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THE ROLE OF EXOTIC GENES IN AUSTRALIAN BEEF PRODUCTION

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I. INTRODUCTION

During the 1960's beef cattle numbers in Australia increased by 54 percent from 11.6 million to 17.9 million (Coutts and Fernon 1971). The major expansion occurred in the high rainfall areas of Southern Australia, but substantial increases occurred in all beef cattle areas. Since 1970 more than 50% of Australia's beef and veal production was exported (Bureau of Agricultural Economics 1973), and FAO projections indicate continued growth in demand in meat importing countries, considerably in excess of domestic supplies (Food and Agriculture Organization 1970).

The major component of Australia's increased beef exports has been manufacturing meat (Bureau of Agricultural Economics 1973), and there is therefore considerable interest in the importation of large European breeds of cattle which are reputed to produce carcases with a higher content of lean meat than traditional British breed animals and to have faster early growth rates. There is in addition sustained interest in the use of breeds with *Bos indicus* ancestry in Northern Australia. This review sets out the framework for assessing the role of such breeds in beef production in the Australian environment.

II. PRODUCTION CHARACTERS

The characters of economic importance in beef cattle production may be divided into three classes: traits concerned with the production of potential carcases or replacements (reproduction), growth characteristics (rate of body weight gain, rate of attainment of maturity) and measures of product quality (percent lean meat, colour, tenderness, etc).

Overseas estimates of the heritability of measures of growth and product quality within breeds are moderate to high (0.3 – 0.5), while reliable estimates for reproductive characters are low (0.01 – 0.04). Genetic correlations between various measures of growth and efficiency of gain are high and positive (0.5 – 0.9), while those between growth and quality traits are moderate and also positive (0.2 – 0.4). Recent surveys of these parameters are given by Warwick 1969, and Preston and Willis 1970. There are few estimates of genetic parameters for Australian conditions, but those available are similar to overseas values (Pattie 1973).

It therefore appears that rapid improvement in growth and quality of product should result from the application of relatively simple breeding plans based on measured performance, but reproductive traits are likely to respond slowly, if at all, to similar pressures. It may nevertheless be possible to increase twinning rate substantially by selection in populations initially based on animals with a history of twinning, as has been demonstrated recently for sheep by Turner 1969.

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III. PRODUCTION ENVIRONMENTS

Australia's production of beef and veal derives almost entirely from grazing animals utilizing unimproved natural grasslands, or sown pastures with or without some supplementary feeding (Alexander and Carrail 1973). Ferguson 1973 has estimated that of the 87 million tonnes of digestible organic matter required for the 1970 production of beef and veal, only 3.5 million tonnes came from harvested feedstuffs.

In Northern Australia the rainfall has a decided summer incidence and also a marked year to year variability (Williams 1973). Accompanying this is a characteristic summer peak in both quantity and quality of pasture and an increased incidence of drought. In addition to the nutritional problems associated with the decline in quality and quantity of pasture in the winter and spring, cattle in this region regularly face extremes of temperature and humidity, and in certain areas must also cope with the effects of ectoparasites such as cattle tick and buffalo fly.

In Southern Australia the rainfall is more reliable and has a tendency towards increased winter incidence which becomes marked in Western Australia. Temperatures are less extreme but there is a greater change in . the number of daylight hours between summer and winter. These factors combine to favour pasture growth in spring and autumn, and to permit growth of improved pastures during the winter months. There is no clear demarcation line between these regions, and although the intermediate zone tends to combine the characteristics of both, year to year variability is high (Alexander and Carrail 1973).

IV. COMPARATIVE PRODUCTION DATA

The beef cattle industry in Australia has been based on British breeds (predominantly Hereford, Angus and Shorthorn) and this remains true in the South. However in Northern Australia there has been an increasing interest in zebu (Bos indicus) cattle and it is estimatedthat in 1970 approximately 30% of beef cattle in Queensland contained some Bos indicus genes (Alexander and Carrail 1973). British breeds of cattle are therefore to the beef industry what the Merino is to the sheep industry, and the various breed crosses or strains must be evaluated by comparison with them or with crosses among them.

(a) Within-breed Selection

Newman, Rahnefeld and Fredeen 1973 have published results for the first 10 years of a study of the response to selection for 12 months weight in two herds of beef Shorthorns in Canada. Measured as deviations from the mean of an unselected control line the responses were 4.8 $\pm$ 3.1 and 4.1 $\pm$ 3.0 kg/yr in males and 3.3 $\pm$ 2.7 and 2.3 $\pm$ 1.5 kg/yr in females. These responses represent realised heritabilities of about 0.5 for males and 0.4 for females, and amount to an overall annual rate of genetic improvement of about 1%. Results from other studies have been variable, some showing negative phenotypic time trends and others positive. However, Newman, Rahnefeld and Fredeen's experiment is the only one with a random bred control population for comparison and their results are therefore highly encouraging.

As far as we are aware there have been no published reports of attempts to improve reproduction rate by within-herd selection. However, reproductive ability is one of the components of selection in herds maintained by this Division at Rockhampton, Queensland (Rendel 1972), and preliminary investigations have recently begun in Western Australia and in this Division into the feasibility of selecting for increased twinning in cattle.

(b) Crosses among British Breeds

The main character we have chosen as a basis for comparison is the weight of calf weaned per cow joined. This is the product of three important components of production, viz. number of cows calving per cow joined, number of calves surviving to weaning per calf born, and weaning weight of calf. Heterosis in any component may arise by contributions from the calf genotype (individual heterosis) and from the cow genotype (maternal heterosis), and most experiments have allowed separation of these effects. Differences between groups in any component have been assessed by percentage deviations, which if not individually large should approximately add to the percentage deviation in the compound character (Turner 1958).

TABLE 1

Weighted average advantage of British crossbreds over purebreds in weight of calf weaned per cow joined and its components (data from Warwick 1970)

Contribution to overall heterosis from	Cows calving per cow joined (%)	Calves weaned per calf born (%)	Calf weaning weight (%)	Weight calf weaned per cow joined* (%)
Calf genotype	1.9	2.7	4.7	9.3
Maternal genotype	4.7	4.8	5.0	14.5
Both*	6.6	7.5	9.7	23.8

*Figures in this row and column are marginal totals and not observed data.

Table 1 summarizes data from 13 studies in which at least two of the Hereford, Angus and Shorthorn breeds and their reciprocal crosses by the same sires have been compared. Eleven of these studies were conducted in the U.S.A. and two in Argentina. Though the heterosis shown by any one component does not exceed 5%, the cumulative effects amount to an increase of more than 20% in weight of calf weaned per cow joined, by comparison with the average of the purebreds. In addition, the crossbreds enjoyed a 2 - 4% advantage in post-weaning rate of gain and/or slaughter or yearling weight, were slightly (0.6%) more efficient, had a tendency toward earlier first heats, and did not differ appreciably in important carcase characters (Warwick 1970).

(c) Dairy by British Breed Crosses

Beef produced from dairy breed animals surplus to requirements for milk production and not slaughtered for veal, is an important component of the total beef produced in Europe. It is a much smaller proportion in Australia, but is a potential source of increase should there be changes in the relative prices of beef and veal. However, in this paper we are interested in the potential usefulness of dairy breeds in enterprises primarily geared to beef production. The interest in utilizing dairy breeds stems from the possibility that increased milk production could make an important contribution to overall productivity, but this has been balanced by a meat industry prejudice against

"dairy-type" beef. Perhaps for this reason the available comparative data are not extensive, and unlike the beef breed crossing experiments, do not generally include all the major components of productivity.

Data on the relative maternal performance of dairy or dairy x beef cross cows and either purebred British beef breeds or their crosses are limited. Comparisons with Angus in New Zealand (Hight, Everitt and Jury 1971) and with Brown Swiss, Hereford and Angus in the United States (Cundiff 1970) have demonstrated the superiority of the purebred Friesian cow over the traditional British beef breeds in calf weaning weight and in weight of calf weaned per cow joined, there being no difference in calf crop weaned. In Britain the Meat and Livestock Commission 1971 has published an extensive set of comparisons of 200-day liveweights of suckler calves from Friesian x beef and various beef and beef cross cows, sired by a range of bull breeds. Calves from the Friesian x beef crossbred cows were always heavier than those from beef cows, but the magnitude of the differences depended on the environment: In harsh hill country the average difference was 1.7% but rose to 6% in the more favourable conditions on lowland farms. Finally, there is a preliminary report from a comparison of beef x Brown Swiss and beef x beef cows (all possible crosses among the Hereford, Angus and Charolais) at the U.S. Range Livestock Experiment Station, Miles City, Montana (Warwick 1970) which indicates an advantage for the beef x Brown Swiss cows of about 5.5% in calf crop weaned, and 11% in calf weaning weight.

There is much more information about breed and breed cross differences in weaning weight and various post-weaning traits, which has been summarized recently by a number of workers (Cundiff 1970; Everitt, Evans and Ward 1970; Meat and Livestock Commission 1971). Space limitations do not permit present-ation of all the data, but the following examples are indicative. At Miles City, Montana, under range conditions, crossbred calves from Brown Swiss cows sired by Hereford and Angus bulls were 18% heavier at 205 days than crossbred calves from Angus and Hereford cows sired by the same bulls (Pahnish et al. 1969). The Brown Swiss crosses were comparable to the beef crossbreds in post-weaning gain and only slightly lower in carcase grade. In an Iowa experiment involving Brown Swiss, Friesian, Angus and Herefords, heterosis estimates for 180 day weight averaged 6.4% for the beef x dairy crosses (Cundiff 1970).

The Meat and Livestock Commission 1971 has published a comparison of growth rates of steers of different breeds and crosses under three different management systems in Britain, viz. intensively fed, grazed, or yarded. 'Taking the value for purebred Friesians as 100, the Hereford x Friesian and Angus x Friesian steers were 108 and 90 respectively under grazing conditions and 107 and 87 in yards. In this latter environment beef breed cross steers had an average relative growth rate of 80.

On the evidence available, therefore, useful production gains can be made by systematic crossing of British beef breed animals and the larger dairy breeds. The increased milk supply of first cross cows is undoubtedly a major component of their superiority, and these crosses would therefore become increasingly useful if methods of increasing the incidence of twinning can be devised.

(d) European by British Breed Crosses

Interest in utilising the large European breeds of cattle to increase beef production stems from earlier work with the Charolais which indicated that this breed had exceptionally high growth rates and lean meat yield (Turton 1964). Since that time there have been many studies of the growth and carcase characteristics of European breed crosses, but because of the shortage of females of these breeds few experiments have included reciprocal crosses, and there are therefore few estimates of heterosis.

There are also too few data for the adequate characterisation of the European breeds for maternal performance or for estimates of heterosis in maternal traits in crosses with other breeds. There is almost no information on the maternal performance of the available European cross females (European breed male x British breed female) compared with either purebred British or British beef breed cross cows. A proper evaluation of these breeds in relation to the total production system is therefore not yet possible, and because much of the growth and carcase data have been obtained with stall-fed animals the usefulness of the breeds as sires of market generation animals in a pasture based production system is by no means clear.

The data in this paper are drawn largely from the reports of Cundiff 1970, Warwick 1970, and the U.S. Meat Animal Research Center, Clay Center, Nebraska 1970, 1973, and these articles should be consulted for further details. The results from a number of American. experiments in which the progeny of topcross or reciprocal cross matings among Charolais and British beef breeds have been evaluated, show that the Charolais crosses exceed the British purebreds and crosses among them in weaning weight, postweaning gain on feed, dressing percentage and tenderness of lean, but have slightly lower carcase grade (Cundiff 1970; Warwick 1970). Many but not all workers report increased incidence of calving difficulty when British beef breed cows carry calves by Charolais bulls, but age of dam has a major effect and first calf heifers are responsible for most of the problem deliveries (Cundiff 1970). The limited information available on the maternal ability of purebred or high grade Charolais cows compared with British beef breeds indicates a lower weaning percentage than Herefords when bred straight, and a higher percentage when crossed, higher milk production than Herefords, and a small advantage in calf weaning weight over Hereford and Angus (Cundiff 1970). Results are somewhat variable with small to moderate amounts of heterosis being observed for growth and efficiency, but little to none for carcase characters (Cundiff 1970; Warwick 1970).

Preliminary reports from the U.S. Meat Animal Research Center 1970, 1973, where bulls of the Charolais, Simmental, Limousin, South Devon and Jersey breeds have been used in the topcrossing phase, provide data in good agreement with the work reviewed by Cundiff and Warwick. Increased calving difficulties occur when calves are sired by bulls of the large breeds as compared with Angus, Hereford or Jersey bulls, and the problems are much more acute in first calf heifers. The large breed crosses are also superior to either the pure British breeds or their crosses in the important growth and carcase traits, but it must be remembered that the calves are creep fed preweaning, and that the postweaning data refer to pen fed animals. These data are summarised in 'Table 2. The original reports should be consulted for details of the minor differences among the large breed crosses.

Attention should be drawn to results from a reciprocal cross experiment involving Hereford, Angus and Charolais reported by Lasley et al. 1973. In this experiment the calves were not creep fed, and in two out of four years were grazed together postweaning for periods of 134 and 189 days prior to entering the feed lot. Dam and Sire breed differences were not significant for postweaning gain on pasture, nor were there significant differences between sire breeds and dam breeds in crosses or between reciprocal crosses. In addition, there was little or no heterosis observed when all crossbreds were compared with all purebreds, nor when specific two-breed crosses were compared with the average of the two breeds making up that cross.

TABLE 2

Performance of first cross calves from Angus and Hereford cows by bulls of the large beef breeds* and by Hereford and Angus bulls (data from U.S. Meat Animal Research Center, Nebraska, 1973)

Calves sired by the large breeds* vs.	Adjusted 200 day weight (%)	Daily gain post-weaning (%)	Efficiency kg TDN/ kg gain (%)	Dressing percentage (%)	Percent retail product (%)	U.S.D.A. quality grade (%)
Purebred and crossbred British	5.4	6.3	-3.0	0.2	5.2	-5.6
Crossbred British	3.6	4.7	-2.9	0.0	6.0	-6.7

*Simple average of mean performance of calves by Charolais, Simmental, Limousin and South Devon.

In assessing the possible role of the large European breeds in tropical and sub-tropical conditions we are severely handicapped by the paucity of data. However, in one study in Louisiana, Damon et al. 1959a,b, 1960 compared the offspring of Charolais, Shorthorn, Angus, Hereford, Brahman and Brangus bulls when bred to cows of the latter four breeds. The cows were run at pasture, but after weaning the steers were fed limited grain rations in addition to their grazing intake. Charolais cross calves at weaning were 2.5% heavier than Hereford cross, 4.9% heavier than the average of the Hereford and Angus crosses, and 8% heavier than the Brahman or Brangus cross calves. The Charolais were also heavier at slaughter (constant age), produced carcases with more lean and less fat, and the lean was as tender as that from any pure breed.

(e) Zebu by British Breed Crosses

The cattle industry in Northern Australia has until recently been dominated by the Shorthorns and Herefords, though their poor growth rate and low reproductive ability in tropical and sub-tropical regions of the world have long been recognised (Rendel 1972). In both the United States and Australia a considerable amount of research has been directed towards assessing the role that zebu breeds or crosses might play in improving production in these regions (Cundiff 1970; Warwick 1970; Mason 1966; Rendel 1972).

Averaged over a number of experiments, the data obtained in the Southern United States indicate that zebu cross calves exceed British types by about 11% in weaning weight, and that calf viability and weaning percentage are unaffected or marginally increased. Zebu cross cows also show advantages over British cows of about 8% in calf crop weaned and 15% in calf weaning weight. In terms of weight of calf weaned per cow joined the total heterosis is of the order of 25 - 35%, and since the difference between the purebreds in this environment is small, this amount of heterosis represents a substantial production increase. Finally, zebu cross steers fed postweaning appear to have an advantage over either purebred in postweaning gain, and to differ little in dressing percentage or carcase grade.

Studies at the C.S.I.R.O. National Cattle Breeding Station, "Belmont", Rockhampton, have shown an overall superiority of zebu cross animals by comparison with Shorthorn x Hereford (SH) crossbreds of roughly 45% in kg beef per cow mated (Seifert and Kennedy 1972). . In the F_1 generation, the Africander crossbreds (AX) and Brahman crossbreds (BX) were comparable in terms of this production index, and both were superior to the SH in fertility and growth rates. In the F_2 generation there was a significant decline in fertility in the BX population by comparison with the F_1's and the AX F_2, but no significant change in the weight gains.

It is therefore clear that substantial gains in production can be achieved by the systematic utilization of crossbreeding in Northern Australia, but zebu introductions in Australia and elsewhere have largely been used to form new breeds combining the heat tolerance and tick resistance of zebus with the beef qualities and temperament of British breed cattle. This process has given rise to the Santa Gertrudis, Braford and Brangus (3/8 zebu and 5/8 Shorthorn, Hereford and Angus respectively), the Droughtmaster (3/8 to 1/2 zebu and 5/8 to 1/2 Shorthorn with some Hereford), and more recently the Belmont Red (1/2 Africander, 1/4 Hereford, 1/4 Shorthorn). Comparative data on the relative performance of these new breeds are not available, but the superiority of the AX and BX selected strains by comparison with the SH selected strain at "Belmont" indicate the likely gain to be made over the traditional British breeds by crossing and selection for adaptation and performance. Both zebu cross strains are currently superior to the selected British crossbreds in weight gain, tick resistance and heat tolerance. The Belmont Red has in addition higher calving percentages than the British crossbred strain, but its weight gain, tick and helminth resistance are lower than in the BX strain.

V. DISCUSSION,

Introduced breeds may be used in Australian beef production in a number of ways, and we are now in a position to discuss the various alternatives. Though it is unlikely that any introduced breed will prove superior as a purebred to, all available local breeds, the possibility nevertheless exists at least in Southern Australia. Assessment of new breeds in the Australian environment should therefore involve both purebred (or high grade) and crossbred performance wherever possible.

The data reviewed in this paper confirm predicted rates of improvement in growth rate due to within-breed selection, and highlight the potential advantages of crossbreeding. The benefits associated with the use of Bos indicus cattle in Northern Australia are well documented and appreciated by producers in that region. The immediate gain in production on crossing is substantial, and new breeds combining the advantages of both Bos indicus and Bos taurus have obvious potential in the Northern regions. However, it is important to stress the value of continued selective breeding in the formation of such new breeds, thus ensuring the progressive increase in frequency of desirable genes from both species.

It could be argued that additional importations of zebu cattle might be valuable in view of the small numbers originally introduced. In our view the benefits would be marginal, except possibly in the case of the purebred Africander, which may possibly be used widely throughout the North as a primary crossing breed (Anon 1970).

In Southern Australia, substantial increases in production are likely to result from systematic crossbreeding among the existing British beef breeds, or from crossing programmes involving beef x dairy crosses. In the longer term,

improvement in growth traits can almost certainly be made by within-breed selection based on measured performance, and this is likely to be reflected in increased crossbred production as well as purebred performance. Improvement in reproductive ability can be achieved only by crossbreeding unless direct selection for twinning proves useful. These expectations are based on overseas data, and though we see no reason why they should not hold for local British breeds, this of course remains to be tested. If they are substantiated, it is not difficult to imagine a beef production system for Southern Australia based on beef x beef or beef x dairy cross females, with sires from breeds selected solely for growth and carcase qualities.

What then is the role of the large European breeds? There is as yet little information obtained under grazing conditions. In many American experiments calves have access to creep feeding, and while the large breed crosses have higher weaning weights, this advantage might be reduced in a pure pasture situation and be more than offset by the increased calving difficulties. It is not an original remark but nonetheless-very pertinent in this context, "dead calves have exceedingly poor growth rates!" As regards postweaning gain, the only evidence obtained under grazing conditions (Lasley et al. 1973) indicated no advantage for the large breeds.

It is likely that the European breeds and the South Devon have useful genes to contribute to Australian cattle populations, if only in the formation of synthetic populations from which new breeds may be evolved by selective breeding. They may of course also prove valuable in systematic crossing programmes. The present need is for carefully controlled experimental comparisons in a number of environments, involving a small number of the most promising new breeds. State Departments of Agriculture are currently involved in such evaluations, and will provide the critical data necessary for the decisions regarding further imports of European genotypes.

Evidence from American experiments clearly illustrates the substantial advantages in growth, carcase traits, and efficiency of food conversion of the large breed crosses in a feedlot environment. Provided the calving difficulty problems associated with their use as sires can be overcome (perhaps by joining them with dairy cross dams), the large breeds will undoubtedly play a major role in the production of beef from feedlots.

Given the uncertainties regarding the gains to be made by utilising large beef breeds in production systems based on grazing animals, and the small size of the feedlot industry in Australia, the total requirement for exotic genes should not be large. Under these circumstances Australia can afford to be selective in its importations, and from a genetic standpoint should ensure that semen from bulls with known genetic defects is not imported, that prospective semen donors be checked for the more obvious cytological defects, and if possible be proven high producers, and that too great a concentration on semen from any one bull is not permitted.

The animal health implications are also clear. For the present, and until evidence establishing the role of these breeds in Australia is obtained, minimum-risk importation procedures should be retained.

VI. REFERENCES

ALEXANDER, G.I., and CARRAIL, R.M. (1973). "The Pastoral Industries of Australia". (Ed. G. Alexander and O.B. Williams.) 143. (Sydney University Press: Sydney).

ANON. (1970). Rural Research in C.S.I.R.O. 69: 18.
BUREAU OF AGRICULTURAL ECONOMICS. (1973). "National Agricultural Outlook Conference - Documents and Discussion" (v.2. Livestock Products.) F 1. (Aust. Govt. Publ. Serv: Canberra).
COUTTS, D., and FERNON, B. (1971). Q. Rev. agric. Econ. 24: 25.
CUNDIFF, L.V. (1970). J. Anim. Sci. 30: 694.
DAMON, R.A., McCRAINE, S.E., CROWN, R.M., and SINGLETARY, C.B. (1959a). J. Anim. Sci. 18: 437.
DAMON, R.A., McCRAINE, S.E., CROWN, R.M., and SINGLETARY, C.B. (1959b). J. Anim. Sci. 18: 1103.
DAMON, R.A., CROWN, R.M., SINGLETARY, C.B., and McCRAINE, S.E. (1960). J. Anim. Sci. 19: 820.
EVERITT, G.C., EVANS, S.T., and WARD, J.D.B. (1970). "New Zealand beef -production, processing and marketing." (Ed. A.G. Campbell.) 113. (N.Z. Institute of Agricultural Science: Wellington).
FERGUSON, K.A. (1973). "The Pastoral Industries of Australia". (Ed. G. Alexander and O.B. Williams.) 521. (Sydney University Press: Sydney).
FOOD AND AGRICULTURE ORGANIZATION (1970). "Agricultural Commodity Projections, 1970-1980." (Vol. 1, Part 2.) 126.(F.A.O.: Rome.)
HIGHT, G.K., EVERITT, G.C., and JURY, K.E. (1971). Proc. N.Z. Soc. Anim. Prod. 31: 43.
LASLEY, J.F., SIBBIT, B., LANGFORD, L., COMFORT, J.E., DYER, A.J., KRAUSE, G.F., and HEDRICK, H.B. (1973). J. Anim. Sci. 36: 1044.
MASON, I.L. (1966). Anim. Breed. Abstr. 34: 453.
MEAT AND LIVESTOCK COMMISSION (1971). "Beef Improvement - Scientific Study Group Report." (Meat and Livestock Commission: London).
NEWMAN, J.A., RAHNEFELD, G.W., and FREDEEN, H.T. (1973). Can. J. Anim. Sci. 53: 1.
PAHNISH, O.F., BRINKS, J.S., URICK, J.J., KNAPP, B.W., and RILEY, T.M. (1969). J. Anim. Sci. 28: 291.
PATTIE, W.A. (1973). "The Pastoral Industries of Australia." (Ed. G. Alexander and O.B. Williams.) 303. (Sydney University Press: Sydney).
PRESTON, T.R., and WILLIS, M.B. (1970). "Intensive Beef Production." (Pergamon Press: New York).
RENDEL, J.M. (1972). Wld. Rev. Anim. Prod. 8: 48.
SEIFERT, G.W., and KENNEDY, J.F. (1972). Proc. Aust. Soc. Anim. Prod. 9: 143.
TURNER, H.N. (1958). Aust. J. agric. Res. 9: 521.
TURNER, H.N. (1969). Anim. Breed. Abstr. 37: 545.
TURTON, J.D. (1964). Anim. Breed. Abstr. 32: 119.
U.S. MEAT ANIMAL RESEARCH CENTER (1970). "Cattle Germ Plasm Evaluation Program - A preliminary report." (Clay Center: Nebraska.)
U.S. MEAT ANIMAL RESEARCH CENTER (1973). "Cattle Germ Plasm Evaluation Program - Preliminary report." (Clay Center: Nebraska).
WARWICK: E.J. (1969). "Proceedings of the Second World Conference on Animal Production, University of Maryland." 149. (American Dairy Science Assocn.: Urbana, Ill.)
WARWICK, E.J. (1970). "Proceedings of Refresher Course for Veterinarians on Beef Production." 1. (University of Sydney Post-Graduate Committee in Veterinary Science: Sydney).
WILLIAMS, O.B. (1973). "The Pastoral Industries of Australia." (Ed. G. Alexander and O.B. Williams) 3. (Sydney University Press: Sydney).