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DOE LITTER PERFORMANCE AT WEANING FOR TWO BREEDS OF RABBITS WITH SPECIAL EMPHASIS ON SIRE AND DOE EFFECTS

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Introduction

Litter size and mean kit weight at weaning are usually regarded as the best estimates of numerical and weight productivity of the doe since they are functions of all preweaning effects. Preweaning litter losses control litter size and litter gain at weaning and, consequently, quantify the number of kilograms weaned per doe per year of production; i.e. the higher the litter losses the smaller the number of kilograms produced at weaning per doe and the lower the income that would be obtained.

In spite of the economic importance of these component traits for the rabbit industry, sire and doe effects on litter traits have not been subjected to extensive studies (Rouvier et al., 1973; Randi and Scossiroli, 1980). The objective of the present study was to investigate sire and doe effects on litter traits measured at weaning in Bauscat and Giza White rabbits as well as to detect non-genetic factors affecting these traits.

Materials and Methods

Rabbits of a foreign (Bauscat) and native breed (Giza White) were raised at the Experimental Rabbitry of the Faculty of Agriculture at Moshtohor, Zagazig University, Egypt, in the period from October, 1975, to September, 1983. At the beginning of the breeding season (October), females within each breed were grouped at random into groups ranging from 3 to 5 does. For each group of does a buck from the same breed was assigned at random except for the restriction of avoiding full-sib (full-sisters) and half-sib (paternal or maternal half-sisters) matings. Each buck was allowed to produce all his litters from the same female in all years of production.

Each doe was transferred to the buck to be bred. Hand mating was exercised by restraining the doe to assure copulation. Does were palpated 10 days thereafter to determine pregnancy. Does that failed to conceive were returned to the same buck to be rebred, and were returned to the same buck every other 10 days thereafter until a service was observed. The litter of young rabbits was exmamined and recorded within 24 hours of birth. Kits were weaned five weeks after birth, sexed, ear-tagged and housed in wire cages in groups, with a maximum number of 10 individuals of nearly similar age in each cage. Feeding regimes were carried out according to the normal system of feeding that prevails in Experimental Farms in Egypt.

Weaning litter traits collected were: litter size, litter gain (the difference between weaning- and birth-litter weights), preweaning litter mortality (%) and mean kit weight (litter weight/litter size) at weaning. A total of 840 litter-trait records were included in the study. The percentages of preweaning litter mortality were subjected to arc-sin transformation before being analysed in order to make variances homogeneous. Data were analysed by using the following mixed model (Harvey, 1977):

$$Y_{ijklmn} = M + S_i + D_{ij} + A_k + B_l + C_m + b\,(X_{ijklmn} - \bar{X}) + e_{ijklmn}$$

where:

Y_{ijklmn} = the observation on the $ijklmn^{th}$ litter,

M = the overall mean, common element to all observations,

S_i = the random effect of i^{th} sire of doe,

D_{ij} = the random effect of jth doe nested within a random effect of i^{th} sire,

A_k = the fixed effect of k^{th} parity,

B_l = the fixed effect of l^{st} month of kindling,

C_m = the fixed effect of m^{th} litter size at birth,

b^m = the linear regression coefficient of the observation of the $ijklmn^{th}$ litter on its litter weight at birth (as a covariate),

$\bar{X}$ = the mean of X_{ijklmn}, and

e_{ijklmn} = a random deviation of the n^{th} litter of ij^{th} doe and assumed to be independently randomly distributed $0, \sigma_e^2$).

Results and Discussion

Factors affecting litter size:

For both Bauscat and Giza White rabbits, litter size differed with parity (Table 1). Upon examination of parity least-squares means, no pattern was observed. The present study and those of Kalinowski and Rudolph (1977) and Afifi et al. (1982b) show that the inconsistency in parity effects on litter size at weaning may be due to differential mortality until weaning within litters of different parities. Differences in litter size due to parity effects were not significant ($P > 0.05$). Similar results were reported by Afifi et al. (1976), Khalil (1980), Afifi et al. (1982a), Afifi et al. (1982b), Emara (1982) and Lukefahr et al. (1983c).

There was a general tendency for litter size at weaning to be relatively low in October and November and to increase as month of kindling in the year of production advanced and to decrease again during April and May (Table 1). This trend was observed by other Egyptian investigators (El-Khishin et al., 1951; Khalil, 1980; Emara, 1982). The differences in average litter size at weaning in the present and other Egyptian studies may be attributed to differences in preweaning litter losses during the suckling period which occurred in litters born at different months. The significant linear, quadratic and cubic relationships between litter size and month of kindling in both breeds (Table 2) lead to an expected curvilinear effect of month of kindling on litter size. Evidence is available in the Egyptian studies on month-of-kindling differences for litter size by Khalil (1980). Most of the studies in countries other than Egypt (Broeck and Lampo, 1975; Lukefahr et al., 1983a,b) have shown that season or month-of-birth effects on litter size at weaning are not significant.

Litter size at weaning increased ($p < 0.001$) with increase of litter size at birth (Tables 1 and 2). Also, a linear relationship ($P < 0.001$) between litter size at weaning and litter size at birth was found, with no observable quadratic and cubic effects. Our interpretation is that the size of the litter at weaning improved significantly in a linear fashion from the smallest ($\leq$ 3 young) to the largest ($\geq$ 9 young) size of litter at birth. However, the relative sizes of the F-values indicate that litter size at birth was the most important factor influencing litter size at weaning. This is because of the part-whole relationship between the 2 variables. Furthermore, these results indicate the possibility of increasing litter size at weaning through early selection for large litter size at birth.

Each 100 gram increase in litter weight at birth was associated with an increase of 0.4 and 0.1 young in the size of the litter at weaning in Bauscat and Giza White does, respectively (Table 1). The superiority of Bauscat rabbits over those of Giza White in this respect may be due to better maternal ability of Bauscat does during the suckling period. The linear regression coefficient of litter size at weaning on litter weight at birth was significant ($P < 0.05$) for Bauscat and non-significant for Giza White rabbits (Table 2). Accordingly, the analysis of variance offered an indication that litter size at weaning in Bauscat rabbits was significantly linearly increased by the improvement of weight of litter at birth.

Factors affecting litter gain:

Preweaning litter gain increased linearly ($P < 0.001$) as parity advanced (Tables 1 and 2). This trend is thought to be due to the improvement in the care and ability of the doe to suckle her young with advance of parity sequence. The relative sizes of the F-values for the non-genetic effects included in the model of analysis indicate that parity effects contribute ($P < 0.001$) to the variance of litter gain in both breeds of the present study. Similar results have been reported by Afifi et al. (1982b).

Results in Tables 1 and 2 lead to the conclusion that preweaning litter gain increased significantly ($P < 0.001$ or $P < 0.05$) in a curvilinear fashion from the early months of the year of production (October and November) to its end during April and May (Table 1).

Preweaning litter gain increased linearly ($P < 0.001$ or $P < 0.01$) with increase of litter size at birth (Tables 1 and 2). Also, the overall means of preweaning litter gain (adjusted for other effects in the model of analysis) were observed to increase by 0.305 and 0.297 kg for each kg increase in litter weight at birth of Bauscat and Giza White rabbits, respectively. From these linear regression coefficients, prediction equations for preweaning litter gain (adjusted for other effects) in Bauscat and Giza White breeds, respectively, are calculated:

$$\hat{Y}_B = 1742.9 + 0.305\ (LWB - \bar{x})$$
$$\hat{Y}_G = 1643.4 + 0.297\ (LWB - \bar{x})$$

Y_B and Y_G are the predicted preweaning litter gain for Bauscat and Giza White breeds, respectively, LWB = observed litter weight at birth, and $\bar{x}$ = mean of the trait. Therefore, a prediction curve based on the regression of litter gain on litter weight at birth, adjusted for other effects in the model, could be plotted to indicate the changes that would be expected in preweaning litter gain with increasing litter weight at birth.

Factors affecting mean kit weight:

Mean kit weight at weaning increased linearly as parity sequence advanced until the 6th litter (Table 1). However, comparing this trend with that observed previously for litter gain confirms the direct and positive association between litter gain and individual kit weight measured at the same age. This trend is thought to be because milk yield of does increases as parity increases (Holds and Szendro, 1982). Possibly, the present findings are expected because does in their 1st parity have just reached sexual maturity and, consequently, their lactational performance during the suckling period is at its lowest level.

As observed for litter gain, results of the analysis given in Tables 1 and 2 showed that mean kit weight at weaning increased in a curvilinear manner, but at a decreasing rate, as month of kindling in the year of production advanced. This confirms the close association

Table 1. Least squares means and their standard error of factors affecting litter traits at weaning in Bauscat and Giza White rabbits.

Independent Variable	Litter Size (Young)				Litter Gain (grams)				Mean Kit Weight (grams)				Preweaning Mortality (%)			
	Bauscat		Giza White		Bauscat		Giza White		Bauscat		Giza White		Basucat		Giza White	
	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE	N	Mean	N	Mean
Parity																
1st	79	4.9 ± 0.2	55	4.4 ± 0.3	79	1523 ± 120	55	1329 ± 149	79	432 ± 17	55	385 ± 22	90	18.1	65	22.9
2nd	80	4.4 ± 0.2	52	4.3 ± 0.3	79	1500 ± 119	52	1420 ± 146	80	481 ± 16	52	431 ± 22	87	18.7	61	24.1
3rd	79	4.7 ± 0.2	60	4.0 ± 0.2	79	1712 ± 118	60	1445 ± 139	79	462 ± 16	60	465 ± 20	99	30.8	67	27.4
4th	72	4.8 ± 0.2	52	4.5 ± 0.2	73	1870 ± 116	52	1618 ± 140	72	456 ± 16	52	441 ± 20	88	31.2	54	15.5
5th	60	4.6 ± 0.2	31	4.4 ± 0.3	60	1785 ± 124	31	1871 ± 169	60	474 ± 17	31	520 ± 26	65	25.7	35	27.3
>6th	55	4.8 ± 0.3	58	4.9 ± 0.3	55	2067 ± 140	58	2177 ± 159	55	507 ± 20	58	534 ± 24	73	29.2	66	16.5
Month of Kindling																
Oct-Nov	65	4.0 ± 0.2	40	3.7 ± 0.3	67	1129 ± 127	40	1288 ± 159	65	389 ± 18	40	422 ± 24	79	33.2	44	33.5
Dec	52	4.9 ± 0.3	39	4.7 ± 0.3	52	1853 ± 139	39	1782 ± 166	52	476 ± 20	39	492 ± 25	58	17.1	42	12.8
Jan	78	4.9 ± 0.2	49	4.6 ± 0.3	78	2034 ± 120	49	1727 ± 149	78	524 ± 17	49	481 ± 22	88	19.3	51	13.8
Feb	74	5.1 ± 0.2	63	4.9 ± 0.2	73	2123 ± 122	63	2079 ± 137	74	513 ± 17	63	525 ± 20	82	19.3	69	13.2
March	56	4.8 ± 0.2	46	5.2 ± 0.3	55	1953 ± 133	46	1975 ± 153	56	504 ± 19	46	462 ± 23	61	20.6	50	11.9
Apr-May	100	4.4 ± 0.2	71	3.5 ± 0.2	100	1365 ± 114	71	1009 ± 137	100	405 ± 16	71	394 ± 20	134	44.4	92	56.1
Litter size at birth																
<3	33	3.2 ± 0.4	16	2.7 ± 0.5	34	1490 ± 160	16	1386 ± 212	33	616 ± 31	16	647 ± 40	45	9.1	19	7.9
4	30	3.6 ± 0.3	29	3.2 ± 0.4	30	1515 ± 165	29	1358 ± 177	30	506 ± 26	29	547 ± 29	40	31.1	36	16.7
5	51	4.6 ± 0.3	63	4.2 ± 0.3	50	1757 ± 137	63	1676 ± 144	51	481 ± 20	63	482 ± 22	63	17.2	72	25.4
6	74	4.8 ± 0.2	50	4.6 ± 0.3	74	1710 ± 122	50	1628 ± 150	74	441 ± 17	50	417 ± 22	83	25.6	53	18.8
7	98	4.9 ± 0.2	62	5.0 ± 0.3	98	1721 ± 111	62	1781 ± 143	98	441 ± 15	62	417 ± 21	115	29.8	68	30.0
8	70	6.4 ± 0.2	44	5.3 ± 0.3	68	2166 ± 123	44	1749 ± 160	70	398 ± 18	44	371 ± 26	74	20.9	53	35.7
>9	69	5.4 ± 0.3	44	6.1 ± 0.3	71	1841 ± 126	44	1926 ± 158	69	397 ± 22	44	358 ± 28	82	48.6	47	24.7
Regression on birth litter weight																
linear		0.004 ± 0.001		0.001 ± 0.001		0.305 ± 0.534		0.297 ± 0.648		-0.158 ± 0.124		0.281 ± 0.140		-0.049		-0.009

* The values given are retransformed estimates and, consequently, have no associated standard errors.

Table 2. Least squares means and their standard error of factors affecting litter traits at weaning in Bauscat and Giza White rabbits.

	Litter Size (Young)				Litter Gain (grams)		Mean Kit Weight (grams)		Preweaning Mortality (%)			
	Bauscat		Giza White		Basucat	Giza White	Bauscat	Giza White	Bauscat	Giza White	Bauscat	Giza White
	d.f.[a]	M.S	d.f.[a]	M.S	M.S	M.S	M.S	M.S	d.f.	M.S	d.f.	M.S
Sire of doe	23	4.13***	24	3.67	562114*	1048043***	20971*	32914***	23	913	26	1206*
Doe/Sire	92	1.49	56	2.32	330883*	263862**	11345	10973	99	744	59	631
Parity												
Linear	1	0.08	1	2.64	6292550***	6693596***	43680	278975***	1	2437	1	342
Residual	4	7.53	4	11.18	414672	1053231	71687	85174	4	2728	4	2618
Month of kindling												
Linear	1	13.04***	1	12.20*	3679883***	749434*	308173***	44424*	1	281	1	1156
Quadratic	1	10.48*	1	21.55**	5656849***	3348050***	353098***	260641***	1	11131***	1	19050***
Cubic	1	13.64**	1	17.31**	3020721***	731915*	109338**	74985**	1	1728	1	2015
Quartic	1	0.98	1	23.04***	1367756**	3690383***	56921*	124857***	1	2794	1	7896***
Quintic	1	0.05	1	12.77**	516920	12571	33194	6767	1	891	1	3321**
Litter size of birth												
Linear	1	60.59	1	62.01***	4425224***	1376187**	245003***	325439***	1	2865	1	1189
Quadratic	1	8.32	1	1.99	157968	549167	86175**	107799**	1	565	1	1053
Cubic	1	4.23	1	1.81	77975	86627	23829	12684	1	3237*	1	29
Quartic	1	19.66**	1	2.27	15842	77611	19138	1	1	162	1	996
Quintic	1	29.81***	1	0.04	15497	100426	1822	4534	1	5417**	1	143
Residual	1	1.52	1	0.43	421504	136652	17713	14862	1	142	1	620
Regression on birth litter weight												
Linear	1	10.90*	1	0.19	77537	36336	20009	47669*	1	2894	1	63
Remainder	292	2.20	210	2.24	493091	430694	12286	11886	362	847	245	585

[a] These degrees of freedom are the same for traits of litter gain and mean kit weight.

+ Error term to test sire effect.

* $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

between litter gain and mean kit weight at weaning. Also, the relative sizes of the F-values for the non-genetic effect included in the model of analysis indicates that month of kindling was an important factor influencing mean kit weight at weaning (Table 2).

Average individual kit weight at weaning decreased linearly ($P < 0.001$), but at a decreasing rate, with the increase of litter size at birth (Tables 1 and 2). The same trend was reported by Afifi et al. (1973) for average individual weight per litter at birth. Coupling these findings with the corresponding findings obtained for preweaning litter gain, it could be concluded that larger litter size at birth is related to heavier litter gain at weaning but with lighter average weaning weight per kit in the litter.

The linear regression of mean kit weight at weaning on litter weight at birth was significant ($P < 0.05$) for Giza White and non-significant in Bauscat rabbits (Table 2). Whether these relationships are real or are a result of the limited nature of the data set or due to some other unexplained cause cannot be ascertained.

Factors affecting preweaning litter mortality:

Preweaning mortality changed with advance of parity but no definite trend could be established (Table 1). Most of the studies reviewed showed a general trend indicating that preweaning mortality rate decreased as parity sequence advanced to a certain level, then increased again in subsequent parities. The present and reviewed studies suggest that in rabbits, maternal abilities, such as nest building, improve with experience. Contradictory to this trend, Afifi et al. (1982a) and Emara (1982) reported that percent of litter losses during the suckling period increased from the 1st to subsequent parities. The effect of parity was found to have no significant effect on preweaning mortality (Table 2). These results indicated that parity effects had negligible or no influence on preweaning litter mortality. Findings of the present study are in agreement with those reported by other Egyptian investigators (Khalil, 1980; Emara, 1982).

Preweaning mortality decreased in a quadratic manner ($P < 0.001$), with an increasing rate, as month of kindling advanced until March and increased thereafter during April and May (Tables 1 and 2). Lower litter losses during December to March, as compared with those of other months of the year of production, may be due to higher availability and better nutritive value of green fodder, in addition to milder weather (especially the environmental temperature) which prevails during December, January, February and March months. However, different trends for the effect of month of kindling on preweaning mortality rate were reported by some Egyptian investigators. Ragab and Wanis (1960) found that the lowest mortality rate up to weaning was for rabbits born during January and February. Lower litter losses were recorded by Khalil (1980) during November and December and by Emara (1982) during March and April. The relative sizes of F-values for non-genetic factors presented in Table 2 indicate that month of kindling was the only factor with a meaningful effect ($P < 0.001$) on preweaning mortality. For the breeds studied here and for other breeds of rabbits, results obtained by some Egyptian studies (Ragab and Wanis, 1960; Khalil, 1980; Emara, 1982) showed the same effect of month of kindling on preweaning mortality. Extensive studies in other countries (Rollins and Casady, 1967; Rouvier et al., 1973; Lukefahr et al., 1983c) have demonstrated that month or season-of-birth effect an influence on preweaning mortality rate.

Preweaning litter mortality differed as litter size at birth changed, but the differences were limited and not significant (Tables 1 and 2). These results confirm those obtained by Rollins and Casady (1967), Rao et al. (1977), Khalil (1980) and Emara (1982). In contrast, Ragab and Wanis (1960) found that effects of litter size at birth on preweaning mortality were significant ($P < 0.01$).

Estimates of linear regression coefficients of preweaning mortality on litter weight at birth showed that preweaning mortality decreased insignificantly as litter weight at birth increased (Tables 1 and 2). This expected trend may be due to the fact that increase in litter weight at birth is associated with an increase in average individual weight per litter at birth. Consequently, the larger rabbits become strong, fit and more resistant to diseases and death.

Sire effect:

The sire of doe affected ($P < 0.05$ or $P < 0.001$) all litter traits studied with the exception of litter size in Giza White and preweaning litter mortality in Bauscat breed (Table 2). However, significant sire effects on most of the litter traits suggest that litter traits must be analysed as a trait of the doe. Accordingly, the effect of sire of the doe that produced the litter must be considered in genetic analyses instead of the mating-buck effect. In conclusion, selection of sires of does based on the doe's performances for litter traits at weaning will be effective for the genetic improvement of these traits.

Doe effect:

The doe had non-significant effects on litter traits of both breeds with the exception of preweaning litter gain. It may be possible that feeding and management practices masked full expression of doe differences. Additionally, a negative covariance may have existed between litters in adjacent years because of imbalances in body reserves of the doe from one year to another. Differences due to doe effects in litter traits measured at weaning may be attributed to differences in maternal effects determined by nourishment of the young during the suckling period (Randi and Scossiroli, 1980). Differences in the phenotypic relationships between growth rate of does and their reproductive traits (Rollins _et al_., 1963) could be added as another cause in this respect. In short, if a doe has large litters, her daughter will have lower litter size and her grand-daughter large litters again, assuming that there would be a negative correlation between direct and maternal effects and positive between direct and grand-maternal effects (Blasco _et al_., 1982). Therefore, selection for increased growth rate or increased mature size of the dam is expected to increase litter size, litter weight and litter gain. In conclusion, evidence from the literature reviewed and other suggested interpretations here indicate that litter traits are primarily associated with the dam rather than the sire. Improvement of litter traits is accomplished primarily through the selection of does based on their own or their dams' reproductive performance.

Summary

Records of 840 litters of Bauscat (B) and Giza White (G) rabbits were analyzed to quantify sire of doe, doe within sire, parity, month of kindling, birth litter size and birth litter weight effects for litter traits at weaning.

No definite trends for parity effects on weaning litter size and preweaning litter mortality were detected. Preweaning litter gain and mean kit weight at weaning (except mean kit weight in B rabbits) increased linearly ($P < 0.001$) as parity advanced.

There was a general tendency for litter size, litter gain and mean kit weight to be low when kindling took place in the early months of the year of production (October and November) and to increase significantly in a curvilinear manner as month of kindling advanced. Preweaning litter mortality decreased in quadratic pattern ($P < 0.001$) as month of kindling advanced until March and increased thereafter during April and May.

Litter size at weaning and preweaning litter gain increased linearly ($P < 0.01$ or $P < 0.001$) with increase of litter size at birth while mean kit weight decreased linearly ($P < 0.001$) but at a decreasing rate. Birth-litter-size effects on preweaning mortality were very limited.

Litter size, litter gain and mean kit weight increased by the improvement of weight of litter at birth. Preweaning mortality decreased as birth litter weight increased, but the differences were of little magnitude and can be ignored.

The sire of doe significantly affected all litter traits studied with the exception of litter size in G breed and preweaning mortality in B while the doe had a non-significant effect on traits of both breeds, with the exception of litter gain ($P < 0.05$ or $P < 0.01$).

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Research Review

Fiber and starch levels in fattening rabbit diets. J.C. de Blas *et al.*, J. Animal Sci. 63:1897-1904

(Reviewed by P.R. Cheeke)

The authors, of the Polytechnical University of Madrid, Madrid, Spain, conducted a study to determine the effect of dietary fiber and starch levels on growth, enteritis, nutrient digestibility and digestive tract characteristics of fryer rabbits.

One-hundred and eighty New Zealand White rabbits, weaned at 28-30 days of age, were allocated to the dietary treatments. The diets were based on barley, alfalfa, wheat bran, soybean meal, sunflower meal and barley straw, to provide varying levels of fiber and starch. The proportions of feedstuffs were varied to maintain an energy-to-protein ratio of 23-25 kcal DE per g of digestible protein. Nutrient composition of the diets is shown in Table 1.

Growth performance and diarrhea mortality rate are shown in Table 2. The data indicate that at all crude fiber levels between 9.1% and 17.4%, a high growth rate was maintained, while at higher fiber levels, growth rate was reduced. Nutrient digestibility decreased with increasing fiber levels. Diarrhea mortality was low, and was observed primarily in the group receiving the lowest fiber diet.

Some characteristics of the digestive tract were measured in animals from low, medium and high fiber diets (Table 3). Weight of the stomach, stomach contents and weight of soft feces in the stomach were highest with the higher fiber diet. In contrast, cecal weights were highest with the low fiber diet. Increase of stomach contents with higher dietary fiber is probably a consequence of the lower dietary energy level, resulting in a higher feed intake. Increased weight of the empty stomach is probably an adaptation to a low energy diet, allowing greater capacity for increased feed intake.

The increased size of the cecum and cecal contents on a low fiber diet has also been reported by other workers. The most likely explanation is that it is a reflection of hypomotility of the cecum, resulting in a prolonged retention time in this organ. Fiber stimulates hindgut motility. The hypomotility of the cecum on low fiber diets favors development of enteritis and signs of diarrhea, thus producing the seeming anomaly of diarrhea resulting from constipation. The reduced weight of soft feces in the stomach in the animals fed the low fiber diet is a further reflection of cecal hypomotility, resulting in less cecal contents being secreted as soft feces.

In summary, this study supports a number of others, indicating that a dietary crude fiber level of less than 10% is likely to promote enteritis and reduced growth, while a crude fiber level exceeding 17% reduces performance by limiting energy intake.