4. RESULTS AND DISCUSSIONS

4.1. Litter Traits

4.1.1. Actual means

Actual means of different litter traits (litter size at birth, LSB, litter size at 21 days, LS21, litter size at weaning, LSW, litter weight at birth, LWB, litter weight at 21 days, LW21, litter weight at weaning LWW, mean bunny weight per litter at birth, MBWB, at 21 days, MBW21and at weaning, MBWW and pre-weaning litter mortality, PM)) are presented in Table 44. Actual means in that Table are within the ranges of the available literature for litter size traits of Californian rabbits raised in Egypt. However, the means of litter weight traits are somewhat lower than those reported for the same breed in the Egyptian studies. Actual means of mean bunny weight per litter at different ages in that Table are higher than those of the available literature for the same traits under study. While actual means of pre-weaning litter mortality are within the ranges of the available literature on Californian rabbits raised in Egypt.

4.1.2. Variations

The CV% of litter traits ranged from 9.25 to 60.1 % (Table 44). The CV% obtained for these traits in Cal rabbits by different investigators ranged from 23.8 to 43.7% (Table 5).

Estimates of CV% given in Table 44 show a general trend indicating that litter size at weaning had higher phenotypic variation than at birth. Results of Khalil et al (1987a), El-Maghawry (1990) and El-Desoki (1991) confirmed this trend. Moreover, the higher CV% for litter traits at weaning than at birth might be due to that litters would become less sensitive to the non-genetic maternal effect which decreases with advance of litter age.

4.1.3. Non-genetic aspects

Least squares analysis of variance (Table 45) and least squares means of different factors affecting litter traits are presented in Tables 46 and 47.

Table 44. Actual means, standard deviations (SD(and coefficients of variation (CV%(for litter and doe reproductive traits in Californian, Gabali and their two reciprocal crosses.

Traits	N	Mean	SD	CV%
i. Litter Traits				
Litter size at birth (young)	452	5.90	1.9	37.8
Litter size at 21 days (young)	403	3.96	1.5	38.4
Litter size at weaning (young)	369	3.54	3.54	14.2
Litter weight at birth (gm)	452	298.94	95.4	34.2
Litter weight at 21 days (gm)	403	1270.17	578.9	46.3
Litter weight at weaning (gm)	369	1567.45	588.2	36.9
Mean bunny weight at birth (gm)	452	54.10	54.1	12.2
Mean bunny weight at 21 days (gm)	403	318.90	318.9	14.2
Mean bunny weight at weaning (gm)	369	443.20	443.2	10.4
Pre-weaning litter mortality (young /litter)	452	2.10	1.3	60.1
ii. Doe reproductive Traits				
Number services per conception (units)	363	3.44	2.5	71.5
Days open (days)	283	39.72	26.7	67.3
Kindling interval (days)	367	62.16	28.5	45.8
Gestation length (days)	452	31.09	2.3	7.5

Table 45 . F- ratios of least squares analysis of variance of factors affecting litter traits .

Source of variance	df	LSB F- value	LWB F- value	MBWB F- value	df	LS21 F- value	LW21 F- value	MBW21 F- value	df	LSW F- value	LWW F- value	MBWW F- value	df	PM F- value
Mating group	3	3.54*	3.25*	2.61	3	0.18	0.22	1.57	3	0.86	0.24	6.40**	3	1.46
Buck / mating group	37	1.00	0.99	1.59*	37	1.11	1.16	1.21	37	1.74*	1.81**	0.81	37	1.10
Doe / buck / mating group	67	1.46**	1.42*	1.10	66	1.53*	1.12	2.31***	66	1.18	1.20	1.90**	67	1.28
Year of kindling	2	0.94	1.26	0.60	2	1.70	0.83	5.53**	2	1.53	0.19	10.64***	2	0.83
Month of kindling	11	1.52	2.03*	1.70	11	1.03	1.28	0.74	11	1.44	1.68	1.37	11	0.75*
Parity	5	2.19	2.42*	0.50	5	2.31	1.05	2.24*	5	2.31*	2.64	0.77	5	0.64
Mating group x month of kindling	33	1.25	1.49*	0.82	33	1.17	1.09	0.51	33	0.83	0.79	1.24	33	0.92
Mating group x parity	15	0.88	0.88	1.20	15	1.52	1.15	0.85	15	1.47	1.54	2.33**	15	0.86
Remainder	278				230				196				276	
Remainder mean squares		3.02	6780.8	41.23		1.77	327030.4	1241.39		1.45	245187.2	1486.99		1.4

LSB = Litter size at birth, LWB =Litter weight at birth, MBWB = Mean bunny weight a birth, LS21= litter size at 21days, LW21 = Litter weight at 21 days,MBW21 = Mean bunny weight at 21 days LSW = Litter size at weaning, LWW = Litter weight at weaning , MBWW = Mean bunny weight at weaning, PM = Pre-weaning mortality .
* = $P < 0.05$, ** = $P < 0.01$ or ***= $P < 0.001$.

Table 46. Least squares means and standard errors of factors affecting litter size traits .

Indepented variable	N	LSB Mean± SE	N	LS21 Mean± SE	N	LSW Mean ± SE
Mating group						
Cal x Cal	185	5.7 ± .22	176	4.1 ± .19	160	3.64 ± 0.24
Gab x Gab	82	5.0 ± .34	70	4.2 ± .32	65	3.96 ± 0.36
Cal x Gab	82	4.7 ± .29	72	4.1 ± .27	67	3.70 ± 0.23
Gab x Cal	103	4.8 ± .26	85	3.9 ± .24	77	3.37 ± 0.24
Year of kindling						
1993-1994	115	5.0 ± .52	107	3.9 ± .45	98	3.76 ± 0.48
1994-1995	240	4.7 ± .28	207	3.8 ± .24	183	3.30 ± 0.27
1995-1996	97	4.4 ± .26	89	4.6 ± .41	88	3.95 ± 0.42
Month of kindling						
September	22	5.2 ± .52	20	4.1 ± .42	17	3.66 ± .52
October	51	6.0 ± .39	48	4.8 ± .35	43	4.95 ± .36
November	58	6.0 ± .32	55	4.4 ± .28	53	3.76 ± .28
December	43	5.2 ± .35	37	4.1 ± .32	34	3.53 ± .33
January	41	5.0 ± .42	39	3.9 ± .35	37	3.62 ± .36
February	47	5.4 ± .33	42	4.1 ± .28	39	3.66 ± .28
March	26	5.0 ± .45	23	3.9 ± .39	22	3.42 ± .39
April	40	5.0 ± .40	32	4.5 ± .39	30	4.16 ± .37
May	24	4.4 ± .45	19	3.9 ± .40	18	3.61 ± .40
June	46	4.6 ± .39	41	3.8 ± .41	37	3.91 ± .43
July	34	4.6 ± .50	30	3.7 ± .47	25	3.03 ± .49
August	20	4.7 ± .52	17	4.1 ± .47	14	3.66 ± .47
Parity						
1 St.	78	4.8 ± .34	72	3.8 ±.31	67	3.37 ± .31
2 nd	80	4.4 ± .29	73	3.5 ± .26	67	3.04 ± .27
3 rd	84	5.0 ± .28	73	4.3 ± .25	67	3.56 ± .26
4 Th.	72	5.4 ± .30	66	4.2 ± .26	61	3.62 ± .27
5 Th.	51	5.6 ± .34	46	4.7 ± .30	43	4.29 ± .32
>6 Th.	87	4.8 ± .35	73	3.4 ± .32	64	4.11 ± .32

LSB = Litter size at birth, LS21 = Litter size at 21 days, LSW = Litter size at weaning
Cal=Californian, Gab= Gabali.
St =First, nd =Second, Th. =third.

Table 47. Least squares means and standard errors of factors affecting litter weight, mean bunny weight per litter and pre-weaning mortality .

Indepented variable	N	LWB Mean± SE	MBWB Mean± SE	N	LW21 Mean ± SE	MBW21 Mean± SE	N	LWW Mean ± SE	MBWW Mean± SE	N	PM Mean ± SE
Mating group											
Cal x Cal	185	294.8±10.1	52.5±1.0	176	1274.8±072.5	315.1±07.1	160	1540.62±101.1	428.1±06.2	185	2.38±0.15
Gab x Gab	82	259.6±15.7	55.3±1.3	70	1183.2±116.5	300.9±11.2	65	1623.15±153.5	414.0±11.3	82	1.99±0.21
Cal x Gab	82	248.2±13.4	54.9±1.2	72	1192.6±103.3	312.1±09.6	67	1600.00±140.4	435.1±09.2	82	1.92±0.19
Gab x Cal	103	257.4±11.9	56.1±1.0	85	1236.3± 86.0	326.1±08.2	77	1506.03±102.5	455.9±07.2	103	2.09±0.16
Year of kindling											
1993-1994	115	269.4±24.7	56.7±2.0	107	1005.4±189.4	329.6±12.2	98	1558.17±200.8	417.6±15.4	115	2.16±0.35
1994-1995	240	245.9±13.3	54.6±1.1	207	1230.1±100.2	326.3±07.2	183	1519.13±114.6	466.7±08.4	240	2.29±0.19
1995-1996	97	279.6±22.4	52.9±1.8	89	1429.7±174.2	284.8±11.4	88	1625.05±173.7	415.4±13.2	97	1.83±0.32
Month of kindling											
September	22	275.0±24.3	57.6±1.9	20	1196.5±179.3	311.5±11.6	17	1560.75±213.49	432.9±16.4	22	2.11±0.35
October	51	323.1±18.6	51.8±1.5	48	1625.6±145.9	812.5±09.7	43	1979.68±147.68	434.7±11.1	51	2.11±0.26
November	58	314.7±15.2	53.8±1.3	55	1350.5±115.3	328.3±08.0	53	1642.99±118.30	450.2±08.7	58	2.34±0.22
December	43	273.2±16.8	55.8±1.4	37	1125.7±132.9	315.4±09.0	34	1483.41±138.30	442.3±10.4	43	2.27±0.24
January	41	277.0±20.0	56.8±1.6	39	1157.8±147.5	308.5±09.8	37	1557.59±150.61	442.5±11.4	41	1.97±0.29
February	47	277.2±15.6	53.1±1.3	42	1169.8±115.4	311.9±08.1	39	1586.87±117.45	436.4±08.7	47	2.23±0.22
March	26	253.4±21.3	55.0±1.7	23	1114.3±165.1	312.9±10.9	22	1455.04±161.32	423.9±12.2	26	2.29±0.31
April	40	245.0±19.0	52.0±1.5	32	1423.8±164.6	313.2±10.8	30	1742.96±154.91	415.5±11.7	40	1.73±0.27
May	24	224.0±21.2	55.3±1.7	19	0973.8±169.8	297.9±11.1	18	1248.53±164.37	400.9±12.5	24	1.74±0.31
June	46	240.8±24.0	55.4±1.5	41	1211.0±156.3	317.8±10.3	37	1712.99±180.24	440.9±13.7	46	1.89±0.26
July	34	238.1±23.5	53.2±1.9	30	1088.5±212.9	313.1±13.7	25	1131.53±204.31	435.5±15.6	34	2.49±0.34
August	20	248.0±24.6	57.3±1.9	17	1224.2±201.1	319.7±12.9	14	1590.05±195.55	443.1±14.9	20	1.95±0.35
Parity											
1 st	78	244.0±16.0	1.3±1.3	72	1081.9±129.4	292.5±08.8	67	1399.36±127.38	422.7±09.5	78	2.13±0.23
2 nd	80	234.0±14.0	1.1±1.1	73	1055.5±105.9	315.9±07.5	67	1315.94±111.31	433.5±08.2	80	2.12±0.25
3 rd	84	277.3±13.1	1.1±1.1	73	1292.9±101.3	308.8±07.3	67	1498.82±107.27	426.1±07.9	84	2.38±0.19
4 th	72	282.7±14.0	1.1±1.1	66	1261.7±109.4	3189±07.7	61	1535.32±113.37	438.4±08.2	72	2.06±0.20
5 th	51	292.5±16.1	1.3±1.3	46	1376.9±126.8	319.5±08.7	43	1866.30±133.56	443.1±10.0	51	1.99±0.23
<6 th	87	259.6±16.7	1.3±1.3	73	1261.4 ±132.2	325.9±08.9	64	1788.95±134.31	435.6±10.0	87	1.90±0.24

LWB= Litter weight at birth, , LW21 = Litter weight at 21 days, , LWW = Litter weight at weaning , MBWB = Mean bunny weight at birth , MBW21 = Mean bunny weight at 21day , MBWW= Mean bunny weight at weaning.
Cal = Californian, Gab = Gabali .

i. Year of kindling

Year-of-kindling effect on litter traits from birth up to weaning at four weeks except MBW21 and MBWW was found to be non-significant (Table 45). Similarly, Kawinska and Niedzwiade, (1967), Kown et al (1982), Afifi and Emara (1984), Afifi et al (1987), Nunes and Polaster (1988), Sallam et al (1989), Mohamed (1989), Afifi et al (1992), Hassan et al (1994) and Farghaly, (1996) reported that year-of-kindling effect on litter traits was non-significant. However, year-of-kindling effects was observed by different investigators to contribute significantly ($P<0.05$, $P<0.01$ or $P<0.001$) to the variance of different litter traits (e.g. Rollins and Casady, 1967; Afifi et al., 1976a&b; Khalil, 1980; Afifi et al., 1982b; Emara, 1982; Afifi and Emara, 1985; El-Boushy, 1985; Khalil et al., 1987a; Khalil and Mansour, 1987; Afifi and Emara, 1988; Lee et al., 1988; Hassan, 1988; Khalil et al., 1988; Afifi et al., 1989; Khalil et al., 1989; Khalil and Soliman, 1989; Abdella et al., 1990; Ahmed, 1997). In this respect, Youssef (1992) and Khalil et al (1995) found that year-of-kindling effect was significant on litter traits at weaning (LSW , LWW and MWW)) while non-significant on these traits when measured at birth and at 21 days of age (LSB, LWB, LS21, LW21 and MW21). Year influence might be due to changes and fluctuations in environmental, climatic, feeding and managerial conditions, caretaker skill, along with genetic make-up which may occur within long periods which were associated with year of production (Khalil et al., 1988 and Afifi et al., 1989). Youssef (1992) noted that sometimes year effect was not clear because of existence of partial or complete confounding with any other fixed (such as season or parity) or random effects (such as doe or buck when used for one year). Accordingly, the influence of year effect as a major part of the environment must be considered in the analysis of genetic studies for doe performance.

Year of kindling effect on pre-weaning litter mortality was not significant (Table 45). Similarly, Afifi and Emara (1984b), Khalil and Mansour (1987), Afifi et al (1992), reported non-significant year effect on pre-weaning litter mortality. On the contrary, Khalil and Mansour (1987), Khalil et al

(1987d) indicated that year-of-kindling effect was significant (P<0.01 or P<0.001) on pre-weaning litters mortality.

ii. Month of kindling

Month-of-kindling effect was not significant on LSB, MBWB, LS21, LW21, MBW21, LSW, LWW and MBWW, but significant (P<0.05) on LWB and PM (Table 45). Results reported by El-Qen, (1988); Hassan, (1988); El-Maghawry (1990); El-Desoki (1991); Sedki (1991); Yamani et al (1991b); Afifi et al (1992); El-Sayiad et al (1993a); Hassan (1993&1995) showed that month of kindling did not contribute significantly to the variance of litter traits (viz., LSB, LS21, LSW and LWW and PM). On the contrary, many Egyptian studies gave evidence that month-of-kindling effect was significant (P<0.05, P<0.01, P<0.001 or P<0.0001) on most litter traits (e.g. Ragab and Wanis, 1960; Afifi and Emara, 1984a&1987; Khalil et al., 1987a&d; Khalil and Mansour, 1987; El-Magawry et al., 1988; Afifi and Khalil, 1989; Sedki, 1991; Khalil and Afifi, 1991; Yamani et al., 1991a&b; Tag El-Din et al., 1992; Youssef 1992; Farghaly and El-Darawary, 1994).

Pre-weaning litter mortality was significantly (P<0.05) affected by month of kindling. In agreement with the present results, Oudha (1990) with Cal, NZW and Baladi rabbits and Hilmy (1991) with NZW reported that month-of-kindling effect was significant (P<0.01) on pre-weaning litter mortality. Hilmy (1991), NZW and Cal observed the contrary when considering Baladi Red by Sedki (1991) since they were not able to detect any significant effect in this respect. Least squares means listed in Tables 46-and47 show that no consistent trend was observed for month-of-kindling effect on litter traits under study. Sallam et al (1989); Abdella et al (1990) and Afifi et al (1992) found the same trend for the effect of month of kindling on some litter traits (viz., LSB, LS21, LSW, LWB, and LW21).

iii .Parity

Parity effect was found to be non-significant on LSB, MBWB, LS21, LWB, MBWW, LWW and PM but significant (P<0.05) on MBW21, LWB and LSW (Table 45) . Afifi and Emara (1987), Khalil et al (1987d), Khalil and Mansour (1987), El-Maghawry et al (1988); Afifi and Khalil (1989); Hassan

(1993) and Nasr (1994) reported that parity effect was not significant on litter traits (LSB, LS21, LSW, LWB, MBWB, LW21, MBW21, LWW, MBWW and PM). On the contrary, Afifi et al (1982a&b); Neidzwideck et al (1983); Ouhda (1990), Sedki (1991), Sallam et al (1992), Tagel Din et al (1992), Hassan (1993); Farghaly and Darawany (1994) and Nofal et al (1996) found significant (P<0.05, P <0.01 or P<0.001) effect on LSB, LS21, LWB and/or LWW. In non-Egyptian studies, Gecele et al (1985), Grandi and Stefanetti (1987); Castellini and Panella, (1987); Nunes and Polaster, (1988); Ferraz et al (1991b) and Moura et al (1991b) indicated significant (P<0.05 or P<0.01) parity effect on most litter traits (LSB, LWB, LS21, LSW and LWW). Results in Tables 46 and 47 show inconsistent pattern of parity effect on litter traits. The same findings were observed by Afifi and Emara (1985); Afifi and Kadry (1985); Khalil et al (1987a&d); Khalil and Soliman (1989); Youssef (1992); Abdel Raouf (1993); Khalil et al(1993) and Nasr (1994). In this respect, a curvilinear effect of parity on litter size and weight traits was detected by many investigators (e.g. Afifi and Emara, 1985; Afifi and Kadry, 1985; Khalil et al., 1987a&d; Khalil and Soliman, 1989, Abdel Raouf, 1993; Khalil et al, 1993; Nasr, 1994).

The differences in litter size and litter weight at birth due to parity effects may be attributed to changes in the physiological efficiency of the doe which occur with advance of parity (age) by Afifi et al (1982a&b) and (1992), Emara, (1982); Afifi and Emara (1984a); Khalil et al (1987a); Afifi et al (1992).

iv. Interactions

Effects of the interaction between mating group and month of kindling was insignificant on litter traits of the study, except litter size at birth which proved significance (P<0.05). Most of the interactions between mating group and parity were found to be non-significant for all litter traits under study, but significant (P<0.01) on MBWW only (Table 45).

4.1.4. Genetic aspects

i. Mating group

Litter traits (MBWB, LS21, LW21, MBW21, LSW, LWW and PM) varied with mating group but without significant differences (Table45).

However, LSB LWB and MBWW showed significant ($P<0.05$ or $P<0.01$) variability caused by mating group differences (Table45).

least squares means of litter traits of the study according to mating group are illustrated in Tables 48 and 49. Cal x Cal mating produced litters with the largest size and the heaviest weight at birth but Gab x Gab mating gave litters with the largest size and heaviest weight at weaning, while Gab x Cal mating gave the heaviest MBWB, MBW21 and MBWW. The ranking of litters of the mating groups for litter sizes and litter weight at birth, 21 days and at weaning was not the same (Tables 48&49). For pre-weaning mortality, litters of Cal x Gab ranked the best then followed in a descending order by those of Gab x Gab, Gab x Cal and Cal x Cal. This may be due to the non-genetic influences to which the litters are exposed.

ii. Purebred differences

Linear contrasts of purebred Cal and Gab given in Tables 48 and 49 are in favour of Cal rabbits for LSB, LWB, LW21 and MBW21, MBWW while in favour of Gab rabbits for LS21, LSW, LWW and MBWB. The differences between the two breeds were significant ($P<0.05$) for MBWB and MBW21. The linear contrasts revealed that PM in Cal rabbits was higher than in Gab ones but without significant difference. These results were supported by those of Khalil (1996) and Afifi (1997) which showed that Gab rabbits recorded lower performance for LSB, and LSW than the exotic breed (NZW) and nearly similar performance to that of NZW for LWB and LWW (Unpublished data).

iii. Heterotic effects

Estimates of direct heterosis (calculated in actual units and as percentages) for litter traits are presented in Tables 48 and 49.
These estimates show that direct heterosis was negative for all litter traits except mean bunny weight at different ages which proved significant ($P<0.05$, $P<0.01$ or $P<0.001$).

Table 48. Estimates of mating group means (± SE), purebred differences, heterosis, maternal additive effect (G^m) and direct additive effect (G^i) of litter size traits .

Item	LSB		LS21		LSW	
	N	Mean ± SE	N	Mean ± SE	N	Mean ± SE
Mating group						
Cal x Cal	185	5.7 ± .22	176	4.06 ± .19	160	3.6 ± .24
Gab x Gab	82	5.0 ± .34	70	4.15 ± .32	65	4.0 ± .36
Cal x Gab	82	4.7 ± .29	72	4.02 ± .27	67	3.7 ± .33
Gab x Cal	103	5.0 ± .26	85	4.00 ± .24	77	3.4 ± .24
Purebred difference						
$\{(G^i_{Cal} + G^m_{Cal}) - (G^i_{Gab} + G^m_{Gab})\}$		0.7±0.3		- 0.1±0.3		- 0.3±0.3
Heterosis contrast						
$H^i_{Cal \times Gab}$ unit		- 0.59 ± . 21*		- 0.14 ± .18		-0.26 ± .18
Percent		-11.2%		- 3.5%		- 6.8%
Maternal additive effect						
$(G^m_{Cal} - G^m_{Gab})$		0.03 ± .29		- 0.11 ± .25		0.033 ± .24
Direct additive effect						
$(G^i_{Cal} - G^i_{Gab})$		0.34 ± .22		0.02± .18		0.005 ± .18

LSB = Litter size at birth, LS21 = Litter size at 21 days, LSW = Litter size at weaning
* = $P< 0.05$; ** = $P < 0.01$.
Cal =Californian, Gab =Gaball.

Table 49. Estimates of mating group, means ± SE, purebred difference, heterosis, maternal additive effect (G^m) and direct additive effect (G^i) on litter weight, mean bunny weight per litter and pre-weaning traits .

Item	N	LWB Mean ± SE	MBWB Mean ± SE	N	LW21 Mean ± SE	MBW21 Mean ± SE	N	LWW Mean ± SE	MBWW Mean ± SE	PM Mean ± SE
Mating group										
Cal x Cal	185	294.75±10.1	52.6±0.9	176	1274.78 ±072.6	315.1±07.0	160	1540.62±101.2	428.1±06.2	2.38±0.15
Gab x Gab	82	259.54±15.7	55.3±1.3	70	1183.23 ±116.5	300.9±11.2	65	1623.15±153.6	413.9±11.4	1.98±0.22
Cal x Gab	82	248.03±13.4	54.9±1.2	72	1192.63 ±103.3	312.1±09.6	67	1599.99±140.5	435.1±09.2	1.92±0.19
Gab x Cal	103	257.46±11.9	56.1±0.9	85	1236.32 ± 86.0	326.1±08.2	77	1506.03±102.6	455.9±07.9	2.09±0.16
Purebred differences										
{(G^i_{Cal} + G^m_{Cal}) - (G^i_{Gab} + G^m_{Gab})}		35.2±14.9	- 2.6±1.2**		91.6±115.1	14.2±07.1**		- 82.5±107.8	14.1±08.3	0.4±0.2
Heterosis contrast										
$H^i_{Cal x Gab,}$ unit		- 24.41 ± 9.95	1.5±0.8**		-14.4 ± 78.25	11.1±4.8**		- 28.9 ± 72.6	24.5±5.7***	- 0.18 ± 0.14
Percent		- 8.8%	2.8%		- 1.2%	3.6%		- 1.85%	5.8%	- 16.4%
Maternal additive effect (G^m_{Cal} - G^m_{Gab})		9.41± 13.7	1.2±1.1		-43.69 ±107.6	14.1±6.6**		- 93.97 ± 99.2	20.8±07.7**	0.18 ± 0.20
Direct additive effect (G^i_{Cal} - G^i_{Gab})		12.9 ± 10.4	- 1.9±.75**		23.93 ± 80.2	0.1±4.75		5.72 ± 74.6	- 3.35±5.6	0.115 ±.145

LWB = Litter weight at birth, MBWB = Mean bunny weight at birth, LW21 = Litter weight at 21 days, MBW21 = Mean bunny weight at 21 days, LWW = Litter weight at weaning, MBWW = Mean bunny weight at weaning, PM=Pre-weaning litter mortality .
+ Buck breed listed before the doe breed ; * = P< 0.05 ; ** = P < 0.01 .
Cal =Californian, Gab =Gabali.

Estimates of heterosis percentages ranged from 2.8 to 5.8 % for mean bunny weight traits (MBWB, MBW21 and MBWW) and was -16.4% for pre-weaning litter mortality (PM). In this respect, Youssef (1992) found that heterosis percentages ranged from - 8.2 to 12 % for litter size traits (LSB, LS21), from - 0.9 to 16.5% for litter weight traits (LWB, LW21& LWW), from 6.2 to 11.4% for mean bunny weight traits and - 2.0% for PM.

Findings of the present study reveal that crossing between Cal and Gab rabbits, did not improve litter size and litter weight from birth to weaning but improved mean bunny weight traits and reduced pre-weaning mortality, i.e. improved livability. However, Emara (1982) and Soliman (1983) showed that crossing between local breeds had little or no heterotic effect on litter traits of their crossbred litters. In this respect, Afifi (1971); Afifi et al (1976b); Emara (1982); Soliman (1983); Afifi and Emara (1987); Khalil (1989); Afifi and Khalil (1989); Ozimba and Lukefahr (1991); Youssef (1992); Khalil et al (1995) and Nofal et al (1996) reported that crossbred litters excelled purebred litters of their parental breeds for litter traits, i.e. positive heterotic effect was observed in most crossbreeding groups. In agreement with the present results, Khalil (1980); Afifi and khalil (1989); Youssef (1992); Khalil et al (1995) indicated that crossing between the different breeds was associated with a reduction in pre-weaning litter mortality.

iv. Maternal additive (breed) effect

Maternal additive (breed) effect on litter traits expressed as the differences between reciprocal crosses [(i.e. Cal X Gab - Gab x Cal)] were not significant for litter traits except mean bunny weight at 21days and weaning which proved significant (P<0.01) as shown in Tables 48 and 49. These results agree with Afifi (1971); Afifi et al (1976a&b); Dora (1979); Tagel-Din (1979); El-Qen (1988); Afifi and Khalil, (1989); Khattab (1990); Oudah (1990); Youssef (1992); Khalil et al (1995) who evidenced that maternal breed additive effect (expressed as the difference between reciprocal crosses) on litter traits (LSB, LWB, LS21, LW21, LSW, LWW and PM) were not significant.

Estimates of maternal additive (breed) effect on most litter traits was in favour of Cal damed litters. (Tables 48&49). This means that using Cal rabbits as a doe breed and Gabali rabbits as a buck breed is generally better than the reverse. The superiority of Cal does over Gab ones for litter traits could be attributed to favorable maternal abilities, presumably due to increasing milk production levels compared to Gab does (Khalil, 1996 and Afifi, 1997). Balsco et al (1992) explained the maternal ability component contributing to the variation of litter traits at birth to the variation related to ovulation rate, ova wastage, implantation sites, embryonic mortality, embryo survival, uterine capacity and intra-uterine environment, while at weaning litters are largely depended upon the maternal care provided by the doe for her young during the suckling period. In conclusion, Cal rabbits could be used as breed of doe in crossbreeding programs for improving litter traits utilizing both Gab and NZW breeds.

v. Direct additive (breed) effect:

Direct additive (breed) effect differences (G^{i}_{Cal} - G^{i}_{Gab}) reflect one-half of the differences in direct effect between Cal x Cal and Gab x Gab mating group, i.e. {[(Cal x Cal) + (Cal x Gab)] - [(Gab x Gab) + (Gab x Cal)]}. The linear contrasts of direct additive (breed) effect was not significant for most litter traits but was significant ($P<0.01$) for MBWB only (Tables 48&49) i.e. little contribution of buck breed effect in the inheritance of litter traits was observed. In this respect, Youssef, (1992) and khalil et al (1995) using NZW, Baladi Red and their reciprocal crosses found that the linear contrasts of direct additive effects for all litter traits of his study were not significant. Lukefahr et al (1983) stated that direct paternity effects on litter traits (LSB, LWB, LSW, LWW and PM) were mostly in favour of Cal litter's Vs litters sired by NZW rabbits. They added also that direct Flemish Giant paternity effects on pre-weaning litters were positive and high compared with litters of NZW paternity.

4.2. Doe Reproductive Traits

4.2.1. Actual means

The actual means of number of services per conception, NSC, was relatively high (3.4 services) compared with means obtained on different breeds of rabbits in the Egyptian studies (1.1 - 2.9 services) and non-Egyptian literature (1.2 - 2.8 services). Means of days open (DO), kindling interval (KI) and gestation length (GL) presented in Table 44 (39.7, 62.2 and 31.1 days, respectively) are lower than those reported in the literature being 50.7, 78.0 and 31.3 days for the same traits in the same order.

.2.2. Variations

Estimates of CV% of NSC, DO and KI being 71.5, 67.3 and 45.8 % are relatively high. These findings were confirmed by those of different Egyptian studies (e.g. El-Maghawry et al., 1988; Afifi et al., 1992; Abdel Raouf 1993; Hassan 1993; Nasr 1994; Yamani et al., 1994; Ahmed 1997).

4.2.3. Non-genetic aspects

Least squares analysis of variance and means of different factors affecting doe reproductive traits in Cal and Gab rabbits as well as their two reciprocal crosses are given in Table 50.

i. Year of kindling

Year-of-kindling effect was significant (P<0.01) on NSC and KI while was non-significant on DO and GL (Table 50). In agreement with these results, Khalil and Mansour (1987), Khalil and Soliman (1989) and Hassan (1993) reported that year-of-kindling effect on NSC and KI was significant (P< 0.01 or P<0.001) and Khalil and Mansour (1987); Youssef (1992) and Farghaly, (1996) evidenced that year-of-kindling effect was non-significant on DO and GL. In this respect, Hassan (1993) found that year-of-kindling constituted a significant (P<0.001) source of variation in DO. However, Youssef (1992) found that year-of-kindling did not contribute significantly to KI variance.

Table 50. F- ratios of least squares analysis variance of factors affecting doe reproductive traits .

Source of variance	NSC		DO		KI		GL	
	df	F-value	df	F-value	df	F-value	df	F-value
Mating group	3	0.34	3	2.09	3	1.03	3	0.26
Buck / mating group	36	0.73	36	0.86	36	0.54	37	1.44
Doe / buck / mating group	63	1.16	60	0.94	63	1.12	67	0.83
Year of production	2	5.20**	2	1.98	2	5.74**	2	0.90
Month of kindling	11	1.41	11	1.22	11	1.26	11	1.15
Parity	5	1.41	5	1.74	5	1.95	5	1.77
Mating group x month of kindling	33	1.48*	33	1.06	33	1.23	33	1.17
Mating group x parity	15	1.21	15	0.79	15	1.01	15	1.13
Remainder	194		117		198		278	
Remainder mean squares		5.66		680.3		786.21		5.17

NSC = Number of service per-conception, DO = Days open, KI = Kindling interval, GL = Gestation length.
* P < 0.05 or ** P < 0.01 or *** P < 0.001.

Table 51. Least squares means and standard errors of factors affecting doe reproductive traits .

Independented variable	N	NSC Mean± SE	N	DO Mean± SE	N	KI Mean± SE	N	GL Mean ± SE
Mating group								
Cal x Cal	149	3.42 ± .32	123	39.23 ±03.39	149	62.85 ± 3.67	185	31.19 ± .17
Gab x Gab	69	3.22 ± .49	50	33.70 ±05.75	70	58.09 ± 5.09	82	31.13 ± .38
Cal x Gab	61	3.75 ± .45	46	48.34 ±04.78	62	66.11 ± 4.67	82	30.86 ± .34
Gab x Cal	84	3.37 ± .39	64	37.64 ±04.08	86	61.57 ± 3.98	103	31.19 ± .29
Year of kindling								
1993-1994	97	5.97 ± .83	84	60.66 ±10.96	79	93.03 ± 9.60	115	31.20 ± .68
1994-1995	198	2.99 ± .46	144	35.23 ±06.25	202	54.96 ± 5.30	240	30.65 ± .36
1995-1996	68	1.34 ± .79	55	23.29 ±10.72	68	38.49 ± 9.31	97	31.43 ± .61
Month of kindling								
September	20	3.02 ± .83	15	31.77 ±10.40	20	49.90 ± 9.28	22	31.86 ± .67
October	47	2.80 ± .61	32	26.54 ±11.57	47	58.27 ± 6.93	51	31.65 ± .51
November	54	4.24 ± .48	39	47.65 ±08.18	54	70.65 ± 5.57	58	31.28 ± .41
December	39	4.59 ± .57	34	44.67 ±08.77	39	76.72 ± 6.59	43	31.50 ± .46
January	34	3.50 ± .66	29	44.63 ±08.61	35	67.00 ± 7.64	41	31.32 ± .55
February	37	4.11 ± .53	27	57.51 ±07.09	36	69.04 ± 6.12	47	30.71 ± .42
March	18	3.39 ± .80	12	47.75 ±12.62	18	56.38 ± 9.28	26	30.62 ± .58
April	35	4.22 ± .67	31	56.87 ±08.84	35	73.89 ± 7.43	40	30.73 ± .52
May	12	1.67 ± .94	11	29.45 ±11.65	14	49.90 ± 9.81	24	30.15 ± .58
June	26	2.88 ± .75	19	30.94 ±10.26	26	59.35 ± 8.63	46	30.59 ± .51
July	26	3.36 ± 1.0	20	25.29 ±14.73	25	54.55 ± 9.76	34	32.50 ± 65
August	15	3.44 ± 1.0	14	33.59 ±11.53	18	60.23 ± 9.10	20	30.25 ± .68
Parity								
1 St.	75	3.17 ± .61	57	47.38 ±09.63	75	58.11 ± 6.54	78	30.34 ± .43
2 nd	76	2.58 ± .46	57	31.77 ±08.26	76	49.31 ± 5.22	80	30.64 ± .37
3 rd	74	3.11 ± .43	59	33.90 ±05.89	74	57.70 ± 4.97	84	30.66 ± .35
4 Th.	54	4.30 ± .51	43	51.54 ±06.43	54	69.00 ± 5.75	72	31.39 ± .38
5 Th.	29	3.47 ± 68	22	30.55 ±06.43	30	62.21 ± 7.78	51	31.29 ± .44
>6 Th.	55	3.98 ± .67	45	43.21 ±08.99	58	76.62 ± 7.52	87	32.22 ± .46

NSC= Number of service per-conception, DO = Days open, KI = Kindling interval, GL = Gestation length .
Cal = Californian, Gab = Gabali .

ii. Month of kindling

Month-of-kindling effect on doe reproductive traits (NSC, DO, KI and GL) was found to be non- significant (Table 50). In this respect, El-Sayaad et al (1993a); Khalil and Mansour (1987); Khalil and Soliman (1989); Tawfeek and El-Hindawy (1991); Hassan (1995) found that month-of-kindling effect on NSC and/or GL was not significant. On the other hand, Khalil and Mansour (1987); Khalil and Soliman, (1989); Hassan, (1993) evidenced that month of kindling effect was significant ($P<0.05$ or $P<0.01$ or $P<0.001$or $p<0.0001$) on doe reproductive traits. Least squares means (Table 51) show no consistent pattern for month-of-kindling effect on doe reproductive traits. Similarly, El-Tawil et al (1971); Khalil and Soliman (1989); Hilmy (1991) and El-Sayaad et al (1993b) were not able to detect any clear trend for the effect of month of kindling on GL.

iii. Parity

Effect of parity on doe reproductive traits (NSC, DO, KI and GL) was found to be non-significant (Table 51). Least squares means in Table 51 showed inconsistent trend for parity effect on NSC and DO, while KI and GL increased, in general, with advance in parity. In this respect, El Tawil et al (1971); Afifi and Emara (1985); Khalil and Monsour (1987); Tagel-Din and Mervat (1989); Khalil and Soliman (1989); Sedki (1991); Youssef (1992); Abdel-Raouf (1993); El-Sayiad et al (1993b); Hassan (1993); Nasr (1994) and Hassan (1995) reported that parity had no significant effect on NSC, DO and GL. On the contrary, Afifi and Kadry (1985); Khalil and Monsour (1987); Khalil and Soliman (1989); Abdel-Raouf (1993); El-Sayiad et al (1993b); Hassan (1993); and Farghali (1996) observed that parity effect on doe reproductive traits was significant ($p<0.05$ or $p<0.01$ or $p<0.001$).

El Tawil et al (1971); Gecele et al (1985); Afifi and Emara (1985); Afifi and Kadry (1985); Khalil et al (1987); Abdella et al (1990); El Desoki (1991); Sedki (1991); Youssef (1992); Abdel-Raouf (1993); and Khalil et al (1995) observed an inconsistent trend of the effect of parity on reproductive traits. parity effect might be attributed to changes in physiological efficiency of doe that occur with advance of parity , it might be related to their effects on ovulation, implantation sites, embryonic mortality, viability of the fetus and to differences in the intra-uterine environment during pregnancy (Afifi and Kadry, 1985; Afifi and Emara, 1985; Khalil, 1989).

4.2.4. Genetic aspects

i. Mating group

Mating group effect on NSC, DO, KI and GL were found to be non-significant (Table50). Least squares means of reproductive traits of the study according to mating group are presented in Table 51. Gab x Gab mating recorded the lowest means for NSC, DO and KI but Cal X Gab mating gave the lowest mean for GL. These results might indicate that Gab breed was better as a buck breed as it showed the smallest NSC and shortest for DO which would reflect the increase in productive efficiency of rabbits.

ii. Purebred differences

Linear contrasts of purebreds Cal and Gab rabbits given in Table 52, were in favour of Gab rabbits when compared to Cal ones for reproductive traits of the study but without significant differences. In this respect, Youssef (1992) and Khalil et al (1995) observed that Baladi Red rabbits were shorter in DO and KI relative to NZW rabbits.

iii. Heterotic effects

Estimates of direct heterosis, calculated in actual unit and percentage for doe reproductive traits, are given in Table 52. These estimates show that direct heterosis had positive values for NSC, DO and KI and negative values for GL. Heterotic effect on all doe reproductive traits were not significant. Estimates heterosis percentages for NSC, DO, KI and GL were 6.93, 17.2, 4.55 and - 7.64%, respectively. These results might indicate that crossing Gab. with Cal. was associated with an increase in NSC, DO and KI, i.e. was not associated with improving these traits . On the contrary, Soliman (1983), Afifi and Khalil (1989), El-Desoki (1991), Youssef (1992) and Khalil et al (1995) observed that crossbreeding was associated with a reduction in the intervals of DO and KI.

Table 52. Estimates of mating group, means (± SE), purebred differences, heterosis, maternal additive effect (G^m) and direct additve effect (G^i) on doe reproductive I traits .

Item	N	NSC Mean ± SE	N	DO Mean ± SE	N	KI Mean ± SE	N	GL Mean ± SE
Mating group								
Cal x Cal	149	3.42 ±0.32	123	39.23 ±3.40	149	62.85 ±3.67	185	31.19 ±0.26
Gab x Gab	69	3.22 ±0.49	50	33.70 ±5.75	70	58.09 ±5.09	82	31.12 ±0.38
Cal x Gab	61	3.37 ±0.45	46	48.33 ±4.78	62	66.11 ±4.67	82	30.86 ±0.35
Gab x Cal	84	3.73 ±0.39	64	37.64 ±4.08	86	61.57 ±3.80	103	31.20 ±0.29
Purebred differences								
$\{(G^i_{Cal} + G^m_{Cal}) - (G^i_{Gab} + G^m_{Gab})\}$		0.07±0.41		0.20±0.53		5.52±6.68		4.76±5.80
Heterosis contrast								
$H^i_{Cal \times Gab,}$								
Unit		0.23 ±0.39		6.52 ±4.45		3.36 ±3.9		- 0.135 ±0.28
Percent		6.93%		17.2%		4.55%		- 7.64%
Maternal additive effect								
$(G^m_{Cal} - G^m_{Gab})$		- 0.36 ±0.25		-10.69 ±6.08		- 4.54 ±5.45		0.34 ±0.38
Direct additive effect								
$(G^i_{Cal} - G^i_{Gab})$		0.28 ±0.39		8.11 ±4.76		4.65 ±4.43		-0.135 ±0.285

NSC = Number of service per-conception, DO = Days open, KI = Kindling interval, GL = Gestation length.
+ Buck breed listed before the doe breed.
Cal =Californian, Gab =Gaball

iv. **Maternal additive (doe breed) effect**

Maternal additive (breed) effect on doe reproductive traits as the differences between reciprocal crosses was not significant, i.e. little contribution of maternal additive effect on the genetics of these traits (Table 52). Estimates of maternal additive (breed) effect was in favour of Cal does for NSC, DO and KI, i.e. using Cal rabbits is better than using Gab rabbits as a doe breed for these three reproductive traits .In this respect, Youssef (1992) with NZW, Baladi Red (BR) and their crosses, indicated that BR-damed litters recorded shorter DO and KI compared to NZW-damed litters, i.e. BR rabbits showed better maternity for DO, KI than NZW ones.

v. **Direct additive (buck breed) effect**

The linear contrasts of direct additive (buck breed) effect on doe reproductive traits was not significant (Table 52) . Gab-sired litters recorded lower performance for NSC, DO and KI than Cal-sired litters. Direct paternity effect for lactation ability of Cal might be responsible for such a case, i.e more NSC, long DO and KI. Youssef (1992) and Khalil et al (1995) with NZW, Baladi Red (BR) and their crosses observed that little or non-significant contribution for direct additive effect in the inheritance of both DO and KI. They added that the linear contrasts of direct additive effects on DO and KI were not significant.