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HETEROSIS, MATERNAL AND DIRECT GENETIC EFFECTS FOR LITTER PERFORMANCE AND REPRODUCTIVE INTERVALS IN RABBIT CROSSES

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ABSTRACT : A crossbreeding experiment was carried out in Egypt involving a local breed (Baladi Red, BR) and an exotic one (New Zealand White, NZ) to estimate direct heterosis, maternal additive effects and direct additive effects on some litter traits and reproductive intervals in doe rabbits. Litter traits included litter size and weight and mean young weight (at birth, 21 days and at weaning), number born alive and preweaning litter gain and mortality, while reproductive intervals included days open (interval from kindling to next conception) and kindling interval (period between two consecutive parturitions). Data were analysed using a linear mixed model. Winter kindlings recorded the largest litter size and the heaviest weight and gain of litter weight up to weaning along with the lowest preweaning mortality compared to autumn and spring kindlings. Heterosis was found at weaning on litter size and weight at weaning and on some interval traits but not on litter size at birth, where negative values are found. Crossbred litters obtained from mating BR bucks with NZ does were generally associated with superiority compared to those litters obtained from the reverse mating. Maternal additive effects on all litter traits were in favour of NZ breed, although the differences between the two breeds were not significant. In terms of reproductive intervals, BR-mothered litters recorded shorter intervals compared to NZ-mothered litters. For all litter traits and reproductive intervals, the direct additive effect was not significant. NZ-sired litters had higher direct additive effects compared to BR-sired litters, while BR-sired litters recorded shorter reproductive intervals relative to NZ-sired litters.

RÉSUMÉ : Hétérosis, effets génétiques maternels et directs sur les performances des portées et les intervalles entre mises bas dans le cas de croisements entre lapins.

Une expérience de croisement a été réalisée en Egypte en utilisant une race locale (Baladi Red, BR) et un race étrangère (New Zealand White, NZ) afin d'étudier l'hétérosis direct, les effets additifs maternels et les effets additifs directs sur quelques unes des caractéristiques des portées et des intervalles entre mise bas des lapines. Les caractéristiques des portées sont la taille et le poids des portées, le poids moyen des lapereaux (à la naissance, 21 jours et au sevrage), le nombre de jeunes nés vivants, le gain de poids avant le sevrage et le taux de mortalité ; les intervalles entre mise bas comprennent le délai entre une mise-bas et la conception suivante, ainsi que la durée entre 2 mises bas consécutives. Les résultats ont été analysés en utilisant un modèle linéaire mixte. Au total, 190 femelles et 47 mâles ont été utilisés. Les mises bas hivernales conduisent à des portées de taille et de poids plus élevé, ainsi qu'à un gain de poids des portées plus élevé entre la naissance et le sevrage, comparativement aux mises bas d'automne et de printemps. Il y a hétérosis au sevrage pour la taille et le poids de portée au sevrage et sur quelques paramètres liés au rythme de reproduction mais pas sur la taille de la portée à la naissance où l'on a trouvé des valeurs négatives. Les portées croisées obtenues par fécondation de femelles NZ par des mâles BR, donnent généralement de meilleurs résultats que le croisement inverse. L'effet additif maternel appliqué à toutes les caractéristiques des portées est en faveur de la race NZ, bien que les différences entre les deux races ne soient pas significatives. En ce qui concerne les intervalles entre mises bas, les portées issues de mères BR enregistrent les intervalles les plus courts comparés aux portées issues de mères NZ. Pour toutes les caractéristiques de portées et d'intervalles de reproduction l'effet additif direct n'est pas significatif. Les portées issues de mâles NZ ont des effets additifs directs plus élevés que les portées issues de mâles BR, tandis que les portées issues de mâles BR enregistrent les intervalles de reproduction les plus courts comparés aux portées issues de mâles NZ.

INTRODUCTION

Crossbreeding among available breeds (e.g. Baladi, Baladi Red, Baladi Black, Baladi White) has been extensively used in Egypt (AFIFI, 1971 ; EL-QEN, 1988 ; AFIFI and KHALIL, 1989 ; EL-DESOKI, 1991) whereby existing breed differences from a heterotic and complementary standpoint are utilized. Breed differences, direct and maternal heterosis, maternal additive effects and direct additive effect from crossbreeding experiments of rabbits were shown to be important for reproductive performance of doe rabbits. In the last ten years, new standard breeds (New Zealand White and, to a lesser extent Californian) were introduced to Egypt and used in crossbreeding experiments with our local breeds. The New Zealand White breed was found to exhibit out standing maternal abilities as related to behaviour, fecundity and lactation (LUKEFAHR *et al.*, 1983ab ; OZIMBA and

Table 1 : Number of bucks, does, litters and young distributed in the four breed groups of the study.

Mating type*	Bucks	Does	Litters born	Litters weaned	Young born	Young weaned
NZ x NZ	15	60	193	170	1238	691
BR x BR	9	37	124	104	782	364
NZ x BR	9	37	122	111	750	461
BR x NZ	14	56	164	147	1025	637
Total	*47*	*190*	*603*	*531*	*3795*	*2153*

* Breed of buck is listed before breed of doe.

LUKEFAHR, 1991). To date, few publications concerning crossbreeding of New Zealand White rabbits in Egypt are available. Results of most crossbreeding experiments carried out in Egypt reported that crossing does of New Zealand White breed with bucks of local breeds were generally associated with considerable heterotic effects on most litter and reproductive interval traits (OUDAH, 1990 ; EL-DESOKI, 1991). Therefore, this study was conducted to evaluate the importance of heterosis, maternal and direct additive effects on some litter traits and reproductive performances in a crossbreeding experiment involving New Zealand White and Baladi Red rabbits.

MATERIAL AND METHODS

A crossbreeding experiment was carried out in Gezireit EL–Sheir Experimental Station at EL–Kanater EL–Khairia (about 12 km to the north of Cairo) during two consecutive years of production started in September 1988. This experimental station belongs to the Animal Production Research Institute, Ministry of Agriculture, Egypt.

Breeding plan and management

Rabbits used in this study represent one local Egyptian breed (Baladi Red, BR) and one exotic breed (New Zealand White, NZ). Details and description of general features of the two breeds are reported by GALAL and KHALIL (1994). Does and bucks of the exotic breed (NZ) were descendants of NZ rabbits raised under the Egyptian conditions. At the beginning of the experiment (September, 1988), breeding does of each of the two breeds were divided at random into two groups. Does of the first group in each breed were mated with bucks from their own breed while those of the second group were mated with bucks from the other breed. Bucks were assigned at random to mate the does with a restriction to avoid the matings of animals with common grand–parents. Throughout the two years of this study, each buck was allowed to sire all his litters from the same does, i.e. separate bucks in each of the four breed groups were used. The breeding plan permitted the simultaneous production of BR, NZ, BR x NZ and NZ x BR litters in each parity. In each year of production, matings started in September and stopped in May. Distribution of breeding does and bucks and number of litters and young born and weaned of the four different breed groups are presented in Table 1.

Rabbits were raised in a semi–closed rabbitry. Breeding does and bucks were housed separately in individual wired cages arranged in double–tier batteries (California cage) allocated in two rows along the rabbitry. At the time of breeding, each doe was transferred to the cage of her assigned buck to be hand mated and returned to her own cage after being mated. Each doe was palpated 10 days thereafter to determine pregnancy and those who failed to conceive were returned to the same mating–buck to be remated. Does were mated from the same assigned bucks 15 days after each kindling. On the 25^{th} day of pregnancy, the nest boxes were supplied with rice straw to help the doe in preparing a warm comfortable nest for the young of her litter. After kindling, litters were checked and recorded. Young rabbits were weaned at five weeks, ear tagged, sexed and transferred to standard progeny wire cages equipped by feeding hoppers and drinking nipples. Feeding practices were described by AFIFI *et al.* (1994).

Data and statistical analysis

Litter traits included number born alive (NBA), litter size at birth (LSB), at 21 days (LS21) and at weaning (LSW), litter weight at birth (LWB), 21 days (LW21) and at weaning (LWW), mean young weight at birth (MWB), 21 days (MW21) and at weaning (MWW), 21-days absolute weight gain in litter (as indicator of peak of lactation, AG21), preweaning litter gain (AGW) and preweaning litter mortality (PM) ; while interval reproductive traits included kindling interval (period between two consecutive parturitions, KI) and days open (interval from kindling to next conception, DO). Mortality percentages were subjected to arc–sin transformation to approximate normal distribution before being analyzed.

Data on 603 litters were analyzed using the following mixed model:

$$Y_{ijklmn} = \mu + G_i + B_{ij} + D_{ijk} + YS_l + P_m + (GP)_{im} + e_{ijklmn}$$

Where :

Y_{ijklmn} = The observation on the ijklmnth litter
μ = overall mean, common element to all observations,
G_i = fixed effect of ith breed group,
B_{ij} = random effect of jth buck nested within ith breed group,
D_{ijk} = random effect of kth doe nested within jth buck and ith breed group,
YS_l = fixed effect of lth year-season of kindling (i = 1,...,6)
P_m = fixed effect of mth parity (m = 1,....,5)
$(GP)_{im}$ = fixed effect of interaction between ith breed group and mth parity,
e_{ijklmn} = a random deviation particular to the nth litter, assumed to be independently randomly distributed with zero mean and variance $\sigma^2 e$, i.e. NID $(0,\sigma^2 e)$.

Breed group was tested against buck within breed group and buck within breed group tested against doe within buck within breed group, while other fixed effects were tested against remainder. HARVEY's least squares and maximum likelihood computer program (HARVEY, 1990) was used.

Genetic model and estimation of crossbreeding effects

Crossbreeding effects (maternal additive, direct additive and direct heterosis) on different litter traits and reproductive intervals were estimated according to DICKERSON (1992). Such genetic model permits to derive a selected set of linear contrasts, i.e. direct additive effect, maternal additive effect and direct heterotic effects were estimated as :

Direct heterosis effect (units) :
H^iNZ x BR = [(NZ x BR + BR x NZ) - (NZ x NZ + BR x BR)]
Maternal additive effect:
(G^mNZ - G^mBR) = [(BR x NZ) - (NZ x BR)], i.e. reciprocal crosses differences
Direct additive effect:
(G^iNZ - G^iBR)= {[(NZ x NZ) + (NZ x BR)] - [(BR x BR) + (BR x NZ)]}, i.e. breed group of sire differences

Where G^i and G^m represent direct additive and maternal additive effects, respectively, of the subscript genetic group. Each single degree of freedom contrast was tested for significance with the Student's t-test.

RESULTS AND DISCUSSION

Year and season of kindling

Year-season of kindling contributes significantly to the variation of litter traits and reproductive intervals except LSB, MWW and PM. F–ratios obtained for year–season effect on litter traits measured after birth are higher than those measured at birth and gave an evidence that litter traits at 21 days and at weaning are more affected by year–season of kindling than those at birth. This reflects the effect of season of kindling on milk production.

For most traits, winter–kindlings recorded the largest size and the heaviest weight and gain of litter compared to autumn and spring kindlings (Tables 2 & 3). In addition, litters born in winter had lower PM than those litters born in autumn and spring. MWB and MWW of winter kindlers had the smallest young weight per litter while autumn or spring kindlers recorded the largest MWB or MWW. Similarly, most Egyptian reviewed studies (e.g. KHALIL *et al.*, 1987 ; ABDELLA *et al.*, 1990) showed a general trend indicating that litter size and weight, gain in litter and mean young weight per litter had a curvilinear relationship with season of kindling where these traits seem to be low in the first month of the year of production (during September, October or November, i.e. during autumn), and increased as months of that year advanced (during winter and early months of spring) and decreased again at the end of the year of production (during May and thereafter). This reflects the pattern of seasonality of weather conditions. Here, feed availability is not of considerable importance since pregnant and suckling does were fed on pelleted ration all the year round, while seasonality had a considerable contrast importance.

Parity

The pattern of parity effect on litter and interval traits appeared inconsistent. Most Egyptian studies showed also inconsistent trend for the effect of parity on litter and interval traits in rabbits (e.g. KHALIL *et al.*, 1987 ; ABDELLA *et al.*, 1990 ; EL-DESOKI, 1991 ; SEDKI, 1991). Moreover, F–ratios obtained here showed that parity had no effect or contributed little to the variation of all litter and interval traits. From kindling up to weaning, KHALIL (1994) reported that variation in litter traits measured during this period for different parities may be associated with the lactation ability of the doe as well as her ability to care and suckle her young till weaning.

Table 2 : Least squares means (±SE) of reproductive intervals and litter size traits in different year–season subclasses.

	1988/1989			1889-1990			
	Autumn	Winter	Spring	Autumn	Winter	Spring	F–ratio
N	*63*	*86*	-	*126*	*117*	-	
Days open	53±11	45±8	-	80±8	67± 10	-	4.0**
Kindling interval	80±10	76±7	-	99±6	90±7	-	3.7**
N	*64*	*119*	*55*	*129*	*126*	*110*	
Litter size at birth	7.7±1.1	8.6±0.8	7.6±0.7	5.4±0.7	5.9±0.8	5.3±0.9	2.1ns
Number born alive	7.7±0.8	8.3±0.6	7.6±0.5	5.2±0.5	5.3±0.6	5.0±0.7	2.5*
N	*54*	*105*	*51*	*116*	*106*	*104*	
Litter size at 21 days	5.6±0.7	7.4±0.5	5.8±0.5	4.0±0.4	4.2±0.5	3.6±0.6	8.9***
N	53	103	51	116	105	104	
Litter size at weaning	2.7±0.6	4.8±0.5	3.2±0.4	3.7±0.4	4.0±0.5	4.0±0.6	10.6***

ns = non significant ; * = P<0.05 ; ** = P<0.01 ; *** = P<0.001.

Breed-group by parity interaction

All traits except DO and KI were not significantly affected by breed–group x parity interaction. Therefore, DO or KI of a certain breed group used in a definite parity may be of considerable advantage. Scarce information on the effect of such interaction on litter traits and reproductive intervals are available and consequently no comparisons with the present results were made.

Mating-type means

Mating–type least square means and comparisons among purebreds for litter traits and reproductive intervals are given in Tables 4 & 5. The NZ x NZ matings resulted in a larger litter size and heavier litter weight along with higher growth of litter compared to the BR x BR matings (Tables 4 & 5). The linear contrasts evidenced that NZ breed had superior performance in terms of NBA (P<0.05), LS21, MWB and AG21 (P<0.01), and LSW, LWB, LW21, LWW and AGW (P<0.001) compared to BR rabbits. These results were expected and reflect the superiority of NZ rabbits in fertility, maternal behaviour, milk production, pre–weaning growth and survival. On the other hand, DO and KI were shorter in BR rabbits than NZ rabbits (Table 4). Stress of large litters and high milk production in NZ rabbits may have influenced the reproductive performance and consequently exerted longer periods of DO and KI. Further research is needed to identify the genetic aspects of lactation performance in NZ breed and its genetic association with other litter traits and reproductive intervals.

Table 3 : Least squares means (± SE) of litter weight traits in different year–season subclasses.

	1988/1989			1889-1990			
	Autumn	Winter	Spring	Autumn	Winter	Spring	F–ratio
N	*64*	*119*	*55*	*129*	*126*	*110*	
Litter weight at birth	373±34	407±25	338±24	315±23	292±26	289±30	3.5**
Mean young weight at birth	48±3.7	48±2.8	46±2.7	57±2.5	53±2.9	56±3.3	2.1*
N	*54*	*105*	*51*	*116*	*106*	*104*	
Litter weight at 21 d.	1226±123	1480±91	1040±83	1045±79	949±94	923±110	10.6***
Mean young weight at 21 d.	237±27	205±20	191±18	264±17	240±20	257±24	2.7*
Litter weight gain at 21d.	843±11	1047±82	697±74	733±71	666±84	641±99	8.2***
N	*53*	*103*	*51*	*116*	*105*	*104*	
Litter weight at weaning	1170±234	1944±173	1100±156	1471±150	1511±178	1663±208	15.4***
Mean young weight at weaning	437±44	411±32	370±29	416±28	409±33	432±39	1.8ns
Preweaning litter gain	794±226	1508±168	758±151	1160±144	1225±172	1380±200	13.8***
N	*64*	*119*	*55*	*129*	*126*	*110*	
Preweaning mortality %	43.0	32.1	41.3	36.2	37.6	34.0	1.4ns

ns = non significant ; * = P<0.05; ** = P<0.01 ; *** = P<0.001

Table 4 : Estimates of mating type Means (± SE), heterosis (H^1), maternal additive effect (G^m) and direct additive effect (G^i) of reproductive intervals and litter size traits *.

	Reproductive intervals			Litter size traits					
Item	*N*	**DO**	**KI**	*N*	**LSB**	**NBA**	**LS21**	*N*	**LSW**
R^2 of model		0.55	0.55		0.52	0.53	0.56		0.56
Mating type +									
NZ x NZ	*127*	64±3.0	87±2.3	*193*	7.0±0.3	7.0±0.2	5.5±0.2	*170*	4.0±0.1
BR x BR	*80*	64±2.8	87±2.2	*124*	6.6±0.4	6.4±0.3	4.9±0.2	*104*	3.2±0.2
NZ x BR	*81*	59±3.4	83±2.6	*122*	6.6±0.4	6.4±0.2	4.8±0.2	*111*	3.7±0.2
BR x NZ	*104*	58±3.9	81±3.0	*164*	6.8±0.4	6.5±0.3	5.2±0.2	*147*	4.0±0.2
Significance							*		**
Purebred differences $\{(G^i_{NZ} + G^m_{NZ}) - (G^i_{BR} + G^m_{BR})\}$		0.4±3.9	0.08±3.0	–	0.42±0.35	0.56± 0.25*	0.61± 0.22**	–	0.78± 0.2***
Heterosis contrast									
$H^i_{NZ\ x\ BR}$ (units)		–5.8±3.2*	–4.7±2.5*	–	–0.14±0.28	–0.26±0.20	–0.17±0.17	–	0.25±0.15
Percentage		– 9.0 %	– 5.4 %	–	– 2.0 %	– 3.8 %	– 3.2 %	–	6.9 %
Maternal additive effect $(G^m_{NZ} - G^m_{BR})$		–1.2±5.0	–1.8±3.8	–	0.28±0.43	0.13±0.31	0.38±0.27	–	0.27±0.24
Direct additive effect $G^i_{NZ} - G^i_{BR})$		0.81±3.2	0.93±2.4	–	0.07±0.28	0.21±0.20	0.12±0.18	–	0.25±0.15

+ Buck breed listed first ; * = P<0.05 ; ** = P<0.01 ; *** = P<0.001.

Heterotic effects

Estimates of direct heterosis (calculated in actual units and as percentages) for different traits are given in Tables 4&5. These estimates indicated that crossing between NZ and BR rabbits was usually associated with an existence of heterotic effects on some litter traits studied, especially those traits measured after kindling. Direct heterosis was significant for MWB, LWW and AGW (P<0.01) and for DO and KI (P<0.05). Results of the different crossbreeding experiments carried out in Egypt (AFIFI, 1971 ; AFIFI and EMARA, 1984 ; AFIFI and KHALIL, 1989) revealed that heterotic effects were evidenced in most of the possible crossbreds for litter size, litter weight, pre–weaning litter gain and average birth weight per litter.

Estimates of heterosis for weight productivity traits (litter weight and litter weight gain) showed that heterotic effects increased with advance of litter's age (Table 5). Negative and low estimates of heterosis were recorded for litter traits at birth (LSB, NBA and LWB), while positive and high estimates were recorded for litter traits at weaning (LSW, LWW and AGW) ; heterosis percentages for litter traits ranged from –3.8 % to 5.0 % at birth while from 4.8 % to 14.8 % at weaning.

Crossing of NZ with BR was associated with a reduction in PM, DO and KI (Tables 4 & 5), i.e. an improvement in pre–weaning viability and a reduction in reproductive intervals of the doe will be attained. Similarly, AFIFI and KHALIL (1989) and EL–DESOKI (1991) evidenced that crossbreeding was associated with a reduction in the rate of PM and/or the length of DO and KI.

Maternal additive effect

Maternal breed effects on all litter traits (expressed as the differences between reciprocal crosses) were not statistically significant and they were mainly in favour of NZ breed (Tables 4 & 5). Crossbreeding experiments carried out in Egypt (AFIFI, 1971 ; EL–QEN, 1988 ; AFIFI and KHALIL, 1989 ; OUDAH, 1990) indicated also that maternal additive effects on pre–weaning litter traits were not significant.

For most litter traits, litters of the BR x NZ matings had better performance than those from the NZ x BR matings (Tables 4 & 5). This means also that using of NZ rabbits as dam–breed with BR as a sire–breed gives an advantage in litter performance in terms of larger litter size, heavier litter weight and gain along with lower mortality rate. This superiority of NZ does is attributable to favourable maternal abilities, presumably due to increased milk production levels compared to BR does. However, most of the Egyptian findings reported a general trend indicating that litters mothered by exotic breeds (e.g. New Zealand White, Californian, Chinchilla... etc.) recorded better performance than litters mothered by native breeds (e.g. Giza White, Baladi Red, Baladi White... etc.). This evidenced the superiority of exotic breeds in their maternity (in terms of milk production, maternal behaviour and care for young). Differences in breed

Table 5 : Estimates of mating type Means (± SE), heterosis (H^1), maternal additive effect (G^m) and direct additive effec(G^m) for weight of the traits*

Item	N	LWB	MWB	N	LW21	MW21	AG21	N	LWW	MWW	AGW	N	PM%
R^2 of model		0.52	0.54		0.57	0.54	0.56		0.59	0.54	0.58		0.38
Mating type +													
NZ x NZ	*193*	358±9.5	52±1.5	*172*	1173±31	227±6.7	811±27	*170*	1558±53	404±10	1196±51	*193*	37.2
BR x BR	*124*	316±11.7	49±1.9	*106*	1047±34	229±7.6	726±31	*104*	1245±60	401±12	922±59	*124*	45.6
NZ x BR	*122*	332±11.8	53±1.9	*111*	1093±37	242±8.2	760±33	*111*	1482±64	418±13	1149±62	*122*	36.4
BR x NZ	*164*	339±12.9	53±2.1	*147*	1128±44	232±9.6	788±39	*147*	1622±76	426±15	1282±73	*164*	37.0
Significance		*			*				***		***		
Purebred differences $\{(G^i_{NZ} + G^m_{NZ}) - (G^i_{BR} + G^m_{BR})\}$		42±11.4***	3.1±2.1**		125±39***	−2.2±8.4	85±35**		313±74***	2.8±14	275±71***		−4.9
Heterosis contrast													
$H^i_{NZ \times BR}$ (units)		-1.2±9.1	2.5±1.0**		0.7±31	9.0±6.7	6.1±28		150±59**	19.1±11	156±57**		−2.8
Percentage		−0.4 %	5.0 %		0.1 %	3.9 %	0.8 %		10.7 %	4.8 %	14.8 %		−6.8 %
Maternal additive effect $(G^m_{NZ} - G^m_{BR})$		7.7±14.0	−0.3±1.5		34.6±48	−10.4±10.5	27.8±43		140±91	8.0±17	133±88		0.3
Direct additive effect $(G^i_{NZ} - G^i_{BR})$		17.1±9.0*	1.7±1.0		45.4±31	4.1±6.7	28.8±28		86.5±58	−2.6±11	70.6±56		−2.6

* Buck breed listed first ; * = P<0.05 ; ** = P<0.01 ; *** = P<0.001.

maternity may have been also a reflection of heavier body weight of NZ does compared with BR ones. For most pre–weaning litter traits, the maternal superiority of NZ breed compared with other standard breeds has been demonstrated in the American studies (e.g. LUKEFAHR *et al.*, 1983ab ; OZIMBA and LUKEFAHR, 1991) and in the European studies (e.g. PARTRIDGE *et al.*, 1981 ; MASOERO *et al.*, 1985 ; ROUVIER and BRUN, 1990), i.e. using NZ as a dam breed produced high performances in litter size, weight, gain and mortality rate compared to other dam breeds.

BR-mothered litters recorded shorter DO and KI compared to NZ–mothered litters (Table 4). Longer reproductive intervals for NZ–mothered litters could be attributable to that NZ–mothered litters are more affected by lactation stress than BR–mothered litters. Such lactation stress leads to an antagonistic relationship between reproductive intervals (DO and KI) and pre–weaning litter traits.

Direct additive effect

The linear contrasts of direct additive effect for all litter and interval traits were not significant (Tables 4 & 5), i.e. little contribution of buck breed effects in the inheritance of litter traits was observed. Such limited differences in direct effects between the two breeds may be due to that BR rabbits had originated from a Giant breed which may approach the NZ breed in performance. Consequently, BR could be used as a buck-breed in crossbreeding programmes.

The NZ buck–breed generally produced litters with larger size and heavier weight along with heavier mean young weight at birth and at 21 days of age than did the BR buck–breed (Tables 4 & 5), i.e. NZ-sired litters had higher direct sire values than BR–sired litters did. The observed direct paternity effects on litter traits lead to indicate that NZ breed could be used as a terminal sire breed. In France, ROUVIER and BRUN (1990) reported in an early experiment (1970) that Californian–sired litters had higher direct genetic effects on pre-weaning litter traits than that of NZ–sired litters and a reverse trend was observed in an experiment performed 20 years later (BRUN, 1993). In Brazil, CARREGAL (1980) demonstrated minor differences in litter traits attributable to NZ *vs* Californian sires. The American study by LUKEFAHR *et al.* (1983a) stated that direct paternity effects on pre–weaning litter traits (LSB, LWB, LSW, LWW, AGW and PM) were mostly in favour of Californian litters vs litters sired by NZ rabbits. They added also that direct Flemish Giant paternity effects on pre–weaning litters were positive and high compared with litters of NZ paternity. BR–sired litters recorded shorter lengths of DO and KI compared to NZ–sired litters, although the differences were not significant (Table 4).

In general, maternal additive effects appear to be more important than paternal additive effects in influencing most preweaning litter and interval traits. However, most estimates of linear contrasts for maternal additive effects are higher compared to those estimates of paternal additive direct effects (Tables 4

& 5). LUKEFAHR *et al.* (1983ab) and EL-DESOKI (1991) confirmed this trend.

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