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Crossbreeding parameters for growth traits in a complete three breeds diallel cross design of rabbits in Egypt

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ABSTRACT

The present study was conducted to estimate crossbreeding parameters for growth traits of growing rabbits in a complete 3 × 3 diallel crossing experiment involving three breeds namely New Zealand White (NN), Californian (CC) and Rex (RR). Highly significant differences ($p \leq 0.001$) were observed among different genotypes for almost traits studied with the exception of relative growth rates (RGR) at 4-12 weeks of age. Direct genetic effects of NN were found as positive for most of studied traits. Positive total maternal genetic effect was estimated for kits of NN dose for weight at weaning (57 g) and 12 weeks of age (92 g). Strong individual heterosis was estimated for NN × CC crossbreds for all body weight (BW) and most of body weight gains (BWG). In conclusion, direct additive genetic effects were infavor NN for growth traits and maternal genetic effects were infavor NN for weaning and final weights and higher individual heterosis has been estimated for NN × CC crossbred rabbits for growth traits.

Keywords

Body weight, Breed, Crossbreeding, Diallel, Growth rate, Rabbit

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INTRODUCTION

The advantages of rabbits as microlivestock include small body size, short generation interval, ability to utilize less competitive feeds, rapid growth, potentials for genetic improvement and production of high quality meat and useful by-products (Egbo et al, 2001; Herbert, 2011). Crossbreeding has been established breeding systems that can be performed in rabbit to increase production through the explosion of heterosis (Reddy et al, 2003). Dickerson (1992) reported that genetic diversity among strains is large relative to genetic variation within breeds so comparing the performance of different breeds and their crosses can be justified. Gains in the performance can be established from complementary breed effects and heterosis in crossbreeding (Abd El-Halim, 2005).

In meat rabbit production, in most breeding programmes, post-weaning daily weight gain or weight at the end of the fattening period is used as selection criteria of sire lines (Estany et al, 1992). Growth traits occupied a predominant position in the economics of rabbit farms as heavier market weight is the key for farm profit (Rashwan et al, 1997). The heavier is the market weight, the higher is the kilograms of rabbit marketed and the higher is the profit (Zeferino et al, 2013). The main purposes of crossing is to produce superior crosses (i.e. make use of hybrid vigor), to improve fitness and fertility traits and to combine different characteristics in which the crossed breeds were premium. Therefore, this study was conducted to evaluate genetically BW, BWG and RGR from weaning (at 4-week) up to marketing (at 12-week) of age, using diallel crossing scheme, involving three imported breeds CC, NN and RR to estimate mating type, direct additive and maternal additive effects. In addition, direct heterotic effect on the previously mentioned traits and the recognition of the optimal mating group combination associated with crossbreeding between the three considered breeds.

MATERIALS AND METHODS

Location and duration of the study: This study was located at experimental farm belonging to Animal Wealth Development Department, Faculty of Veterinary Medicine, Zagazig University, Sharkia, Egypt during the period from January to May, 2014. Experimental procedures were conducted in accordance with the Zagazig University Animal Ethics Committee guidelines (ANWD-206).

Experimental animals: Source: San-El-Hagar Agricultural company farm, Sharkia Governorate, Egypt. The study was carried out on three breeds of rabbits which were: New Zealand White (NN), Californian (CC) and Rex (RR). Ten does and three bucks from each breed were used as foundation animals to produce 166 kits upon which the experiment took placed. Experimental design: three breeds diallel cross design was constructed as presented in **Table 1**.

Table 1. Experimental design.

Female line	Male line		
	New Zealand White	Californian	Rex
N	NN (25)	CN(17)	RN(19)
C	NC(17)	CC(18)	RC(18)
R	NR(19)	CR(14)	RR(19)

Housing and management: Bucks and doses were about 6 months of age and free from diseases and healthy and kept individually in metal cages (40 × 50 × 60 cm) which provided with metal feeders and nipple watering system. They leaved for 2 weeks for accommodation then does introduced to buck's cage, date of service was recorded and dose palpated at about 14th day after service. For positive doses before expected date of kindling by about 3 days, clean with some rice straw nest boxes (40 × 40 × 40 cm) were fitted to cage of doe. Negative palpated does were reintroduced to buck's cage again. Kits were inspected daily until weaning at thirty days of age which is done by separation of kits to the fattening cages (40 × 50 × 50 cm) which were provided with metal feeders and nipple watering system. Kits were ear tagged with metal numbers. Fourteen hours lighting was provided thought the experimental period. Commercial pelleted diets with the following characteristics: 17.5% crude protein, 14-16% crude fibers and 2300-2500 kcal/kg diet digestible energy were given ad libitum. There was daily hygienic disposal of manure coupled with good ventilation and temperature maintained as possible inside the house within a range of 18-26°C.

Traits recorded: Body weights (BW): recorded at 4, 6, 8, 10 and 12 weeks of age. Body weight gain (BWG): estimated as the difference between any two weights recorded at any two different periods. Relative growth rate (RGR): measured according to Broody (1945).

$$RGR = \frac{W_2 - W_1}{\frac{1}{2}(W_2 - W_1)} \times 100$$

Where: W1, body weight at the beginning of period. W2, body weight at the end of period.

Statistical analysis: One-way ANOVA test of SAS (2008) was used to investigate the effect of genotype of rabbits on BW, BWG and RGR using the following model:

$$Y_{ij} = \mu + G_i + e_{ij}$$

Where:Y_{ij}, any observed value. μ, overall mean. G_i, the fixed effect of genotype. e_{ij}, random deviation due to unexplained source. Crossbreeding genetic parameters were estimated according to Dickerson (1969) using the following equations: Direct genetic effect of breed $(g_D^I - g_S^I) = (D + DS) - (S + SD)$. Total maternal genetic effect of breed $(g_D^M - g_D^{M\prime}) - (g_S^M - g_S^{M\prime}) = (SD + DS)$. Individual heterosis $(h^I) = 0.5(SD + DS) - 0.5(S + D)$. where: D and S represented any two breeds.

RESULTS AND DISCUSSION

Mating type:

Mean and standard error of BW, BWG and RGR of different mating types of rabbits after crossing of NN, CC and RR were presented in **Table 2, 3, & 4**. Highly significant differences ($p \leq 0.001$) were observed among different genotypes for almost traits studied with the exception of RGR at 4-12 weeks of age ($p > 0.05$). CC × NN crossbred rabbits showed superiority for BW at weaning (664±21.76 g), 12-week of age (2310±40.53 g), and BWG from 4-12 weeks of age (1610±33.25 g) as compared to other crossbreds; however, purebred RR rabbit were the superior genotype for this trait (1734±39.04 g). For RGR, purebred surpassed crossbreds at 4-6, 6-8, and 4-12 weeks intervals in age.

Simillar results are cited by Akinsola et al. (2014) who found that individual kit weight at 35 days of age are (744.94 ± 16.64 g) and (752.71 ± 20.23 g) in purebred and crossbred Hyla rabbits respectively. Also, El-Bayomi et al. (2012) reported that among different progeny genotypes significant differences are observed for

Table 2. Effects of Mating type of rabbit on body weights at different ages.

Mating type	Body weight (g)				
	4th Week	6th Week	8th Week	10th Week	12th Week
NN	590 ± 26.91^{abc}	1105 ± 21.85^{b}	1494 ± 19.69^{b}	1810 ± 29.21^{c}	2131 ± 32.94^{cd}
CC	517 ± 33.30^{c}	1073 ± 25.95^{b}	1534 ± 26.58^{b}	1795 ± 36.89^{c}	2002 ± 45.79^{e}
RR	570 ± 24.55^{bc}	1227 ± 28.34^{a}	1730 ± 27.60^{a}	2114 ± 36.82^{a}	2304 ± 30.70^{ab}
NN × CC	607 ± 28.59^{ab}	1307 ± 26.90^{a}	1710 ± 30.88^{a}	1977 ± 27.79^{b}	2218 ± 30.89^{abc}
NN × RR	606 ± 23.72^{ab}	1046 ± 35.89^{b}	1505 ± 39.67^{b}	1851 ± 37.04^{c}	2124 ± 48.10^{cd}
CC × NN	664 ± 21.76^{a}	1312 ± 16.57^{a}	1707 ± 22.45^{a}	1960 ± 26.62^{b}	2310 ± 40.53^{a}
RR × NN	600 ± 33.29^{abc}	1063 ± 49.40^{b}	1508 ± 49.31^{b}	1807 ± 45.71^{c}	2033 ± 38.55^{de}
CC × RR	633 ± 21.27^{ab}	1275 ± 34.62^{a}	1725 ± 36.35^{a}	1974 ± 50.43^{b}	2187 ± 56.25^{bc}
RR × CC	585 ± 26.84^{abc}	1043 ± 50.55^{b}	1445 ± 43.66^{b}	1794 ± 48.69^{c}	1999 ± 36.24^{e}
p-value	0.044	<0.001	<0.001	<0.001	<0.001

N = New Zealand White, C = Californian, R = Rex.
Means within the same column having different letter were significantly different at $p<0.05$.

Table 3. Effects of Mating type of rabbit on body weight gains at different age intervals

Mating type	Body weight gain (g)				
	4-6 Week	6-8 Week	8-10 Week	10-12 Week	4-12 Week
NN	515 ± 25.78^{cd}	389 ± 15.33^{c}	316 ± 19.89^{abc}	321 ± 12.94^{ab}	1541 ± 32.69^{bcde}
CC	555 ± 29.55^{bc}	461 ± 25.03^{ab}	260 ± 23.52^{c}	207 ± 19.66^{d}	1485 ± 55.71^{cde}
RR	657 ± 9.39^{a}	503 ± 20.20^{a}	383 ± 29.30^{a}	190 ± 13.03^{d}	1734 ± 39.04^{a}
NN × CC	699 ± 28.41^{a}	402 ± 13.79^{bc}	267 ± 20.83^{c}	240 ± 14.61^{cd}	1610 ± 33.25^{abc}
NN × RR	440 ± 37.54^{d}	458 ± 17.41^{ab}	345 ± 17.51^{ab}	273 ± 22.87^{bc}	1517 ± 48.38^{bcde}
CC × NN	648 ± 29.35^{a}	394 ± 18.39^{c}	252 ± 22.09^{c}	350 ± 22.10^{a}	1645 ± 40.24^{ab}
RR × NN	462 ± 44.52^{d}	445 ± 21.72^{abc}	298 ± 19.92^{bc}	226 ± 15.23^{cd}	1433 ± 49.37^{de}
CC × RR	641 ± 29.59^{ab}	450 ± 14.97^{abc}	248 ± 40.12^{c}	213 ± 19.34^{d}	1553 ± 40.37^{bcd}
RR × CC	457 ± 31.46^{d}	402 ± 23.89^{bc}	348 ± 32.78^{ab}	205 ± 24.55^{d}	1413 ± 30.48^{e}
p-value	<0.001	<0.001	0.001	<0.001	<0.001

N = New Zealand White, C = Californian, R = Rex.
Means within the same column having different letter were significantly different at $p<0.05$.

Table 4. Effects of Mating type of rabbit on Relative growth rates at different age intervals

Mating type	Relative growth rate (%)				
	4-6 Week	6-8 Week	8-10 Week	10-12 Week	4-12 Week
NN	62.14 ± 3.96^{abc}	30.15 ± 1.36^{bc}	18.99 ± 1.13^{abc}	16.31 ± 0.64^{a}	114 ± 2.92^{ab}
CC	71.77 ± 5.11^{a}	35.56 ± 1.97^{ab}	15.55 ± 1.30^{bcd}	10.80 ± 0.92^{bcd}	118 ± 4.50^{ab}
RR	74.33 ± 2.49^{a}	34.26 ± 1.70^{ab}	19.88 ± 1.45^{ab}	8.74 ± 0.65^{d}	120 ± 3.07^{a}
NN × CC	73.91 ± 3.84^{a}	26.77 ± 0.90^{c}	14.61 ± 1.23^{cd}	11.46 ± 0.68^{bcd}	114 ± 3.09^{ab}
NN × RR	52.98 ± 4.30^{c}	36.42 ± 1.58^{a}	20.86 ± 1.20^{a}	13.63 ± 1.03^{ab}	111 ± 2.79^{ab}
CC × NN	65.90 ± 3.40^{c}	26.07 ± 1.16^{c}	13.78 ± 1.17^{d}	16.31 ± 0.89^{a}	110 ± 2.37^{ab}
RR × NN	55.97 ± 5.49^{ab}	35.32 ± 1.98^{ab}	18.36 ± 1.29^{abc}	12.05 ± 0.95^{bc}	109 ± 4.20^{b}
CC × RR	67.29 ± 2.77^{bc}	30.15 ± 1.09^{bc}	13.26 ± 2.11^{d}	10.26 ± 0.83^{cd}	110 ± 1.34^{b}
RR × CC	55.67 ± 2.56^{ab}	33.65 ± 2.91^{ab}	21.63 ± 1.98^{a}	11.15 ± 1.50^{bcd}	109 ± 2.76^{b}
p-value	<0.001	<0.001	<0.001	<0.001	0.136

N = New Zealand White, C = Californian, R = Rex.
Means within the same column having different letter were significantly different at $p<0.05$.

Table 5. Direct and maternal genetic effects for growth traits after crossing New Zealand White, Californian and Rex rabbits.

Variable	g^I			g^M		
	g^I_{NN}	g^I_{CC}	g^I_{RR}	g^M_{NN}	g^M_{CC}	g^M_{RR}
Body weight						
4th week	16	26	-5	57	-6	-48
6th week	27	-139	78	5	17	-232
8th week	-37	-239	84	-3	3	-280
10th week	32	-260	-139	-17	-44	-180
12th week	37	-82	-114	92	-91	-188
Body weight gain						
4-6 week	11	-164	82	-51	22	-184
6-8 week	-64	-101	6	-8	-13	-48
8-10 week	71	-20	-223	-15	-47	100
10-12 week	4	178	25	110	-47	-8
4-12 week	21	-109	-109	35	-84	-140
Relative growth rate						
4-6 week	-1.62	-15.18	9.06	-8.01	2.99	-11.62
6-8 week	-4.71	-3.01	-2.2	-0.7	-1.1	3.5
8-10 week	4.27	1.61	-12.7	-0.83	-2.5	8.37
10-12 week	0.66	9.15	1.17	4.85	-1.58	0.89
4-12 week	0.00	-4	-1	-4	-2	-1

N = New Zealand White, C = Californian, R = Rex, g^I = direct genetic effect, g^M = maternal genetic effect.

Table 6. Individual heterosis for growth traits after crossing New Zealand White, Californian and Rex rabbits.

Variable	**NN × CC**		**NN × RR**		**CC × RR**	
	h^I (units)	%	h^I (units)	%	h^I (units)	%
Body weight						
4th week	82.00	14.81	23.00	3.97	65.50	12.05
6th week	220.50	20.24	-111.50	-9.56	9.00	0.78
8th week	194.50	12.84	-105.50	-6.54	-47.00	-2.88
10th week	166.00	9.20	-133.00	-6.78	-70.50	-3.61
12th week	197.50	9.55	-139.00	-6.27	-60.00	-2.79
Body weight gain						
4-6 week	138.50	25.89	-135.00	-23.04	-57.00	-9.41
6-8 week	-27.00	-6.35	5.50	1.23	-56.00	-11.62
8-10 week	-28.50	-9.90	-28.00	-8.01	-23.5	-7.31
10-12 week	31.00	11.74	-6.00	-2.35	10.50	5.29
4-12 week	114.50	7.57	-162.50	-9.92	-126.50	-7.86
Relative growth rate						
4-6 week	2.95	4.41	-13.76	-20.17	-11.57	-15.84
6-8 week	-6.44	-19.59	3.67	11.38	-3.01	-8.62
8-10 week	-3.08	-17.81	0.18	0.90	-0.27	-1.52
10-12 week	0.33	2.43	0.32	2.51	0.94	9.57
4-12 week	-4.00	-3.45	-7.00	-5.98	-9.5	-7.98

N = New Zealand White, C = Californian, R = Rex, h^I = individual heterosis.

BW, average daily gain and RGR at weaning and post-weaning growing period. New Zealand White × Flander rabbits showed the highest weaning weight (668.18 g). On the contrary, Californian × New Zealand White depicted the highest weight at 12 weeks of age (2278.52 g). New Zealand White × Californian recorded the highest RGR at the age period of 4-6 weeks (72.50%). Maj et al. (2009) found that CC × NN and NN × CC rabbits were heavier than purebred animals.

Direct genetic effect:

Direct genetic effect of NN was positive for all traits studied, but for BW at 8th week, BWG at 6-8 weeks of age, RGR at 4-6 and RGR at 6-8 weeks of age, the estimates were negative (-37 g, -64 g, -1.62% and -4.71%; respectively) (**Table 5**). The estimates for CC were negative for all traits with the exception of BW at 4th week, BWG at 10-12 weeks of age, RGR at 8-10 and RGR at 10-12 weeks of age, the estimates were positive (26 g, 178 g, 1.61% and 9.15%; respectively). RR rabbits showed nearly equal distribution of negative and positives estimates of direct genetic effect among traits under investigation. We could say that additive sire effect is higher for NN rabbit for weaning and post-weaning growth traits so it is better to be used as sire breed than CC and RR.

The present results are agreed with those cited in previous work (Piles et al., 2004) who reported that direct additive genetic effect is only significant for live weight at 60 days and daily feed intake. Also, they cited that significant differences between genetic types are observed for body weight, but not for growth rate. Supportive results are depicted by Hekil et al. (2011). They reported that Crossbreds had significantly higher (p<0.01) body weight comparing with purebreds at all ages studied, and breed groups genotype had significant effect (p<0.01) on growth rate at all ages intervals studied as well as direct genetic effect of breed on weaning and post-weaning body weight and daily gains were mostly significant and in favour of NN for weaning and post-weaning body weights. In addition, they concluded that paternity of NN rabbits are better than that of CC ones. The obtained results are in the same line of those recorded by Abdel-Azeem et al. (2007), Abou Khadiga (2008) and Iraqi et al. (2008) on crossbreeding experiments carried out in Egypt. Abd El-Ghany et al. (2000) found that direct additive effect on body weight and daily gain traits was significantly in favor of Baladi Black bucks except body weight at 6 weeks of age. Direct genetic effects estimates are significant (p<0.01), in favor of line V rabbits comparing with Baladi Black. These differences in direct genetic effects for growth traits encourage the utilization of line V rabbits in crossbreeding programs in Egypt (Abou Khadiga, 2008). The maximal differences for direct genetic effects for body weight at 60 days reached 368.6 g between lines A and R and 224.6 g between lines A and C. There are non-significant differences in BW at 32 days of age for direct genetic effects (Orengo et al, 2009).

Total maternal genetic effect:

Table 5 shows total maternal genetic effects after crossing NN, CC and RR. High positive direct maternal genetic effect was estimated for kits of NN dose for weight at weaning (57 g), 12 weeks of age (92 g), BWG at 10-12 weeks of age (110 g) and RGR at 10-12 weeks of age (4.85%) suggesting good maternity of NN does for weaning and post-weaning growth performance comparing with CC and RR doses so NN can be used as a dame breed. Negative estimates were recorded for CC and RR rabbit for most of studied traits, but RR rabbits showed high positive estimates for BWG at 8-10 weeks of age (100 g) and RGR at the same period (8.37%). Our results are harmonious with those reported in other studies (Afifi et al, 1994; Abd El-Ghany et al, 2000). They worked on medium-sized breeds and found that maternal breed effects were comparable to or higher than additive genetic effects for individual growth. Hekil et al. (2011) reinforced our finding; they found that maternal additive effects in favour NN breed over CC for most body weight traits of the study and post-weaning growth rates and NN-damed rabbits are heavier than those of CC-damed ones at most ages studied. Orengo et al. (2004) found that V line showed an unfavourable maternal genetic effect comparing with the rest of lines ranging from 59 to 81 g for individual body weight at 32 days. They attributed this to less adult weight of V line (Blasco and Gómez, 1993). Ouyed and Brun (2008) reported that CC maternal genetic effects are negative on body weights at 35 and 63 days and daily weight gains (-33 g, -40 g and -0.5 g/d; respectively). Contradicted results are cited in previous studies (Gomez et al., 1999; Piles et al., 2004) who reported that maternal effects are non-significant for any of the traits analyzed. Contradicated results are cited previously (Maj et al., 2009) who concluded that Maximum effects in crosses for growth traits were obtained when the Californian breed was used as a maternal component. Abd El-Ghany et al. (2000) proved that maternal additive effect on body weight and daily gain was positive and significant in preference of New Zealand White at all considered age periods. Maternal genetic effects were found to be positive and significant, in favour of Line V dams, for BW at 8 and 12 weeks of age (Abou Khadiga et al, 2008). That line V had an unfavorable maternal genetic effect on BW at 32 days of age, ranging from 54.3 to 86.0 g. Maternal genetic effects are significant, ranged from 99.5 to 162.0 g for line A vs. V and line C vs. V, respectively for body weight at 60 days (Orengo et al, 2009).

Individual heterosis:

Individual heterosis in units and as percentage of parental average for NN, CC and RR crosses was summarized in **Table 6**. Strong individual heterosis were estimated for NN × CC crossbreds for all body weights especially at 6th week of age (20.24%) and most of BWG especially at 4-6 weeks of age (25.89%). However, negative estimates were recorded for most of RGR. In contrast, NN × RR and CC × RR crossbreds, they showed negative estimates for all studied trait at most ages and age intervals. Piles et al. (2004) supported our investigation. They estimated individual heterosis for body weight at 60 days of age (49 g) and -0.3 g/d for growth rate. Also, Ouyed and Brun (2008) found that direct heterotic effect on growth traits is non-significant. Szendrõ et al. (1996) and Medellin and Lukefahr (2001) estimated direct heterosis for live weight at different ages (from 2.4% to 6.8%), while for growth rate (from 4.8% to 7.3%) in crosses between strains of different composition. The present results are in agreement with those reported previously (Hekil et al, 2011) who found that crossing of NN with CC associated with improvement of body weights and RGR and direct heterosis high and positive. The present results indicated that NN × CC crossbreds can be utilized to exploit heterotic effect on weaning and post-weaning growth performance. Some authors estimated positive heterosis for body weights and daily gains (Abou-Khadiga, 2004; Attalah, 2006) after crossing different breeds of rabbits recorded at different ages and growth stages. This may be explained by the existence of non-additive inter-breed genetic effects. In contrast, others estimated negative heterosis (Abd El-Ghany et al, 2000; Khalil and Afifi, 2000) after crossing local Egyptian breeds. Also, Abdel-Azeem et al. (2007) estimated negative heterosis% for body weight at all ages studied. Estimates of direct heterosis for body weights of rabbits raised in hot countries were mainly positive and ranging from 1.3 to 14.5%, but the estimates for maternal heterosis were mainly negative and ranging from -0.2 to -5.3% (Khalil and Bolet, 2010). Abd El-Ghany et al. (2000) recorded that heterosis percentages ranged from 2.7 to 9.5% for post-weaning body weights and gains by crossing New Zealand White with Baladi Black or Baladi Red in Egypt. Heterosis% for body weight at all ages studied (22.69, 17.60, 6.76, 4.50 and 7.60 % for weaning, 6, 8, 10, and 12 weeks of age; respectively) for Californian × New Zealand White rabbits (El-Bayomi et al, 2012). Direct heterosis estimates are positive and significant ($p<0.01$) for body weights and average daily gain which indicated that progeny weights and daily weight gain are improved by crossbreeding (Abou Khadiga et al, 2008). Only the A × R group and its reciprocal cross had greater levels of individual heterosis, which reached 10.5% for BW at 32 days of age. The P × V and R × V crosses showed positive individual heterosis for average daily gain (1.29 g/d) (Orengo et al, 2009).

Our finding may direct us to conclude that crossbreeding of NN rabbits and CC ones will promote BW and BWG traits. However, negative direct heterosis, if any, might be attributable to directional dominance of genes affecting these traits. However, separate-cross heterotic effect revealed some positive estimates which concentrates in the (NN × CC) crossbreds. This may notify us to focus on using NN as a terminal sire breed with CC does to secure appreciable heterotic effect.

CONCLUSION

On the light of the previously mentioned results, we can conclude that Maximum effects in crosses for growth traits were obtained when the New Zealand White breed was used as a maternal and paternal component. New Zealand White buck × Californian doe crossbred rabbits showed the highest individual positive heterosis for most of growth traits which may notify us to focus on using NN as a terminal sire breed with CC does to secure appreciable heterotic effect. Future research should be directed toward repeating this work but on carcass quality and quantity traits to determine any favorable or unfavorable effects of these crosses on these traits.

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