	0,15	0,12	0,08	0,06	
Yearling weight and							
No other traits	do	147,4	103,2	86,4	57,6	43,2	50% of heifers saved; h^2, 0,6 in bulls, 0,4 in heifers; S.D., 80 lb in bulls, 60 lb in heifers
1 other trait	do	104,2	73,0	61,1	40,7	30,5	
2 other traits	do	85,0	59,5	49,8	33,2	24,9	
3 other traits	do	73,7	51,6	43,2	28,8	21,6	
Yearling conformation score and							
No other traits	units	1,39	1,02	0,88	0,64	0,52	50% of heifers saved; h^2, 0,4 in both sexes; S.D., 1 unit in both sexes
1 other trait	do	0,98	0,72	0,62	0,45	0,37	
2 other traits	do	0,80	0,59	0,51	0,37	0,30	
3 other traits	do	0,70	0,51	0,44	0,32	0,26	

[a] Assumes that selection is only for the criteria indicated and when selection is for more than 1 trait, each trait is given equal emphasis and tha the traits are inherited independently. Generation interval, 5 years.

[b] h^2, heritability; S.D., standard deviation.

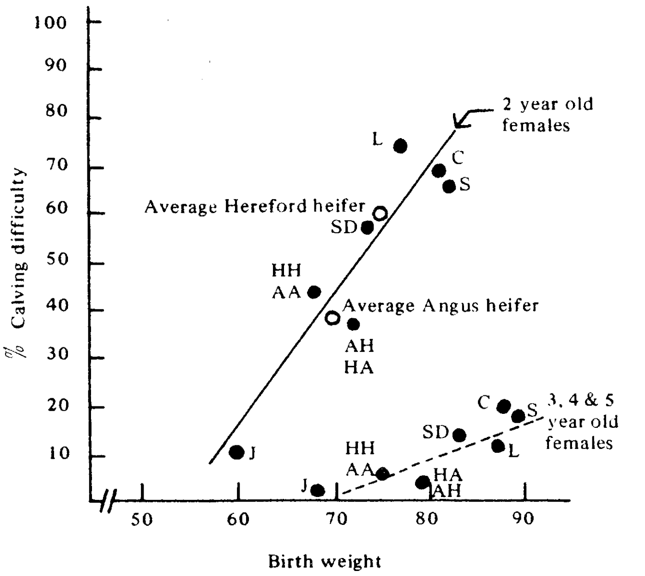

Fig. 1. – *U.S. Meat Animal Research Centre Germ Plasm Program; calving difficulty – birth weight (From 1971 Preliminary Report on First Calf Crop) USDA – Nebraska*

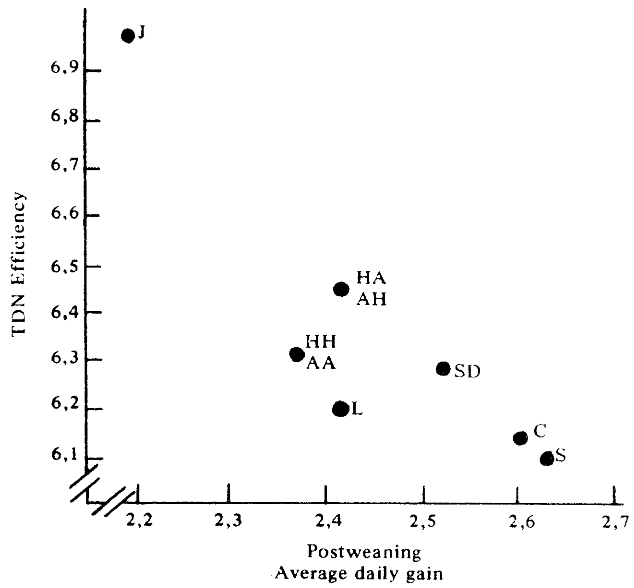

Fig. 2. – *U.S. Meat Animal Research Centre Germ Plasm Evaluation Program; feed efficiency and post-weaning average daily gain over slaughter group and breed of dam (From 1971 Preliminary Report on First Calf Crop) USDA – Nebraska*

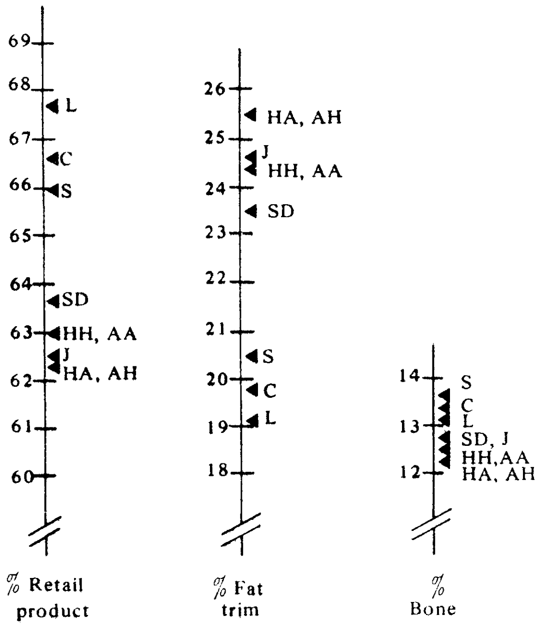

Fig. 3. – *U.S. Meat Animal Research Centre Germ Plasm Evaluation Program; per cent retail product, fat trim and bone averaged over breed of dam and slaughter group (From 1971 Preliminary Report on First Calf Crop) USDA – Nebraska*

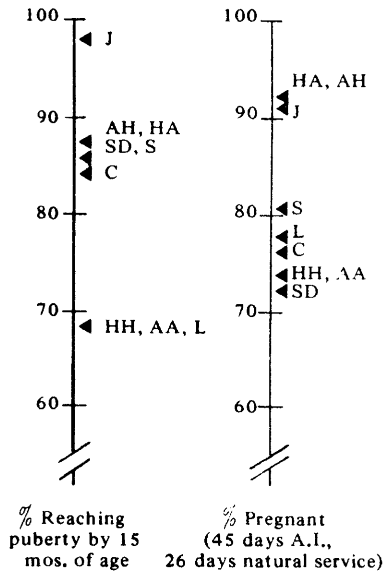

Fig. 4. – *U.S. Meat Animal Research Centre Germ Plasm Program; reproductive performance of heifers averaged over breed of dam (From 1971 preliminary Report on First Calf Crop) USDA – Nebraska*

cattle for a number of economic traits (U.S. Meat Animal Research Center, 1972). All calves are out of Hereford and Angus cows and the sires involved are Hereford, Angus, Jersey, South Devon, Limousin, Simmental and Charolais. This information is from a research program that relates to characterizing breeds that were sampled from a range of biological types with the objective of identifying the optimum performance capability, or biological system, for a range of feed environments. I do not imply that these breeds are useful to you. Rather, I am presenting these data to provide an example of what is involved in selecting among breeds in synchronizing or adjusting the germ plasm component to the feed and other components of different production equations and different production situations.

In the United States, the feed environments that we have available for beef production differ greatly. Up to now we have not given much attention in our research programs

Table 3

U.S. Meat Animal Research Centre Germ Plasm Evaluation Program; Preweaning Average Daily Gain. Adjusted 200-day weights and ratios averaged over breed of dam (Hereford and Angus) (From 1971 Preliminary Report on First Calf Crop)

Breed Group[a]	No. calves	Prewean A.D.G.	Adj. 200-day weight	200-day weight ratio[b]
		lb	lb	%
HH & AA	121	1,89	454	95,4
HA & AH	146	1,96	470	98,7
J	124	1,90	448	94,3
SD	67	1,95	474	99,5
L	133	2,00	486	102,2
S	143	2,04	497	102,4
C	144	2,07	502	105,6

a HH and AA = Straightbred Herefords and Angus, HA and AH =Reciprocal cross Hereford-Angus, and J =Jersey, SD = South Devon, L =Limousin, S =Simmental and C = Charolais crosses out of Hereford and Angus dams, respectively.

b Ratio relative to overall average adjusted to a steer calf and a 4– and 5–year–old cow basis.

Heterosis

Heterosis involves the use of another source of genetic variation to increase productivity per unit of resource use. The principle is generally applicable, regardless of the basic resource situation. Programs to utilize the biological phenomenon of heterosis through systematic crossbreeding can be an important unit of the genetic component of more intensive livestock production systems. Execution of well organized crossbreeding programs to utilize heterosis does increase the managerial requirement. However, this is the major additional input required. Also required is a number of breeds that are generally adapted to the environment, at least in crosses.

I would like to report the results of an experiment designed to evaluate the level of heterosis on a number of economic traits in beef cattle involving breeds that were generally adapted to the environment in which the experiment was conducted.

The breeds involved were Angus, Hereford and Shorthorn and phases I and II of the experiment were conducted at the Fort Robinson Beef Cattle Research Station, Crawford, Nebraska (Gregory, Swiger, Koch, Sumption, Rowden and Ingalls, 1965; Gregory, Swiger, Koch, Sumption, Ingalls, Rowden and Rothlisberger, 1966 a,b,c; Wiltbank, Gregory, Swiger, Ingalls, Rothlisberger and Koch, 1966; Wiltbank, Gregory, Rothlisberger, Ingalls and Kasson, 1967; and Cundiff, 1970). Phase III of the experiment is being conducted at the U.S. Meat Animal Research Centre, Clay Centre, Nebraska, and is evaluating different two-breed and three-breed crossing systems. The design of this comprehensive experiment and some of the more important results are summarized in Tables 5, 6, 7, 8 and 9 and in

Table 4

U.S. Meat Animal Research Centre Germ Plasm Evaluation Program; carcass quality grade, W–B shear and taste panel tenderness, flavour, juiciness and acceptability averaged over breed of dam (Hereford and Angus) and slaughter group (From 1971 Preliminary Report on First Calf Crop)

Breed group	USDA Quality Grade[a]	W–B Shear, lb[b]	Taste Panel[c]			
			Tender.	Flavour	Juic.	Accept.
HH & AA	10,6	6,9	7,3	7,4	6,8	7,2
HA & AH	10,6	7,0	7,4	7,4	6,7	7,2
JH & JA	10,2	6,4	7,5	7,5	7,0	7,3
SDH & SDA	10,6	6,2	7,5	7,3	7,1	7,3
LH & LA	9,4	7,3	7,0	7,4	6,9	7,0
SH & SA	10,1	7,3	7,1	7,6	7,3	7,2
CH & CA	10,5	6,9	7,4	7,5	6,9	7,3

a USDA quality grade: 9 = high good, 10 =low choice, 11 =average choice, etc.

b A measure of pounds of force required to shear one-half inch cores of steaks cooked at 350°F to 150°F internal temperature and cooled for 30 minutes at room temperature.

c Taste panel scores are based on a 9-point hedonic scale, with higher scores indicating greater acceptability.

to adjusting the germ plasm component, or the biological system, to the feed environment. Rather, we have tended to think in terms of a biological system that perhaps has been a reasonable compromise in regard to both the so-called "poor" feed environments and the "good" feed environments. Selection among breeds may provide a more rapid means, than within breed selection, of adjusting the performance capability of the germ plasm component to the series of feed environments and production situations.

Table 5

Experimental design for phase I of heterosis experiment

Dams		Sires			
Breed	No.	Hereford (16)	Angus (17)	Shorthorn (16)	Total
Hereford	80	HH – 118	AH – 60	SH – 72	250
Angus	80	HA – 66	AA – 115	SA – 65	246
Shorthorn	80	HS – 68	AS – 62	SS – 125	255
Total	240	252	237	262	751

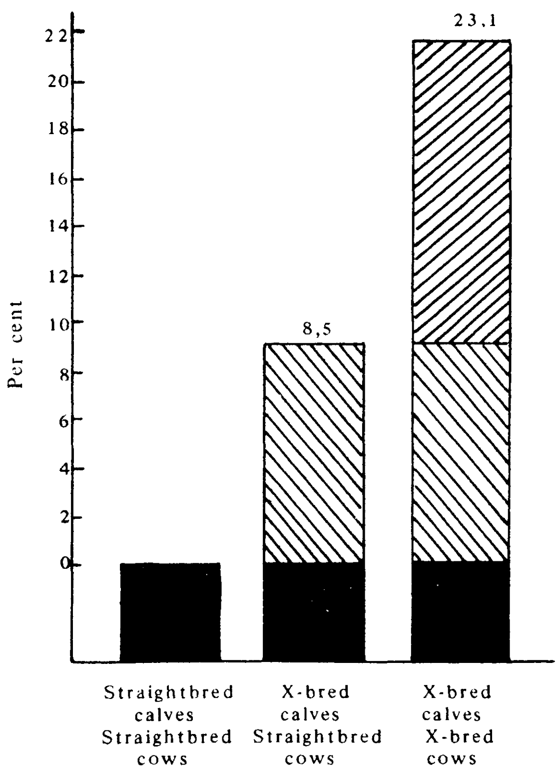

Fig. 5. – *Cumulative heterosis effects for pounds of calf weaned per cow exposed – Fort Robinson USDA – Nebraska*

Table 6

Heterosis effects on per cent calf crop weaned, weaning weight and pounds of calf weaned per cow exposed – Phase I

	Calves weaned	Weaning weight 200 days	Pounds of calf weaned per cow exposed
	%	lb	lb
Crossbred calves	84	437,4	367,4
Straightbred calves	81	418,0	338,6
Difference	+ 3	+19,4	+28,8(8,5 %)

figure 5.

Phase 1

In the first phase of this experiment (Table 5), the three straightbreds and reciprocal crosses among them were produced in four calf crops from 1960 to 1963. Heterosis was evaluated by comparing the crossbreds with the average of the straightbreds. Crossbreds and straightbreds were sired by the same bulls and out of comparable cows. These studies involved an evaluation of the effects of heterosis on embryo survival, postnatal mortality, birth weight, preweaning growth rate, weaning weight, conformation score, postweaning growth rate and yearling weight of heifers developed under two management programs, age and weight at first oestrus of heifers developed under two management programs, postweaning growth rate and yearling weight of steers on a growing-fattening ration, postweaning feed efficiency of steers on a growing-fattening ration. slaughter grade of steers and detailed information on carcass characteristics of steers involving complete cut-out data on one side of each carcass. The data for phase 1 included a total of 751 calves from four calf crops sired by sixteen Hereford, seventeen Angus and sixteen Shorthorn bulls.

The effects of heterosis were significant for most of the economic traits evaluated. A 3% greater calf crop was weaned (Table 6) in the crossbred than in the straightbred calves because of differences in early postnatal mortality. The effects of heterosis on 200-day weight was 19,4 lbs. The effect of heterosis on postweaning

Table 7

Heterosis effects on carcass traits and returns per steer – Phase 1

	No.	Retail product at 452 days	Retail product at 452 days weight adjusted	Fat trim 452 days Weight adjusted	Lb Retail product per lb TDN	Net merit
		lb.				$
Crossbreds	143	331	332	118	0,1345	220,33
Straightbreds	143	320	332	118	0,1338	211,52
Difference		+11	0	0	+ 0,0007	+8,81
H X A & Recip.	44	339	340	109	0,1391	226,80
Av. H & A	92	325	341	107	0,1381	215,89
Difference		+14	– 1	+ 2	+ 0,0010	+ 10,91
H X S & Recip.	52	337	329	119	0,1333	224.29
Av. H & S	98	322	330	118	0,1325	211,45
Difference		+ 15	– 1	+1	+ 0,0008	+ 12,84
A X S & Recip.	47	316	326	125	0,1313	209,91
Av. A & S	96	313	324	127	0,1309	207,21
Difference		+3	+2	– 2	+ 0,0004	+2,70

growth rate of heifers on a low level of feeding was greater than in steers on a growing-fattening ration. The magnitude of the heterosis effect on growth rate was related to level of feeding and age. That is, heterosis tended to decrease with increasing age after approximately one year and heterosis was greatest on a restricted feed intake when comparing heifers with steers. The effect of heterosis on carcass weight of steers at 452 days was 23 lbs. Effects of heterosis on age at first oestrus of heifers were 41 and 35 days for low and moderate levels of feeding respectively. After adjusting age at puberty for the effects of average preweaning and postweaning daily gains, approximately half to three-quarters of the heterosis effect on age at puberty (days) remained. Thus, there was a heterosis effect on age at puberty independent of its effects through average daily gains.

The advantage of the crossbred steers in feed efficiency was small. They produced slightly fatter carcasses when killed at the same age. However, when adjustments were made for the effects of weight, there was no difference in carcass composition. Thus, if they had been slaughtered at the same weight, the composition of the carcasses would have been the same.

In net merit (value of the boneless, closely trimmed retail meat, adjusted for quality grade, minus feed costs from weaning to slaughter) the advantage of the crossbred steers over the straightbred steers was $8,81 per carcass. This net merit difference is among the steers that lived to slaughter. The 3% advantage for the crossbreds in calf crop weaned was not involved in computing this difference.

For growth, feed efficiency, and carcass traits, the effect of heterosis was greater in the Hereford-Angus and Hereford-Shorthorn combinations that for the Angus-Shorthorn combination, while for age and weight at puberty, the heterosis effect was greatest for the Hereford x Shorthorn and reciprocal cross. In evaluating all traits for the effects of heterosis, it can be concluded that heterosis results in an increased rate of maturation.

Phase II

The second phase of this experiment involved evaluation of heterosis on fertility, mothering ability and mature size. Straightbred cows of the three breeds were compared with their crossbred half sisters when both were bred to the same males of the third breed (Table 8). Six calf crops, 1963 to 1968, were produced in Phase II. A total of 1257 matings that produced 975 calves was involved. In each year four bulls of each breed were used and a new group of bulls was used in each year.

Table 8

Experimental design for Phase II heterosis experiment[a]

	Sires		
Dams	Hereford	Angus	Shorthorn
Hereford		A X H	S X H
Angus	H X A		S X A
Shorthorn	H X S	A X S	
H X A & Recip.			S X(H X A)
H X S & Recip.		A X (H X S)	
A X S & Recip.	H X (A X S)		

[a] A total of 1257 matings that produced 975 calves was involved in Phase II.

Calf crop weaned was 6,3% greater for crossbred cows than straightbred cows. In Hereford-Angus reciprocal crosses and Hereford-Shorthorn reciprocal crosses, this was primarily due to the higher percentage of crossbred cows settled on the first service in the breeding pasture.

Table 9

Heterosis effects on per cent calf crop weaned, weaning weight and pounds of calf weaned (actual) per cow exposed in Phase II of heterosis experiment

	Calves weaned	Actual weaning weight	Actual wn. wt. per cow exposed
	%	lb	lb
Crossbred cows	83,8	453,8	396,1
Straightbred cows	77,5	431,2	341,2
Difference	+6,3	+22,6	+ 44,9(14,6 %)

The advantage in Angus-Shorthorn crosses was primarily accrued later in the breeding season and during gestation. There was very little difference in survival of calves from birth to weaning between the two groups. This was expected in this phase of the experiment since crossbred and straightbred cows were both raising crossbred calves.

On the average of all breeding groups, calves raised by crossbred cows were 4,4 % heavier at 200 days than those raised by straightbred cows. This was associated with heavier birth weight of the calves out of crossbred dams, but milk production studies revealed that it was primarily associated with greater and more persistent lactation by the crossbred cows. Higher first service conception resulted in an earlier calving date for crossbred cows which was reflected in a 5,1% heterosis on actual weaning weight as compared to a 4,4% heterosis effect on 200-day weaning weight. The effect of heterosis on mothering ability expressed in terms of milk production and growth of calves tended to be greater in Hereford-Angus and Hereford-Shorthorn crosses than in Angus-Shorthorn crosses.

To assess the total effect of heterosis on production of the crossbred cow, it is desirable to consider the effect of heterosis on pounds of calf weaned per cow exposed to bulls in the breeding herd. The effect of heterosis was 49,9 lb more actual weaning weight per cow in the breeding herd, or a 14,6% advantage in favour of crossbred cows. The effects of heterosis for this trait were consistent for all possible crosses among Herefords, Angus and Shorthorns. This does not take into account the 8,5% advantage of crossbred calves over straightbred calves indicated in Phase I of the experiment. Taking the effect of individual heterosis (phase I) and the effect of maternal heterosis (phase II) both into account, the cumulative effect of heterosis was 22 to 23% .

Heterosis had a significant effect on weight, wither height and condition of the crossbred cows at maturity. Crossbred cows were 47,6 lb heavier at maturity than straightbred cows. When differences in condition were taken into account, the effect on mature weight was reduced to 27,6 lb, indicating that 40% of the additional weight of the crossbreds was associated with fatness. This suggests that the effect of heterosis on metabolic size is somewhat less than that on weight unadjusted for condition.

Phase III

The third phase of this experiment is currently in progress. The objective of this phase of the experiment is to evaluate systems of crossbreeding for commercial production, including three-breed crosses out of F_1 dams, two-breed crisscrosses and the three-breed rotation compared to straightbred control groups of Hereford, Angus and Shorthorn.

It appears reasonable to conclude that production per cow exposed for breeding can be increased from 20–25% by systematic crossing of British breeds. More than half of this advantage is dependent upon the use of crossbred cows to take advantage of the high degree of heterosis for maternal ability and reproduction.

Finnsheep

The U.S. Meat Animal Research Centre (USMARC, 1971) has research in progress to evaluate the usefulness of the Finnsheep in crosses for intensive production systems.

Table 10

Reproductive performance of crossbred ewe lambs

Breed group	No.	Breeding wt. Lbs	Per cent of ewes lambing	Lambs born per ewe lambing	Lambs born per ewe exposed
Rambouillet X Dorset	15	88	94	1,18	1,08
Rambouillet X Targhee	12	94	46	1,00	0.46
Rambouillet X Corriedale	18	89	59	1,08	0,64
Rambouillet X Coarse Wool	13	94	82	1,04	0,85
Av	58	91	70	1,08	0,76
Finnsheep X Dorset	17	87	76	1,94	1,47
Finnsheep X Targhee	35	86	94	1,65	1,55
Finnsheep X Corriedale	12	84	93	1,52	1,41
Finnsheep X Coarse Wool	22	88	79	1,75	1,38
Av	86	86	86	1,72	1,45

Table 11

Mean weights for crossbred ram lambs by breed of sire – 1970

Breed of Sire[a]	No. Lambs[b]	Age in weeks					
		Birth	10	14	18	22	26
		lb	lb	lb	lb	lb	lb
Rambouillet	77(36)	11,0	49,9	64,4	90,4	112,2	133,4
Dorset	75(27)	11,2	50,6	66,9	93,8	115,8	137,2
Coarse Wool	74(38)	11,0	51,4	64,8	90,4	111,8	133,1
Finnsheep	143(59)	10,0	49,7	65,4	88,4	105,8	122,6

[a] Sires from all breeds were used equally on four breeds of ewes (Corriedale, Targhee, Fine Wool and Navajo, a native breed indigenous to the Navajo Indian Reservation in the desert southwestern United States).

[b] The lambs were slaughtered at either 22 or 26 weeks of age. The number slaughtered at 26 weeks is shown in parenthesis.

Table 12

Means for carcass traits for crossbred ram lambs by breed of sire – 1970

Breed of sire[a]	Carcass weight	Carcass[b] grade	Rib eye area	Fat thick	Kidney fat	Est. yield trimmed retail cuts
	lb		Ins^2	Ins	lb	lb
Rambouillet	65,2	5,4	2,26	0,19	2,7	47,3
Dorset	69,0	6,5	2,41	0,18	2,9	49,5
Coarse Wool	67,0	5,3	2,28	0,20	3,0	48,4
Finnsheep	63,2	5,0	2,13	0,20	3,1	45,4

[a] Sires from all breeds were used equally on four breeds of ewes (Corriedale, Targhee, Fine Wool and Navajo).

[b] Carcass grade: 3 =high good; 4 =low choice; 5 =average choice; 6 =high choice; etc.

Preliminary results indicate that this breed has potential for making a major contribution to increasing reproduction rate (Table 10). Growth and carcass data (Tables 11 and 12) indicate that while early growth rate of Finnsheep crosses is reasonably competitive with the Rambouillet and Dorset, growth rate tends to plateau at lighter weights and that the Finnsheep cross carcasses have a less favourable lean-fat ratio. The preliminary results on Finnsheep indicate that they may have potential to use at variable levels in the female parent for specialized crossbreeding programs involving more intensive production systems.

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