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A STUDY ON SELECTION METHODS FOR BULLS IN BEEF CATTLE POPULATION WITH OPEN NUCLEUS BREEDING GROUP

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Introduction

A research plan was designed regarding the optimal breeding plan for beef cattle population with overlapping generations, and it was found that there were differences in the expression pattern of genetic gains among paths of selection, and among traits even within the same path[4]. This suggested that the application of a selection criterion specific to each selection path might be highly effective to improve multiple traits simultaneously. In our previous study[4] we examined the optimal combination of traits on the basis of selection of bulls which were chosen as sires of beef fattening cattle in two stages. The selection method where the bulls were selected for growth traits from records of individual performance test at the first stage and for only carcass traits from progeny records at the second stage was found to be effective to improve the growth and carcass traits simultaneously, even when records of growth traits from progeny tests were available for the second selection.

Discussing the optimal allocation of traits in the selection bases, it was important to confirm the expression pattern in response to the selection and to seize the marginal improvement attained by alternate paths. The objectives of this study are to investigate the response for selection by each path in a simulated beef cattle population, when the selection criterion specific to each path is changed according to the objectives of mating, and to discuss the problems regarding the current plan which has been carried out in Japan. The breeding plans considered here were intended to improve reproductive traits in reproduction cows and beef productive traits in beef fattening cattle simultaneously.

Methods

Beef cattle population was composed of three groups which were the open nucleus breeding group, reproduction cow group and beef fattening cattle group as in our previous study[4]. 400 young bulls produced every year in the nucleus breeding group were tested on individual performance including daily gain and feed conversion ratio, and 80 of the best bulls were selected on the basis of these records at the first stage. The selected young bulls were then progeny-tested on dressing percentage and carcass grade using 20 castrated male progeny per bulls and/or calving interval using 20 daughters. The best 40 tested bulls were selected on the basis of their progeny records at the second stage. Only the best 20 bulls were mated to cows in the nucleus group to produce young bulls and the replacement heifers. The best 40 young bulls selected at the first stage, began mating as sires of beef fattening cattle in some of the breeding systems considered here.

The objectives of improvement were to increase daily gain, dressing percentage, carcass grade and to decrease feed conversion ratio in fattening cattle (beef productive traits), and to decrease calving interval in cows (reproductive trait). Calving intervals were measured in days from the first to the second parturition predicted by the nonreturn of estrus.

Bulls were selected by single stage or two-stage selection. The selection indices for multiple traits, were calculated according to the method of YAMADA et al[5]. Genetic parameters used to compute the selection indices and to predict genetic superiority of selected bulls were the same as in previous paper[4] and the values concerning calving interval are shown in Table 1, in which correlations for calving interval with other beef productive traits are assigned to the same coefficient of genetic and phenotypic correlations. The bias in parameters due to selection at the first stage were justified by the procedure of ROBERTSON[3]. Desired relative genetic gain to define selection indices was a genetic standard deviation for each trait. 11 combinations of the first and second selection basis were compared, and were referred to selection methods (SM-1 to 11) as shown in Table 5.

In this study, the response to selections was predicted on each path of inheritance ; sires of bulls, sires of replacement heifers in the nucleus breeding

Table 1. The genetic parameters of calving interval and its relationship with other treits used in this study.

Standard deviation	65days	
Coefficient of variation	18%	
Heritability	0.05(0.02;3)[a]	
Genetic and phenotypic correlation coefficient	with daily gain, dressing percentage and carcass grade	with feed conversion ratio
(r_g= 0.00)	0.00	0.00
(r_g= 0.10)	0.10	−0.10
(r_g= −0.10)	−0.10	0.10

[a]The values in (;) show median estimates and the number of estimates reported[2].

group (D(N)'s sires) and reproduction cow group (D(R)'s sires), and sires of fattening beef cattle (Beef's sires). Since a part of the young bulls selected at the first stage began to be used as sires of beef cattle, responses to selection of the sires were separately predicted for young bulls and for proven bulls. Therefore, five paths of selection were evaluated in total. The initial nucleus breeding group was assumed to be found by selecting females with 1 genetic standard deviation in daily gain as a criterion of genetic superiority from the reproduction cow group. Age structure of sires depends on the applied methods of performance test and on the age at selection and at first service, and this dependence is reflected on the expression pattern of improvement. Then, 5 types of mating plans according to the age structures were assumed as shown in Table 2.

Selection methods are not always the same for all paths. The assignment of selection methods to each path are presented in Table 3. The combinations of selection methods and paths are called breeding systems (BS-1 to 9) in this study. Official evaluation of bull performance practiced in our country today,is based on both of individual and progeny testing for meat productive traits, but the records of reproductive traits on daughters are not available to evaluate bulls. The first breeding system (BS-1 ; MP-1) corresponds to the current breeding system in Japan. The second and third mating plan (MP-2, 3) assuming that progeny testing for reproductive traits on daughters was practised also, and records of reproductive trait (calving interval) were available in some selection methods,

Table 2. Mating plans and combinations of performance tests applied to bulls.

Mating plans	MP-1	MP-2	MP-3	MP-4	MP-5
Evaluation of					
Bulls					
Individual test	0	0	0	0	0
Progeny test					
Beef test	0	0	0	–	0
Calving test	–	0	0	–	–
Records used to select beef's sires					
Individual test	0	0	0	0	0
Progeny test					
Beef test	0	0	0	–	0
Calving test	–	–	0	–	–
AI service of					
Young bulls	0	0	–	0	–
Proved bulls	0	0	0	–	0

For o refers to applied and – refers to not applied.
For beef and calving test refer to beef production and calving ability testing respectively.

Table 3. Breeding systems and selection methods applied to each path.

Paths	Bull's sire D(N)'s sire	D(R)'s sire	Beef's sire(1) (young bulls)	Beef's sire(2) (proved bulls)	Mating plans
Breeding systems					
1. BS-1	SM2-20	SM2-40	SM11-40	SM2-40	MP-1
2. BS-2	SM1-20	SM1-40	SM11-40	SM2-40	MP-2
3. BS-3	SM1-20	SM7-40	SM11-40	SM2-40	MP-2
4. BS-4	SM1-20	SM1-40	......	SM1-40	MP-3
5. BS-5	SM9-20	SM9-40	SM9-40	......	MP-4
6. BS-6	SM10-20	SM10-40	SM10-40	......	MP-4
7. BS-7	SM4-20	SM4-40	......	SM4-40	MP-5
8. BS-8	SM6-20	SM6-40	......	SM6-40	MP-5
9. BS-9	SM8-20	SM8-40	......	SM8-40	MP-3

In selection method SMm-n, m shows the number of selection method in Table 5 and n shows the number of selected bulls.

except for sires of beef cattle. Selection methods in BS-2 was the same for all sires of bulls and for replacement heifers in nucleus breeding and reproduction cow groups. In BS-3 sires of reproduction group were selected only for calving intervals on the basis of daughter records at the second stage. Selection method in BS-4 was the same for all paths, and young bulls were not used as sires of beef cattle until finishing the progeny test. Breeding system 5 to 9 (BS-5 to 9) were set up to predict the marginal improvements by single trait selection of the same trait for all paths. Procedures to predict selection responses were the same as in the previous paper[4].

Results

1. Yearly responses to selection by paths

Predicted yearly genetic responses in beef productive traits(1) and reproductive traits(2) with the mating plan of MP-2 for five paths of selection and the effect of initial differences were presented in Fig. 1, when the breeding stock with one unit of genetic superiority are selected every year, and the foundation stock of the breeding group was superior to the reproduction cow group by the same unit in daily gain. The selection of bulls as sires of fattening cattle contributed to a large response in beef productive traits sooner and rapidly, but it reached a plateau early. In contrast, the selection effects of sires of bulls and reproduction cows increased linearly, and yielded the largest responses in the long-term.

The soonest and the most rapid response in calving interval was attained through selection of sires of reproduction cows. Selection of bull sires expressed the response later than that path, at the same rate of increase as in beef productive traits. The effect of initial difference was expressed rapidly in early years corresponding with the start of AI service as sires of fattening cattle (for beef production) or as sires of reproduction cows (for calving interval), but here again,

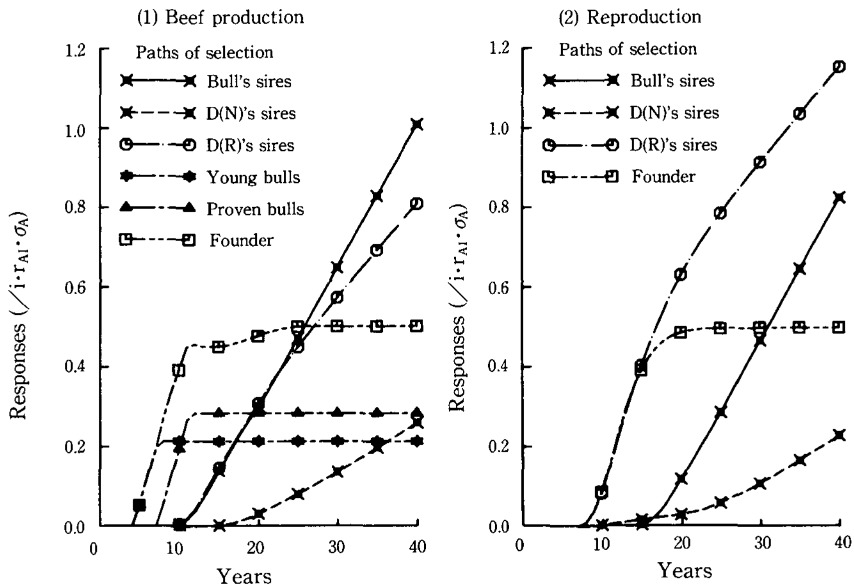

Fig. 1 Predicted response to selection in beef productive traits(1) and reproductive traits(2) by paths when MP-2 is applied. D(N)'s sires, D(R)'s sires, and Founder refer to sires of nucleus female replacements, sires of reproduction cows and initial foundation stock of nucleus respectively.

the plateau was reached. The effects of bulls as sires of replacement cows in breeding group were smaller for both traits than other paths of selection.

2. Effects of different age structures of parents on the expression of responses

When the records combined in the selection criteria are not always measured at the same age, the age at selection depend on the age at which the last record can be obtained, and the ages at mating reflected on the age structure of parent and generation intervals (mating plans), affecting the expression of responses.

Yearly responses when five mating plans in Table 2 were applied, were shown in Fig. 2 (beef productive traits) and 3 (reproductive trait) by paths of selection. Differences among mating plans (MP-1, 2, 3, 4, 5) in the expression patterns of responses are due to differences in generation intervals. The average ages of sires at the birth of their offspring are presented in Table 4. MP-4 was the shortest (15.2 years) of 5 paths and was followed by MP-1, -5, -2, -3 (25.6, 27.2, 28. 6, 31.2) in the total years of four generation intervals. The higher selection responses in beef productive traits for sires of bulls and cows in the nucleus and reproduction groups were obtained at smaller amount of total years. However, the response of sires of fattening cattle depended on the average age of the sire alone. The responses in reproductive trait were free from the selection of beef cattle sires and depended on the total years of other three paths of sires. Though

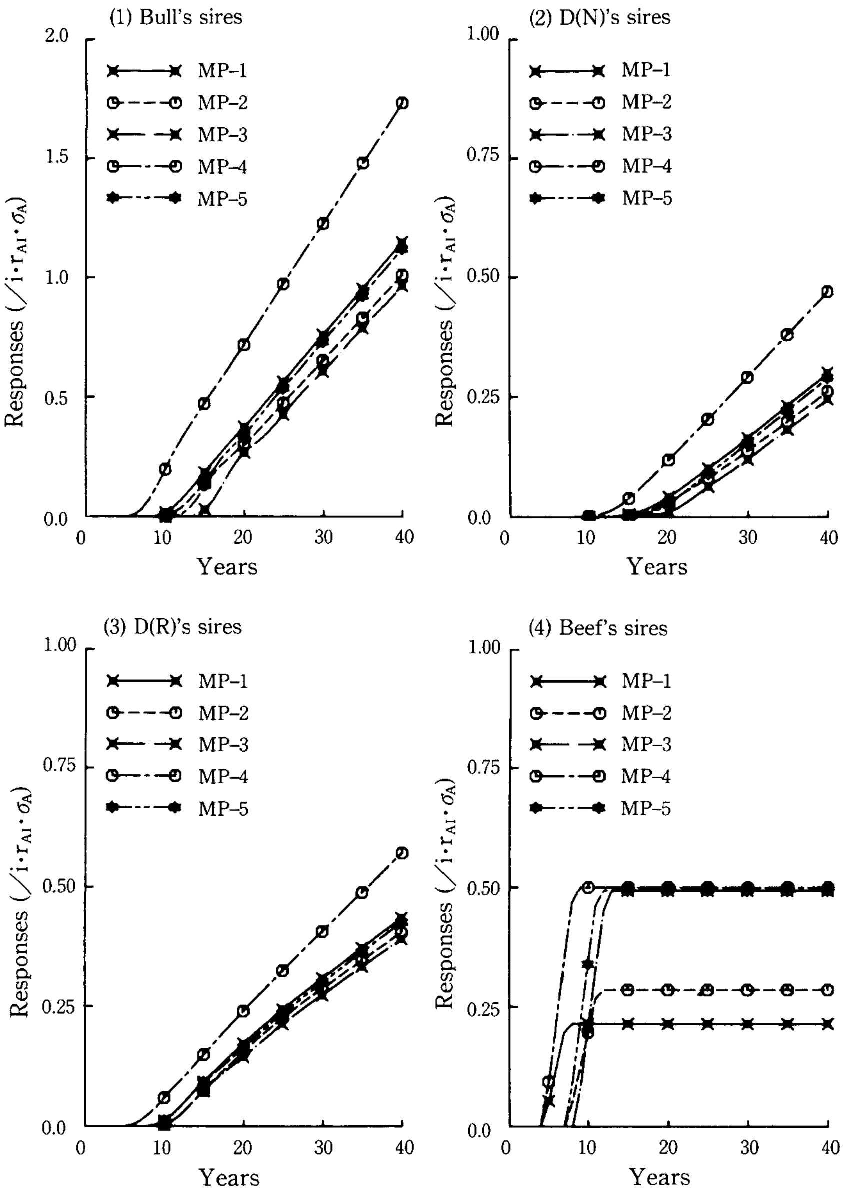

Fig. 2 Comparison of responses in beef productive traits among mating plans by paths of selection. For mating plans refer to Table 2.

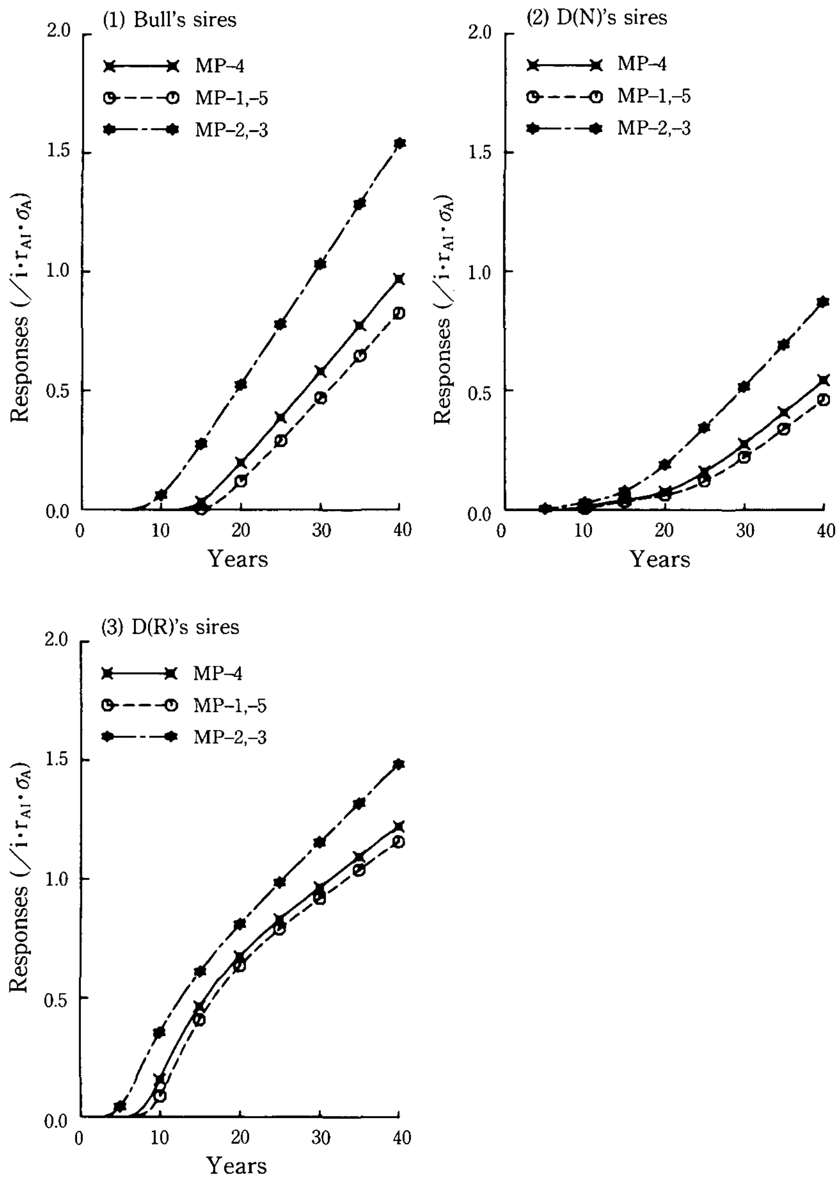

Fig. 3 Comparison of responses in reproductive traits among mating plans by paths of selections.

in the mating plan MP-1 and -5, bulls were selected on beef production based on the individual performances, the appearance of responses in reproductive traits were sooner and more rapid than in other plans. This suggested that the correlated responses to select only beef productive traits would be important if the traits are genetically correlated with the beef productive traits.

Table 4. Average ages of sires at the birth of replacements in next generation by mating plans(years).

Mating plans	Parents		Total age of parents[a]
	Sires of bulls and replacement heifers in both groups.	Sires of beef fattening cattle	
MP-1	6.8	5.2	25.6
MP-2	7.8	5.2	28.6
MP-3	7.8	7.8	31.2
MP-4	3.8	3.8	15.2
MP-5	6.8	6.8	27.2

[a] Total age of parents are the sum of 4 parents.
Example for MP-1, $25.6=6.8\times3+5.2$.

3. Comparison among breeding systems in expected genetic improvement

The expected genetic superiorities of bulls which were selected on the criteria for 11 combinations of objective breeding values at the first and second stage, are presented in the Table 5.

To examine the optimal selection criterion applicable to each of the paths, the predicted genetic improvement after 20 and 40 years, are presented in Fig. 4 ($r_g=0.0$). Selection methods (SM-1, 2, 4, 6, 7, 8, 9, 10, 11) in Table 5 were applied to selection path as shown in Table 3. Breeding method S in Fig. 4 shows the maximum gain resulting from selection by single trait (breeding system BS-5, 6, 7, 8, 9 in Table 3). In breeding system BS-1 bulls were selected only on the individual performances (daily gain and feed conversion ratio) at the first stage and selected on progeny records of carcass traits at the second stage. This system was expected to attain the largest improvement in four meat productive traits especially in carcass traits among the four systems (BS-1, 2, 3, 4), but the response in calving interval was near zero. The improvements by BS-2 in both carcass traits were much smaller than those of BS-1, although a larger improvement in calving interval could be expected. Since sires of beef fattening cattle in BS-4 started mating after the second stage of selection and were selected using the same criteria as other paths, the improvements in four beef production traits were smaller than in BS-2. The largest improvement in calving interval was achieved in BS-3 resulting from large responses to selection of sires of replacement heifers in reproduction cows group, but gains in carcass traits decreased inversely.

Relative genetic improvement among breeding systems can also be compared in Fig. 4 for each trait, but the comparisons among traits in this figure are not always useful. Total expected genetic gains at the 20 th and 40 th year by each breeding system (BS-1, 2, 3, 4) are tabulated in Table 6 in genetic standard deviation units. Expected total genetic improvements at the 40 th year by four paths of selection were 5.57, 4.87, 2.65, 2.45 and 1.01 unit for daily gain, feed

Table 5. Expected genetic superiorities of bulls selected by the following methods.

	Selection methods(SM)										
	SM-1	SM-2	SM-3	SM-4	SM-5	SM-6	SM-7	SM-8	SM-9	SM-10	SM-11
	Desired relative genetic gains										
1st stage selection											
Daily gain(g)	78	78	78	NS	78	NS	78	NS	++	NS	78
Feed con.R.	−0.62	−0.62	−0.62	NS	−0.62	NS	−0.62	NS	NS	--	−0.62
Proportion	80/400	80/400	80/400		80/400		80/400		40/400	40/400	40/400
2nd stage selection											
Dress.%	1.34	1.34	++	++	NS	NS	NS	NS	NS	NS	NS
Carcass G.	0.44	0.44	NS	NS	++	++	NS	NS	NS	NS	NS
Calving I.	−14.5	NS	NS	NS	NS	NS	--	--	NS	NS	NS
Proportion	40/80	40/80	40/80	40/80	40/80	40/80	40/80	40/80			
	Expected genetic superiorities										
r_g=0;											
Daily gain	69	71	62	−3	77	12	66	0	96	47	83
Feed con.R.	−0.53	−0.53	−0.60	−0.08	−0.46	0.06	−0.53	0	−0.42	−0.69	−0.66
Dress.%	0.50	0.80	1.02	0.91	0.32	0.21	0.11	0	−0.08	0.30	0.14
Carcass G.	0.15	0.25	0.10	0.08	0.30	0.27	0.02	0	0.14	−0.07	0.03
Calving I.	−4.3	0	0	0	0	0	−5.2	−5.2	0	0	0
r_g=0.10;											
Daily gain	67	71	62	−3	77	12	64	3	96	47	83
Feed con.R	−0.52	−0.53	−0.60	−0.08	−0.46	0.06	−0.51	0.02	−0.42	−0.69	−0.66
Dress.%	0.48	0.80	1.02	0.91	0.32	0.21	0.06	−0.05	−0.08	−0.30	0.14
Carcass G.	0.15	0.25	0.10	0.08	0.30	0.27	0.02	0	0.14	−0.07	0.03
Calving I.	−2.4	2.2	2.5	1.0	1.6	0.0	−3.6	−5.2	1.8	1.6	2.0
r_g=−0.10;											
Daily gain	71	71	62	−3	77	12	68	3	96	47	83
Feed con.R.	−0.53	−0.53	−0.60	−0.08	−0.46	0.06	−0.54	−0.02	−0.42	−0.69	−0.66
Dress.%	0.52	0.80	1.02	0.91	0.32	0.21	0.16	0.05	−0.08	0.30	0.14
Carcass G.	0.16	0.25	0.10	0.08	0.30	0.27	0.02	0.00	0.14	−0.07	0.03
Calving I.	−6.0	−2.2	−2.5	−1.0	−1.6	0.0	−6.7	−5.2	−1.8	−1.6	−2.0

r_g are genetic relationships of calving interval to daily gain, feed conversion rate and dressing percentage. ++ and -- refer to increasing and decreasing directions and NS nonselection. Feed con.R.,Dress.%, Carcass G. and Calving I. refer to feed conversion ratio, dressing percentage(%), carcass grade and calving interval(days) respectively.

conversion ratio, dressing percentage, carcass grade and calving interval respectively (Table 6), when bulls were selected for a single trait on the basis of SM-9, SM-10, SM-4, SM-6 or SM-8 (Table 5). The fact that the improvement in dressing percentage and carcass grade were smaller than in daily gain and feed conversion ratio, was due to a weaker selection intensity for carcass traits, the

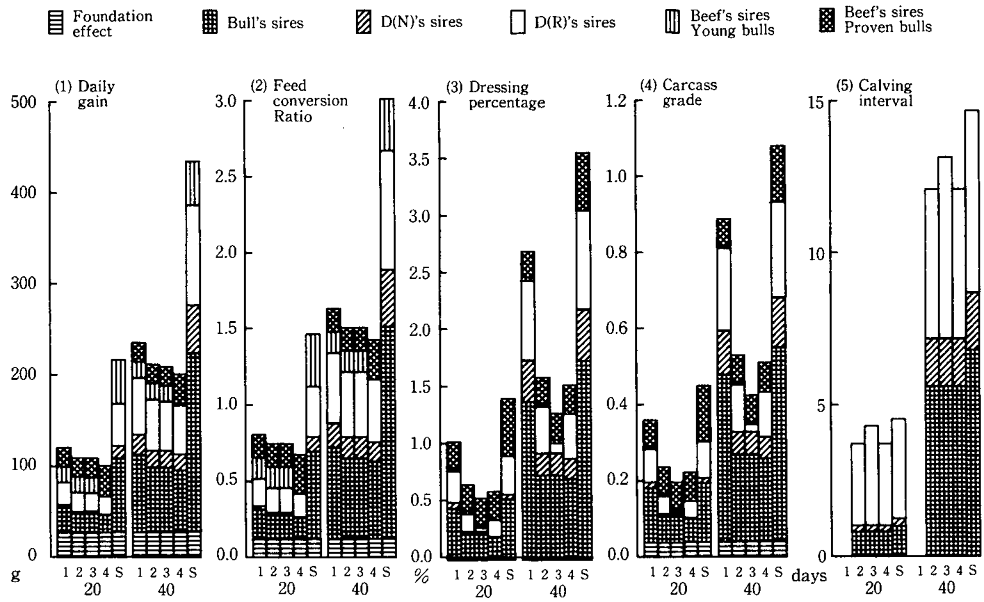

Fig. 4 Predicted total improvement after 20 and 40 years when one of 5 breeding systems is applied. 1 to 4 refer to BS-1 to 4 in Table 3 and S refer to single trait selection (BS-5 to 9 in the same table).

Table 6. Expected total genetic gains by all paths of sires in the unit of genetic standard deviation

Traits	Genetic standard deviations	r_g	BS-1 20	BS-1 40	BS-2 20	BS-2 40	BS-3 20	BS-3 40	BS-4 20	BS-4 40	Single trait 20	Single trait 40
Daily	78	0.00			1.39	2.67	1.40	2.70	1.29	2.57		
gain	g	0.10	1.54	3.00	1.37	2.60	1.38	2.63	1.26	2.49	2.77	5.57
		−0.10			1.41	2.74	1.42	2.76	1.31	2.60		
Feed	0.62	0.00			1.20	2.43	1.20	2.43	1.09	2.30		
conversion		0.10	1.30	2.64	1.19	2.39	1.19	2.40	1.08	2.27	2.36	4.87
ratio		−0.10			1.21	2.47	1.21	2.47	1.11	2.35		
Dressing	1.34	0.00			0.38	0.94	0.48	1.18	0.43	1.13		
percentage	%	0.10	0.76	2.00	0.36	0.87	0.46	1.13	0.41	1.07	1.04	2.65
		−0.10			0.40	0.99	0.49	1.22	0.45	1.17		
Carcass	0.44	0.00			0.45	0.97	0.54	1.20	0.50	1.15		
grade		0.10	0.82	2.02	0.44	0.93	0.53	1.15	0.48	1.10	1.02	2.45
		−0.10			0.46	1.00	0.55	1.24	0.52	1.20		
Calving	14.5	0.00	0.00	0.00	−0.30	−0.90	−0.26	−0.83	−0.26	−0.83		
intervals	days	0.10	0.18	0.43	−0.17	−0.59	−0.03	−0.33	−0.03	−0.33	−0.31	−1.01
		−0.10	−0.18	−0.43	−0.42	−1.20	−0.39	−1.15	−0.39	−1.15		

latter being selected on the records of progeny test. Such a small improvement in calving interval was caused by its low heritability and because of the low selection intensity applied to it. When bulls were selected on BS-1 similar to current breeding method in Japan, the improvement in four traits of beef productive ability were as large as 2 to 3 times of genetic standard deviation after 40 years, but the improvement in calving interval was small. The method which achieved largest improvement in the trait was BS-3. However, gains in dressing percentage and carcass grade were less than a half of those with BS-1, and are also less than those with another two system (BS-2 and 4).

Daily gain and feed conversion ratio were expected to be improved by about 2.3 to 3.0 times of genetic standard deviation after 40 years with any breeding system. However, the improvement in both carcass traits were only 0.9 to 1.2 times, though further improvement could be attained when bulls were selected on the basis including these two traits at the second stage.

As the heritability of calving interval is very low and the record of their daughters are necessary for bulls to be selected, the improvement of this trait is limited especially if this trait has positive genetic relationships with meat productive traits.

The contribution of each selection path to the total improvement was presented in Table 7, when bulls were selected by single trait. These values depend on the proportion of genes transmitted from the selected sires to fattening cattle or reproduction cows, and on the intensity of selection applicable to each path.

Table 7. Contribution of each path selection to total improvement after 20 and 40 years when bulls are selected for single trait.

Traits	Years	Total gain	Contribution(%) Bull's sires	D(N)'s sires	D(R)'s sires	Beef's sires
Daily gain (g)	20	206	39	7	22	23
	40	406	48	13	27	12
Feed conver-tion ratio	20	−1.42	41	7	23	24
	40	−2.90	48	13	27	12
Dressing percentage(%)	20	1.39	38	3	24	36
	40	3.55	49	13	24	14
Carcass grade	20	0.43	36	3	23	34
	40	1.04	49	13	24	14
Calving intervals (days)	20	−4.5	22	6	73	0
	40	−14.6	46	13	41	0

The selection of bull sires shows a maximum contribution to the improvement in 4 beef productive traits after both 20 and 40 years. About a half of the total improvement was attained in all traits after 20 years of selection. The improvement from sires of reproduction cows was about one quarter in beef production traits after either 20 or 40 years, and amounted to about three quarters after 20 years, equalizing the value of bull sires after 40 years in calving interval. The selection of bull sires was the most important to improve all traits and the selection of the sire of reproduction cows contributed mostly to short-term improvement in reproductive trait (calving interval).

Discussion

In the national project for improvement of beef cattle currently practiced in Japan, the top one fifth of young bulls are selected on the basis of individual performance testing (growth traits) and half of the selected young bulls are secondarily selected according to progeny test records (growth and carcass traits). Since the selection for growth traits can be practiced more intensely than for other traits, growth traits (daily gain and feed conversion ratio) can be easily improved as shown in Table 6. If other traits (carcass and reproductive traits) are intended to be improved in addition to growth traits, the intensity of the second selection should be increased with respect to that of the first stage. However, stations with a larger capacity for progeny test will be required. An alternative system to solve the problem is to make full use of the records from fattening beef cattle at slaughter time and from reproduction cows, through field system of progeny test. If bulls were selected for growth traits at the first stage by using the records of individual performance test, it would not be necessary for these traits to be combined in the selection criterion at the second stage[4]. This means that the field system of progeny test for beef production performance will be effective, if collection and analysis of carcass traits records at slaughter time are well organized.

In order to give stability to beef production, improvement of calving ability in reproduction cows is of most important. The selection of sires of reproduction cows contributed a great deal to improvement in the reproductive traits of reproduction cows and also considerably to the improvements in the other traits. This means that calving interval can be largely improved but the levels of genetically correlated traits will be changed, if the bulls selected for only this trait at the second stage are used as sires of reproduction cows. If the improvement in carcass traits is attempted to be increased through other paths, the intensity of selection at the second stage should be increased as described earlier or, another way would be to incorporate a part of carcass traits in the selection criterion at the first stage by the use of the scanning methods in individual performance test. Ultrasonic measurements of the subcutaneous fat layer and eye muscle area have been found to give a good description of carcass composition[1].

Objectives of improvement to be attained are not always of the same level for all traits and they depend on the actual levels and on the relative importances in their economic contribution to productivity. Optimal selection criterion to be applied to each path of sires should be decided by trial and error in response to actual objectives of improvement. If carcass and reproductive traits are intended to be improved more than growth traits, those problems described previously would be solved.

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Summary

In this study, the short- and long-term responses in beef productive and reproductive traits were predicted, when some specific selection criteria were applied to each path of sires according to mating objectives. And also, the optimal allocation of traits to be combined in the criterion was investigated. The traits to be improved were growth traits (daily gain and feed conversion ratio), carcass traits (dressing percentage and carcass grade) and a reproductive trait (calving interval). Bulls were selected at two stages by using records of individual performance testing (growth traits), and records of progeny testing (carcass and reproductive traits). If the top 20% of young bulls were selected for growth traits at the first stage and a half of these chosen bulls were also selected for carcass and/or reproductive traits at the second stage, the improvements in daily gain and feed conversion ratio were expected to be easily obtained. However, those in carcass and reproductive traits were less than half of growth traits, because the intensities of selection for them were low. The selection of bull's sires contributed mostly to the improvement in all traits, though the maximum improvement for calving interval in the short-term, was attained by selecting sires for reproduction cows. If further improvement in calving interval is intended, it is effective to select sires for reproduction cows with criterion which was weighted more than the beef productive trait. However, the improvement in carcass traits through this path of selection would be decreased. The optimal breeding methods to improve these traits evenly and simultaneously would be those in which the selection criteria are specific for the selection path. Namely, at the 1st stage young bulls are selected for growth traits, and at the 2nd stage, bulls sires for both carcass and reproductive traits, sire for fattening cattle for carcass traits only, and sires of reproduction cows are selected for carcass and reproductive traits by the criterion which was weighted according to the relative importance among objectives.

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