WORLD RABBIT SCIENCE 1995, 3(4), 179-186.

SELECTING LITTER SIZE IN RABBITS : ANALYSIS OF DIFFERENT STRATEGIES.

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ABSTRACT : A Family Index and a reduced BLUP using records of two generations, have been compared with a BLUP under a repeatability animal model that used all records (complete BLUP). An analysis of robustness of the methods to changes in genetic parameters was also carried out and four types of assortative mating were compared with random mating through the ratio of expected responses per unit of time. Records of 18 and 14 generations of two lines of rabbits selected for litter size at weaning were used, and the selection process was studied in generation 17, 18 of one line, and 13, 14 of the other. The two simplified methods were practically the same in our study with non overlapping generations and good balance between animals to be selected and fixed effects. The correlations between rankings and between genetic evaluations of matings or individuals of a simplified method and the BLUP using all records ranged between 0.65 and 0.98. The coincidence ratio of selected matings is between 0.62 and 0.94, and the response loss ratio between 0 and 0.17, being the average around 0.05 and 0.06. The methods of selection revealed themselves as very robust. Finally, it was concluded that the only type of assortative mating that increased the response in relation to the random mating was the one carried out early in the process of selection to obtain females, being the range of the ratio of responses per unit of time 1.067-1.197.

RÉSUMÉ : Sélection sur la taille de portée chez le lapin : analyse de différentes stratégies.
Un index de sélection familiale et une sélection selon un BLUP réduit utilisant les données de 2 générations ont été comparés à un sélection par BLUP "complet" basée sur le modèle animal utilisant la totalité des données disponibles. Une analyse de la robustesse des méthodes a aussi été conduite vis à vis des modifications des paramètres génétiques. Quatre types d'accouplements associatifs ont été comparés à des accouplements au hasard, sur la base du rapport des réponses attendues par unité de temps. Les données de 18 et 14 générations de 2 lignées de lapins sélectionnées sur la taille de portée au sevrage ont été employées (120 femelles et 25 mâles par lignée et par génération), et le processus de sélection a été étudié sur les 2 dernières générations de chacune des deux lignées. Les 2 méthodes simplifiées donnent pratiquement le même résultat sans chevauchement de générations et avec un bon équilibre entre les animaux à sélectionner et les effets fixés. Les corrélations entre les classifications et entre les évaluations génétiques des accouplements souhaitables et des individus selon l'une des méthodes simplifiées et selon le BLUP complet, se situent entre 0,65 et 0,98. Le rapport de coïncidence des accouplements retenus est situé entre 0,62 et 0,94. et la proportion du taux de perte varie de 0 à 0,17, pour une valeur moyenne d'environ 0,05 et 0,06. Les méthodes de sélection elles-mêmes apparaissent très robustes. Finalement les auteurs concluent que le seul type de choix d'accouplement au hasard est celui qui est appliqué précocement dans le processus de sélection des femelles ; il conduit en effet à des rapports des réponses attendues par unité de temps de 1,067 à 1,197.

INTRODUCTION

Litter size at birth or weaning have been the traits of choice to select specialized dam lines in meat rabbit production. Selection methods have been improved in time. At first, selection was carried out on phenotype values of individuals, taking into account one or more records per individual and getting progeny from the best evaluated females.

When the trait to be selected has a heritability as in litter size traits, it is also desirable to take into account the information from relatives. POUJARDIEU and ROUVIER (1972) and MATHERON and ROUVIER (1977) gave rules to construct family indexes using the information of the individual to be selected, its mother and a constant number of full and half sibs, with a fixed number of records per animal. BASELGA *et al.* (1984) proposed another index that allowed the use of a variable number of full and half sibs per individual to be evaluated and all the records of each animal.

In order to improve selection efficiency HENDERSON (1975) showed how to use the BLUP for a intraherd evaluation under an animal repeatability model. The BLUP used to select rabbits lines has actually been a reduced BLUP that only takes into account the data of the generation to be selected and the previous one, as it is done by the Family Index (ESTANY, 1987). Research work comparing the efficiency of a complete BLUP *versus* a reduced BLUP to select does for litter size revealed that expected losses in genetic gains were almost negligible (BASELGA *et al.*, 1985 ; ESTANY, 1987). Thus, the use of a reduced BLUP allowed to save computer time, what was important in many cases of rabbit breeding, nevertheless computing facilities are fast increasing with time.

The last two methods, the Family Index and the BLUP, allow to evaluate males and females and consequently matings. Evaluation of the matings implies an improvement of the selection efficiency, thus we can select progeny of the best matings instead of the best females (ESTANY *et al.*, 1989). Commonly, the matings have been random with respect to the predicted breeding values of individuals. A way to improve the process could be then to mate the individuals according to their predicted breeding values, mating the males and the females with the highest values to make up the next generation. In rabbits, the interval between parities is very short, around fifty days. Then the previous information should allow the matings to be reordered to increase breeding values of selected progeny.

There are no experiments in literature concerning reordering of matings based on previous information. However, some experiments have checked the usefulness of positive assortative matings, but most of them have been carried out a long time ago and always in laboratory species. These experiments analyse the effects of assortative matings to improve selection efficiency when selection is actually performed on the progeny that has records not on the mating themselves. MCBRIDE an ROBERTSON (1963) with *Drosophila melanogaster* and DELANGE (1974) in a simulation study concluded that assortative mating may improve response to selection if heritability is high, the number of loci controlling the trait is large and selection intensity is low. WILSON *et al.* (1965, 1968) studied the effects of mating system on selection in *Tribolium* ; assortative mating afforded slightly more progress than did random mating in increasing pupa weight, but the difference was not statistically significant. CAMPO and GARCIA GIL (1994) studied the effectiveness of the assortative mating in *Tribolium castaneum* ; selection responses did not significantly differ between mating systems, although there was a higher selection response with assortative matings.

Currently, prediction of breeding values by BLUP and animal models is quickly expanding to many species involved in livestock production (CARABAÑO and ALENDA, 1990), and the aim of this paper is to compare the complete BLUP with the reduced BLUP and a Family Index often used to select litter size in rabbits. Moreover, four types of assortative mating will be compared with the current random mating. The comparisons will be made on the responses expected when selecting progeny of the best matings, analysing this efficiency in two consecutive generations of two lines of rabbits, that have undergone selection on litter size for a long time.

MATERIALS AND METHODS

Litter size at weaning was recorded in two lines of meat rabbits (lines A and V). We took into account all the litters of the does from the foundation of the lines until generations 18 and 14 in lines A and V respectively.

Both lines have been selected for litter size at weaning, but using different methods. Line A is being selected on a Family Index that takes into account the information of the individual to be evaluated (if it is a doe) and the records of the mother, full sibs and half sibs (BASELGA *et al.*, 1984). Line V is being selected on a reduced BLUP that evaluates the individuals of the last generation considering the previous one as the founding generation (ESTANY *et al.*, 1989).

The repeatability animal model used was (QUASS, 1984) :

$$\mathbf{Y_{ijkl} = L_i + E_j + a_k + p_k + e_{ijkl}}$$

where :

$\mathbf{L_i}$ (fixed effect) is the physiological state of the doe with three levels : primiparous (i=1), non primiparous lactating doe at conception (i=2) and non primiparous non lactating doe at conception (i=3).

$\mathbf{E_j}$ (fixed effect) is the year season in which the parity took place. There are a maximum of 54 levels in line A and 47 in line V.

$\mathbf{a_k}$ (random effect) is the additive value of the doe

$\mathbf{p_k}$ (random effect) is the permanent non additive effect of the doe

$\mathbf{e_{ijkl}}$ (random effect) is the residual effect

$\mathbf{Y_{ijkl}}$ is the litter size at weaning of the l^{th} parity of the k^{th} doe made in the j^{th} year–season and i^{th} reproductive state.

An heritability of 0.136 and a repeatability of 0.20 (GARCIA *et al.*, 1982) were the parameters used both in the Family Index and the reduced BLUP in order to evaluate the matings.

The reproduction of the lines was in non overlapping generations, with random mating. Progeny of the best mating was selected to make up the next generation. The genetic value of a mating was computed as the mean of the predicted breeding values of the sire and the dam. The selection of a generation lasted around 2 or 3 months, was performed weekly and began when a great part of the females had two parities and then the proportion of matings selected was 0.25 but later, when most of females reached its third parity, and the accuracy of the evaluation was higher, this proportion was 0.33. Thus, the continuous process of selection could be imagined as formed by two parts or steps : the first step with a proportion of matings selected of 0.25 and the last one with 0.33 to obtain the females of the next generation. In order to avoid inbreeding, each male contributed with a son to the next generation and matings between mates sharing grand parents were precluded. Each son came from the best mating of its sire. The actual generation interval is 9 months. The females were first mated at the age of 4.5 months.

Three methods of predicting breeding values of matings were compared at the two steps of selection of generations 17, 18 of line A, and 13, 14 of line V. The methods were the Family Index, the reduced BLUP, as explained above, and a BLUP on all records (complete

Table 1 : Number of animals and recorded parities at each step of selection in the generations and lines indicated

	Line A		Line V	
	Gen. 17	Gen. 18	Gen. 13	Gen. 14
Number of animals	121 ♀ 33 ♂	116 ♀ 28 ♂	112 ♀ 25 ♂	103 ♀ 26 ♂
Parities/female at first step	1.85	1.76	1.87	1.98
Parities/female at last step	3.09	3.18	2.76	3.38

BLUP) from the foundation of the line to the moment of selecting the progeny of the best matings.

The size of the lines was around 120 ♀ and 25 ♂ per generation. Table 1 gives the number of animals of the generations involved in the comparison of the methods of evaluation, and the average number of parities per female recorded at each step of selection. The aim of analyzing two lines and two generations per line was to get some knowledge about the variability of the results, because in our study it is not possible to compute standard errors.

To compare the methods four sets of genetic parameters called A, B, C and D were used (Table 2). The set A corresponds to the parameters actually used to select. The B and D sets are REML estimates for lines A and V respectively, got analyzing the totality of data recorded (GOMEZ, 1994). The sets A and B are very like and a different set, the C set, was used in line A, in order to check the robustness of the methods to different parameters. The A, B and C sets were used in line A, and the sets A and D in line V.

In order to study the relative efficiency of the methods, correlations were computed between evaluations and between rankings of matings, dams or sires, and the degree of coincidence of the best matings under different methods and genetic parameters and the losses in response when comparing the different methods, were analyzed.

Finally, four types of assortative matings were compared with random mating across the different methods of predicting breeding values and genetic parameter sets. The way to perform assortative matings to produce males is different to the one to produce females, because we have the constraint of getting a son of each sire. Thus, the assortative matings to obtain females would be to mate the best females (for example, 30) with the best evaluated males (for example, 6). The other females (for example, 90) would be mated at random with all the males (for example, 28). The assortative matings intended to obtain males consist in ordering the males and the females in descending order of its genetic evaluation, and to mate the first male with the first female, the second male with the second female and the last male, for example the 28th, with the 28th female. The rest or females would be mated at random with all the males.

The four types of assortative matings are :

1) Assortative mating at first step of selection to obtain females.

The mating of the 25 % of the dams and sires with the the highest predicted breeding values at the first step were simulated to produce the females of the next generation. A son is selected from the best mating of each sire. The generation interval is not changed.

2) Assortative mating at last step of selection to obtain females.

The procedure is as explained in 1), but the assortative mating was carried out at the last step, being 33 % the proportion selected. The generation interval increases up to 11 months because an additional litter is required.

3) Assortative mating at first step of selection to obtain males.

The females were selected as in random mating. The generation interval remains unchanged.

4) Assortative mating at the first step of selection to obtain males and at the last step to obtain females.

At first step the matings were as in 3), to obtain the males of the next generation, and at the last step were reordered as in 2) to produce the females. In this case the generation interval is, as in 2), 11 months.

In order to compare the efficiency of the five types of matings (random mating and the four types of assortative matings) the expected responses per unit of time were computed. The breeding values of the matings predicted with the complete BLUP at the last step were used to compute the expected responses.

Table 2 : Genetic parameter sets.

	A	B	C	D
h^2	0.136	0.140	0.100	0.064
Repeatability	0.200	0.180	0.180	0.125

RESULTS AND DISCUSSION

Methods of selection

The comparison of the methods of selection is shown in Tables 3-6. Comparisons were made for matings (Tables 3 and 5) and for sires and dams (Tables 4 and 6). The variables analyzed were correlations between evaluations and between

Table 3 : Comparison of mating evaluations and rankings between a reduced BLUP and a Family Index

		Line A						Line V			
		Gen. 17			Gen. 18			Gen. 13		Gen. 14	
SS[a]	GPS[b]	A	B	C	A	B	C	A	D	A	D
First	ME[c]	.99	.99	.99	.98	.98	.98	.99	.99	.98	.98
	MR[d]	.99	.99	.99	.98	.98	.98	.99	.99	.98	.97
	CR[e]	.92	.90	.95	.89	.95	.92	.92	.94	.92	.92
	RLR[f]	.04	.01	.01	.01	.05	.01	.05	.00	−.02	.05
Last	ME	.99	.99	.99	.98	.98	.98	.98	.99	.99	.99
	MR	.98	.98	.99	.97	.98	.98	.97	.98	.98	.98
	CR	.92	.92	.94	.92	.92	.94	.96	.92	.92	.94
	RLR	.02	.02	.04	.02	.02	.02	.03	.02	.01	.04

a : Step of selection ; b : Genetic Parameter Set ; c : Correlations between Mating Evaluations ; d : Correlations between Mating Rankings ; e : Coincidence Ratio of selected matings between both methods ; f : Response Loss Ratio using the Family Index instead of the reduced BLUP.

rankings, the coincidence ratio of selected matings and the response loss ratio between the methods.

Comparing the two simplified methods of evaluating matings, Tables 3 and 4 show that the reduced BLUP and the Family Index gave the same ordering when the criterion to order the matings and the individuals was the genetic value predicted by each method. The correlations between rankings and between genetic evaluations of matings or individuals were always equal or higher than 0.93. Similar results were obtained by BASELGA *et al.* (1985) and by ESTANY (1987) when the comparison between the methods was made based on rankings and genetic evaluations of individuals.

There is a great similarity between the correlations for genetic evaluations and rankings, both for matings and individuals. The same results were obtained by BASELGA *et al.* (1985) for individuals. In general, when there are little differences the values are higher for evaluations than for rankings. It could be due to the relatively important changes in rankings produced by small changes in evaluations. Hereafter we will discuss only on results of rankings.

Another way to analyse the loss of efficiency is to compare the coincidence ratio of selected matings to produce females using a Family Index instead of the reduced BLUP (Table 3). The values ranged between 0.89 and 0.96. These results agree with those observed by BASELGA *et al.* (1985), who calculated the coincidence ratio of individuals selected.

In order to quantify the differences between methods we have also obtained the response loss ratio using the Family Index instead of the reduced BLUP (Table 3). The response loss ratio values were

Table 4 : Comparison of individual (sires and dams) evaluations and rankings between a reduced BLUP and a Family Index.

		Line A						Line V			
		Gen. 17			Gen. 18			Gen. 13		Gen. 14	
SS[a]	GPS[b]	A	B	C	A	B	C	A	D	A	D
First	ED[c]	.99	.99	.99	.98	.98	.99	.99	.99	.99	.98
	DR[d]	.99	.99	.99	.98	.98	.99	.99	.99	.98	.97
	ES[e]	.99	.99	.99	.96	.96	.97	.98	.99	.97	.98
	RS[f]	.99	.99	.99	.95	.95	.96	.98	.99	.96	.97
Last	ED	.98	.98	.99	.98	.98	.98	.98	.99	.99	.99
	DR	.98	.98	.98	.97	.97	.97	.98	.98	.99	.99
	ES	.98	.98	.98	.95	.95	.96	.97	.98	.99	.99
	RS	.97	.96	.97	.93	.93	.94	.97	.98	.99	.98

a : Step of selection ; b : Genetic Parameter Set ; c : Correlations of Evaluation of Dams ; d : Correlations of Ranking of Dams ; e : Correlations of Evaluation of Sires ; f : Correlations of Ranking of Sires.

Table 5 : Comparison of mating evaluations and rankings between a complete BLUP and a Family Index

		Line A						Line V			
		Gen. 17			Gen. 18			Gen. 13		Gen. 14	
SS[a]	GPS[b]	A	B	C	A	B	C	A	D	A	D
First	MR[c]	.90	.91	.89	.90	.90	.87	.95	.92	.86	.79
	CR[d]	.63	.66	.63	.81	.84	.78	.86	.86	.76	.62
	RLR[e]	.17	.14	.15	.01	.02	.04	.06	.07	-.03	.08
Last	MR	.93	.93	.91	.89	.90	.87	.95	.93	.90	.84
	CR	.86	.86	.84	.90	.90	.90	.90	.88	.84	.78
	RLR	.08	.07	.09	.04	.04	.05	.04	.06	.10	.17

[a] : Step of selection ; [b] : Genetic Parameter Set ; [c] : Correlations of Mating Rankings ; [d] : Coincidence Ratio of selected matings between both methods ; [e] : Response Loss Ratio using the Family Index instead of the complete BLUP

calculated with the evaluations predicted with the complete BLUP. The values ranged between –0.02 and 0.05. The predicted responses to selection on the Family Index of the best matings to produce females were 0.17 and 0.15 weaned rabbits/generation for generations 17 and 18 of line A ; and 0.1 for both generations 13 and 14 of line V. Reported responses of different experiments of selection of litter size in rabbits and pigs ranged between 0 and 0.2 young/generation (LAMBERSON *et al.*, 1991 ; BASELGA *et al.*, 1992 ; CASEY *et al.*, 1994 ; ROCHAMBEAU *et al.*, 1994).

The main difference between the Family Index and the reduced BLUP lies in the fixed effects taken into account by the reduced BLUP and not by the Index. These effects seem to be not important to order individuals or matings when the generations non overlap, the animals are housed in the same rabbitry and the females go across the same physiological states. Given the strong similarities between the reduced BLUP and the Family Index, hereafter we will discuss only on results of the Family Index.

To analyze the loss of efficiency when selection is made on predictions of a Family Index instead of a complete BLUP, Table 5 and 6 show the value of the correlations between rankings of matings and of individuals got with each method. The values are often higher than 0.90, for matings and females. The minimum is 0.68 for males in generation 18 of line A, at the first step of selection and the lowest value of heritability.

The lowest values of correlations were observed for males, being the values for matings and females very close. Normally the correlation for females were higher than for matings. Similar results were obtained by BASELGA *et al.* (1985) comparing the correlation for females alone and females and males. The correlations for males were lower because their breeding values are predicted without own data. This is also the reason for the commonly higher values for females than for matings.

There are small differences in correlations across the different genetic parameter sets. This is a first indication of robustness. However, we must note that when comparing the complete BLUP with the Family Index (Tables 5 and 6) the correlations are lower for the C and D sets. These two sets have the lowest heritabilities, which implies a higher importance of the information from the relatives. This is the reason for

Table 6 : Correlations of individual rankings (sires and dams) between a complete BLUP and a Family Index.

		Line A						Line V			
		Gen. 17			Gen. 18			Gen. 13		Gen. 14	
SS[a]	GPS[b]	A	B	C	A	B	C	A	D	A	D
First	Dams	.93	.93	91	.94	.94	.93	.96	.93	.93	.86
	Sires	.78	.77	.75	.71	.72	.68	.84	.81	.76	.70
Last	Dams	.94	.94	.93	.94	.94	.92	.96	.94	.97	.91
	Sires	.73	.74	.71	.70	.72	.65	.87	.83	.76	.73

[a] : Step of selection ; [b] : Genetic Parameter Set

Table 7 : Correlations of mating and individual (dams and sires) rankings at the first and the last step of selection.

		Line A						Line V			
		Gen. 17			Gen. 18			Gen. 13		Gen. 14	
SM[a]	GPS[b]	A	B	C	A	B	C	A	D	A	D
cB	MR[c]	.86	.86	.86	.85	.85	.85	.90	.91	.82	.83
	DR[d]	.85	.85	.84	.83	.82	.83	.85	.87	.79	.82
	SR[e]	.93	.93	.94	.85	.85	.86	.94	.94	.95	.96
FI	MR	.84	.84	.84	.80	.80	.79	.91	.92	.85	.84
	DR	.85	.86	.85	.81	.81	.80	.88	.89	.81	.79
	SR	.89	.90	.88	.76	.76	.73	.92	.93	.93	.92

[a] : Selection method : cB (complete BLUP) ; FI (Family Index) ; [b] : Genetic Parameter Set ; [c] : Correlations of Mating Rankings ; [d] : Correlations of Dam Rankings ; [e] : Correlations of Sire Rankings ;

the higher differences between the complete BLUP and the reduced methods.

The coincidence ratio ranges between 0.62 and 0.86 at the first step of selection, and between 0.78 and 0.90 at the last one (Table 5). It is due to the higher proportion selected at the last step (BASELGA *et al.*, 1985 ; ESTANY, 1987) and probably, to the higher amount of information accumulated at this moment.

The relative loss of response using the Family Index was always lower or equal than 0.17, being the average around 0.05–0.06 (Table 5). Similar results were obtained by BASELGA *et al.* (1985) and ESTANY (1987). However we have observed important differences in the values of response loss ratio between the first and the last steps of selection, and between lines and generations, specially when comparing the complete BLUP with the reduced methods. It seems, from comparison with the reduced BLUP and the Family Index, that the losses in response are mainly due to the amount of information used from previous generations, rather than to the consideration of the fixed effects, year-season and physiological state.

Step of selection

Table 7 reports on correlations for rankings of matings or individuals, between the two steps of selection, within method of evaluation.

The correlations ranged between 0.79 and 0.96 for the complete BLUP and 0.73 to 0.93 for the Family Index, being the modal value near 0.85. It means that relevant changes in the order of matings or individuals can occur between the first and the last step of selection. Consequently, it is sensible to select from a lower proportion of matings at the beginning.

In general, the highest values of correlation have been observed for the complete BLUP, the method where the relative increase in information between the first and the last step of selection is less important.

In addition, we can see that the highest correlations have been observed in males, and the

Table 8 : Comparison of mating evaluations and rankings between different genetic parameter sets.

		Line A						Line V	
		Gen. 17			Gen. 18			Gen. 13	Gen. 14
	SM[a]	BA[b]	CA	CB	BA	CA	CB	AD	AD
COR[c]	cB	.999	.995	.992	.999	.996	.993	.998	.976
	FI	.999	.995	.992	.999	.996	.993	.988	.976
CR[d]	cB	1.00	.941	.941	.980	1.00	.980	.958	.878
	FI	1.00	.941	.941	.980	1.00	.980	.958	.878
RLR[e]	cB	.000	.006	.006	-.000	.000	.000	.010	.032
	FI	.000	.006	.006	-.000	.000	.000	.010	.032

[a] : Selection Method : cB (complete BLUP) ; FI (Family Index) ; [b] : Genetic Parameters Sets ; [c] : Correlations of Mating Rankings ; [d] : Coincidence Ratio of selected matings between both Genetic Parameter Sets ; [e] : Response Loss Ratio using the first genetic parameter set instead of the second one.

Table 9 : Ratio of expected responses per unit of time under different assortative matings and random mating.

		Line A						Line V			
		Gen. 17			Gen. 18			Gen. 13		Gen. 14	
	SM[a]	A[b]	B	C	A	B	C	A	D	A	D
1[c]	cB	1.156	1.147	1.152	1.116	1.121	1.122	1.115	1.093	1.147	1.164
	FI	1.116	1.166	1.162	1.119	1.120	1.105	1.092	1.093	1.067	1.104
2[d]	cB	0.946	0.945	0.949	0.929	0.929	0.932	0.904	0.903	0.956	0.970
	FI	0.939	0.938	0.935	0.899	0.899	0.903	0.905	0.890	0:940	0.936
3[e]	cB	1.056	1.055	1.097	1.008	1.010	0.987	1.055	1.059	1.034	1.049
	FI	1.047	1.047	1.049	1.010	1.014	0.997	1.054	1.032	0.981	0.998
4[f]	cB	0.992	0.990	1.028	0.935	0.937	0.921	0.949	0.952	0.984	1.010
	FI	0.978	0.977	0.975	0.910	0.911	0.901	0.950	0.916	0.925	0.934

[a] : Selection Method : cB (complete BLUP) ; FI (Family Index) ; [b] : Genetic Parameters Sets ; [c] : Assortative mating at first step of selection to obtain females ; [d] : Assortative mating at last step of selection to obtain females ; [e] : Assortative mating at first step of selection to obtain males ; [f] : Assortative mating at first step of selection to obtain males and at last step of selection to obtain females.

lowest in females, being intermediate the values for matings. It is due to the lower increase in the amount of information from the first to the second steps of selection in males.

We must also note that the correlations across parameter sets are practically the same, what is another indication of robustness.

The highest values of correlation have been observed in generation 13 of line V, which has the minimum differences in the number of parities per female between the first and the last step of selection (Table 1). There is only one exception : the ranking of sires with the complete BLUP because they have not information of their own at the two steps.

Robustness of the methods to different genetic parameters.

Table 8 informs about how the methods are robust to changes in genetic parameters to evaluate genetically the matings. The minimum values for the variables computed, correlations and coincidence ratio, have been respectively 0.976 and 0.878 ; and the maximum response loss ratio was 0.032. So the three variables strongly show that the methods are truly robust (SALES and HILL, 1976).

Type of mating

The comparison within method of evaluation of random mating with different assortative matings is shown in Table 9. The variable used to make this comparison is the ratio of expected response per unit of time under an assortative mating and the random mating.

With assortative mating at last step of selection to obtain females (method 2) and at first to obtain males and at last step of selection to obtain females (method 4), the ratio was always lower than unity which implies a higher response with the random mating. It is caused by the increase of the generation interval associated with these two assortative matings.

The ratio of expected responses per unit of time under assortative mating at first step of selection to obtain males (method 3) was in general close to unity, being the range 0.981-1.097. Thus, we can conclude that this assortative mating does not increase noticeably the response in relation to the random mating, being worse in many cases.

Finally the assortative mating with highest ratios was the one at first step of selection to obtain females (method 1), being the range 1.067-1.197. In all the cases the expected response was higher with this assortative mating.

We can conclude then that this will be the method of choice for the matings. However, we should take into account the aspects of practical breeding in order to finally recommend one or another method.

In general the highest values of the ratio have been observed for the complete BLUP, probably due to the greater accuracy in defining the assortative mating.

This could be also the reason for the ratios lower than unity in the assortative mating number 3.

CONCLUSION

When selection of litter size is carried out in discrete generations there is no difference between a Family Index and a reduced BLUP in terms of response to selection. The losses of selecting with these simplified methods instead of a complete BLUP are around 8 %. All the methods seem very robust to changes, relatively important, in genetic parameters, because the decisions of selection remain approximately unchanged. It appears beneficial to reorder assortatively the matings to produce females of the next generation, when a great part of the dams have around two litters.

Acknowledgements : This research has been supported by CICYT project AGF94-0577 (Spain).

Received: April 1995
Accepted : September 1995.

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