THE EFFECTS OF EGG ALBUMEN POLYMORPHISMS ON FERTILITY AND HATCHABILITY IN THE CHICKEN

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INTRODUCTION

Since zone electrophoresis in starch gel was introduced by SMITHIES (1955, (16)), using this method a number of polymorphic biochemical systems with simple inheritance have been detected in farm animals. Physiological significances of these polymorphisms are unknown but it is expected that there may be some associations between these polymorphisms and economical traits, fertility and viability. For example, the transferrin locus has been associated with embryonic mortality in both cattle and pigs (ASHTON and FALLON, 1962, (4), KRISTJANSSON, 1964, (9)). And it was also reported that the transferrin locus has been associated with milk yield and milk fat in cattle (ASHTON, 1960, (3), ASHTON *et al*, 1964, (5)).

Concerning the egg albumen proteins of domestic fowl, LUSH (1961, (11 a), 1964, (11 b, c)), using starch gel electrophoresis, has detected nineteen distinct fractions and demonstrated genetic polymorphisms in three regions of the electrophoretogram. These regions were named loci Ov, II and III, respectively. OGDEN *et al.* (1962, (13)) has reported the genetic variation in conalbumins, which parallel with that in transferrins. Thus it is known that there are four genetic polymorphisms in egg albumen proteins of domestic fowl.

Recently, associations between these polymorphisms in egg albumen proteins and embryonic mortality and production traits have been studied. MORTON *et al.* (1965, (12)) examined the influence of egg albumen polymorphic loci II, III and Tf on embryonic mortality in one commercial flock of Light Sussex hens and concluded that they are associated with mortality differences during the first 15 days of incubation. BUVANENDRAN (1967, (7 a)) examined the influence of dam's genotype at the ovalbumin locus and locus II on the embryonic mortality in two closed flocks of White Leghorn hens and reported that

significant effects were observed with mortality at different stage of incubation but the results were not consistent for the two strains or for the two years studied. BUVANENDRAN (1967, (7b)) also examined the association between loci Ov, II, III and Tf and four production traits in three closed populations consisting of two flocks of White Leghorns and a Light Sussex flock and concluded that three egg albumen loci have statistically significant effects on production traits. However, almost nothing is known of roles of these egg albumen loci in the nutrition and physiology of developing embryo.

In the present study, the population of New Hampshires was used and this population had the genetic variations at loci II and III. And it was objected to examine the influence of loci II and III on the fertility and hatchability in the population of New Hampshires.

MATERIALS AND METHODS

The population used in this experiment was consisted of three New Hampshire strains obtained from a private farm at Tomakomai.

These three strains were derived from a population which was introduced from United States of America in 1952 and 1953. Strain 1 was constructed as increasing egg production for first two laying months while maintaing body weight at nine weeks of age constant. Strain 2 was selected by a independent culling level. Half of the population was selected for body weight at nine weeks of age and the half was selected again for egg production for first two laying months. Strain 3 was selected only for body weight at nine weeks of age.

Eggs used for electrophoretic analyses were stored at 4°C before use, and analyzed within two months after collection. There was no influence of storage for two months on the electrophoretic analysis. Only the outer thin albumen was used for the starch gel electrophoresis.

The data of fertility and hatchability were obtained in the 1966 and 1967 hatching seasons. Mating were carried out on the scheme of another experiment. The eggs were candled on the third day of incubation and determined whether they were fertile or infertile.

Fertility and hatchability were calculated in percentage for the total number of eggs set and for the number of fertile eggs, respectively. The comparison of fertility and hatchability was done by chi-square test.

The discontinuous buffer system of POULIK (1957, (14)) was used for the analysis of egg albumen electrophoretic patterns, regions II and III. The electrolyte was composed of 0.3 M boric acid and 0.05 M sodium hydroxide, pH 8.45, and the gel buffer was 0.076 M tris (hydroxy-methyl) aminomethane

and 0.005 M citric acid, pH 8.65. Gels were prepared from hydrolysed starch (Connaught Laboratories, Toronto, Canada) by the procedure described below. The starch was suspended in one quarter of gel buffer and the remaining three quarters of gel buffer was heated to be boiled, and added rapidly to the suspension of starch. Then, the viscous mass was shaken vigorously for about 15 seconds, and degassed for about one minute by applying a vacuum pump. The hot gel was poured into a plastic tray and covered with a plastic plate. The gels were kept overnight at room temperature before use. A piece of filter paper which was immersed in the egg albumen was inserted in a slit at 3 cm from the cathodic end of the gel. 12 samples were analysed together on the same gel. Electrophoresis was carried out horizontally for about 4 hours at room temperature using a voltage gradient of 6 V/cm length of gel. Then electrophoretograms were about 7.5 cm length. After the electrophoresis, the gel was sliced horizontally and stained for about 5 minutes in Amide Black 10 B dissolved in a mixture of methanol, water and glacial acetic acid (5 : 5 : 1). Then stained gel was washed and fixed with the mixture mentioned above.

It is known that region II is controlled by a pair of autosomal codominant alleles. Homozygous hens have only one region II protein and heterozygous hens have both. The inheritance of region III is similar to that of region II. However, since the egg albumen phenotype is a sex-limited character, it is impossible to know cock's egg albumen genotypes directly. Therefore, cock's genotypes were estimated from the genotypes of hens mated with him and of their daughters.

When a cock has both homozygous and heterozygous daughters in some of matings with homozygous hens, he is a heterozygote. However, it is difficult to determine that a cock is certainly a homozygote. When he is mated with homozygous hens, it is possible that, even if all his daughters are homozygotes, he may be a heterozygote. And in the mating with heterozygous hens, it is also difficult to determine whether his genotype is a homozygote or a heterozygote. When his daughters show both homozygous genotypes, then he is a heterozygote. On the contrary, his daughters don't show either one homozygous genotype, it cannot be edtermined certainly whether he is a homozygote or a heterozygote. Therefore, the estimation was done only when the probability of a cock being a homozygote or a heterozygote was over 75 percent from the theoretical ratio.

RESULTS

The number of hens examined for their egg albumen genotypes was 176 in 1966 and 287 in 1967. Table 1 shows the distribution of their egg albumen

TABLE 1. Distribution of hens examined for egg albumen genotypes at loci II and III in and 1966 and 1967

Genotype†	1966 Strain			1967 Strain		
	1	2	3	1	2	3
II A III A	0	0	0	0	0	0
II A III AB	2	2	1	5	5	2
II A III B	24	17	19	37	26	27
II AB III A	0	1	0	0	0	0
II AB III AB	6	4	4	0	11	6
II AB III B	25	27	21	40	48	34
II B III A	0	1	0	0	0	0
II B III AB	0	2	1	3	0	0
II B III B	8	5	6	15	11	17

† Genotype II A III A means the genotype II A/II A, III A/III A.

genotypes at loci II and III in 1966 and 1967. As shown in Table 1, at locus II homozygotes for the B gene are only a few and, on the contrary, at locus III most of them are homozygotes for the B gene. Especially, hens having genotype III A/III A were only two in 1966 and zero in 1967. This result agrees well with the fact that flocks examined till now have not a frequency of II B higher than 0.5 and have a very low frequency of III A. Effects of egg albumen genotypes at loci II and III on fertility and hatchability were examined from two aspects: one was effects of maternal egg albumen and the other was effects of mating types.

(A) Effects of Maternal Egg Albumen Genotypes

Although strains 1, 2 and 3 were derived from the same strain, each has been selected by different criterions. Therefore, it will be possible that these three strains have different genetic backgrounds. Fertility and hatchability in these three strains are given in Table 2. In 1966, there were no significant differences in fertility between these three strains, but there were significant differences in hatchability between strains 1 and 2 ($\chi^2=4.39$), and between strains 2 and 3 ($\chi^2=5.22$). In 1967, there were significant differences both in fertility and hatchability. The difference in fetility between strains 1 and 2 was not significant, but the fertility of strain 3 was significantly lower than those of strains 1 and2 ($\chi^2=6.83$ and 10.97). In hatchability, there was no significant difference between strains 2 and 3, but these two strains showed significantly lower hatchability than strain 1 ($\chi^2=23.34$ and 15.67).

TABLE 2. Fertility and hatchability of strains 1, 2 and 3 in 1966 and 1967

Year	Strain	Number of eggs set	Fertility (%)	Hatchability (%)
1966	1	995	94.07	91.74
	2	951	93.38	89.98
	3	771	93.77	86.31
1967	1	1999	95.30	85.83
	2	1768	95.87	79.76
	3	1367	93.20	80.53

These results show that strain 1 is superior both in fertility and hatchability, and that strain 2 is superior in fertility but is inferior in hatchability, and that strain 3 is inferior both in fertility and hatchability.

Although there were no significant differences in fertility between years, the differences in hatchability were significant with in each strain. Therefore, statistical analysis was carried out within strains and within years. And effects of maternal egg albumen on fertility and hatchability were examined for locus II, locus III, and the combination of loci II and III.

(1) Locus II

Fertility and hatchability for each genotype in strains 1, 2 and 3 are shown in Table 3.

(a) Strain 1

In 1696, genotypes II A/II B and II B/II B showed higher fertilities than genotype II A/II A, but the differences were not significant. However, there were significant differences in fertility between these three genotypes in 1967. Genotypes II A/II B and II B/II B were significantly more fertile than genotype II A/II A ($\chi^2=4.04$ and 6.74). Therefore, maternal genotype II A/II A may have inferior effects on fertility. With respect to hatchability in 1966 and 1967, there were no significant differences.

(b) Strain 2

There was no significant difference in fertility between genotypes II A/II A and II A/II B in 1966, but these two genotypes were significantly more fertile than genotype II B/II B ($\chi^2=8.74$ and 4.56). Although the differences between these three genotypes were not significant in 1967, genotype II A/II A also showed higher fertility than genotypes II A/II B and II B/II B.

TABLE 3. Fertility and hatchability of strains 1, 2 and 3 at locus II in 1966 and 1967

Strain	Year	Genotype†	Number of eggs set	Fertility (%)	Hatchability (%)
1	1966	II A	431	92.58	92.23
		II AB	439	95.44	92.60
		II B	125	94.40	94.92
	1967	II A	853	93.79	86.63
		II AB	796	95.98	85.60
		II B	350	97.43	84.46
2	1966	II A	329	95.44	91.40
		II AB	511	93.35	89.73
		II B	111	87.39	86.60
	1967	II A	581	96.21	83.18
		II AB	999	95.80	79.62
		II B	188	95.21	69.83
3	1966	II A	311	94.21	86.69
		II AB	358	93.02	84.08
		II B	102	95.10	92.78
	1967	II A	467	93.58	80.09
		II AB	633	92.10	80.96
		II B	267	95.13	80.31

† Genotype II A means the genotype II A/II A.

Therefore, in contrast with strain 1, egg albumen gene II A may have superior effects on fertility in strain 2.

With respect to hatchability in 1966 and 1967, there was a definite tendency between three genotypes, that is to say, genotype II A/II A showed the highest hatchability and genotype II B/II B showed the lowest hatchability. Although the differences in 1966 were not significant, in 1967 the differences were significant between II A/II A and II B/II B, and between II A/II B and II B/II B ($\chi^2=15.07$ and 8.44). Therefore, it seems that in strain 2 the effects of egg albumen gene II A on hatchability are superior to II B.

(c) Strain 3

There were nosignificant differences in fertility between three genotypes both in 1966 and 1967. In 1966, hatchability of genotype II B/II B was

significantly higher than that of genotype II A/II B ($\chi^2=4.73$), but in 1967 three genotypes showed almost equal hatchability. Therefore, in strain 3, it is presumed that the effects of each genotype on fertility and hatchability may be almost equal or genotype II B/II B may be slightly superior to others.

(2) **Locus III**

Hens having genotype III A/III A were excluded from the statistical analysis, because there were only two for two years. Fertility and hatchability of each genotype in strains 1, 2 and 3 are shown in Table 4.

TABLE 4. Fertility and hatchability of strains 1, 2 and 3 at locus III in 1966 and 1967

Strain	Year	Genotype†	Number of eggs set	Fertility (%)	Hatchability (%)
1	1966	III AB	93	95.70	92.13
		III B	902	93.90	92.80
	1967	III AB	134	93.28	91.20
		III B	1865	95.44	85.45
2	1966	III AB	128	98.44	95.24
		III B	791	92.41	88.92
	1967	III AB	235	96.60	84.58
		III B	1535	95.76	79.02
3	1966	III AB	94	97.87	84.78
		III B	677	93.21	86.53
	1967	III AB	122	94.26	86.09
		III B	1245	93.09	79.98

† Genotype III AB means the genotype III A/III B.

There were no significant differences both in fertility and hatchability in strains 1 and 3. In strain 2, however, there was a significant difference in fertility between genotypes III A/III B and III B/III B in 1966. Genotype III A/III B was significantly more fertile than genotype III B/III B ($\chi^2=6.36$). In 1967, however, there was no significant difference between the two genotypes. For hatchability in strain 2, the difference in 1966 was significant ($\chi^2=4.70$) and the difference in 1967 was nearly significant ($\chi^2=3.77$).

These results suggest that maternal genotypes at locus III have no effects on fertility and hatchability in strains 1 and 3 but on hatchability in strain 2 maternal genotype III A/III B is superior to maternal genotype III B/III B.

(3) Combination of loci II and III

Effects of maternal genotypes at the combination of loci II and III were examined with the genotypes that the number of eggs set were above sixty. For simplification, the discription of genotypes was done by the simplest code. For example, genotype II A III AB describes the genotype II A/II A and III A/III B.

(a) Strain 1

For fertility in 1966, the difference between genotypes II AB III B and II A IIIB was singificant (Table 5). In 1967, genotypes II A III B and II A III AB were significantly less fertile than genotype II B III B.

TABLE 5. Differences of fertility in strain 1 at the combination of loci II and III in 1966 and 1967

Year		Genotype†	Number of eggs set	Fertility (%)	Significance of difference from (1)	(2)	(3)
1966	(1)	II AB / III B	370	95.68			
	(2)	II B / III B	125	94.40	—		
	(3)	II AB / III AB	69	94.20	—	—	
	(4)	II A / III B	404	92.14	*	—	—
1967	(1)	II B / III B	306	97.71			
	(2)	II AB / III B	796	95.98	—		
	(3)	II A / III B	763	93.97	*	—	
	(4)	II A / III AB	90	92.22	*	—	—

† Genotype II AB / III B means the genotype II A/II B, III B/ III B.
— = Not significant.
* = Significant at 5% level.

For hatchability in 1966 and 1967, only the difference between genotypes II A III AB and II B III B in 1967 was significant (Table 6).

From these results, it is suggested that maternal genotype II A III B is undesirable for fertilization.

TABLE 6. Differences of hatchability in strain 1 at the combination of loci II and III in 1966 and 1967

Year	Genotype†	Number of fertile eggs	Hatchability (%)	Significance of difference from (1)	(2)	(3)
1966	(1) II B / III B	118	94.92			
	(2) II AB / III AB	65	93.85	—		
	(3) II A / III B	375	92.53	—	—	
	(4) II AB / III B	354	92.37	—	—	—
1966	(1) II A / III AB	83	92.77			
	(2) II A / III B	717	85.91	—		
	(3) II AB / III B	764	85.60	—	—	
	(3) II B / III B	299	83.95	*	—	—

† Genotype $\frac{\text{II B}}{\text{III B}}$ means the genotype II B/II B, III B/III B.

— = Not significant.

* = Significant at 5% level.

(b) Strain 2

Genotype II B III B was significantly less fertile than the other three genotypes in 1966 (Table 7). Genotypes II AB III B, II B III B and II A III AB were significantly less fertile than genotype II AB III AB in 1967.

For hatchability in 1966. the difference between genotypes II AB III AB and II B III B was significant. Genotype II B III B showed significantly lower hatchability than the other four genotypes in 1967 (Table 8).

These results show that maternal genotype II B III B has inferior effects on fertility and hatchability and that maternal genotype II AB III AB has superior effects on fertility and hatchability.

(c) Strain 3

For fertility and hatchability in 1966 and 1967, there were no significant differences among maternal genotypes (Tables 9 and 10).

(B) Effects of Mating Types

Table 11 shows the distribution of cocks' egg albumen genotypes in 1966

TABLE 7. Differences of fertility in strain 2 at the combination of loci II and III in 1966 and 1967

Year		Genotype†	Number of eggs set	Fertility (%)	Significance of difference from			
					(1)	(2)	(3)	(4)
1966	(1)	II AB / III AB	65	98.46				
	(2)	II A / III B	292	94.86	—			
	(3)	II AB / III B	427	92.51	—	—		
	(4)	II B / III B	72	81.94	**	**	**	
1967	(1)	II AB / III AB	136	99.26				
	(2)	II A / III B	482	96.89	—			
	(3)	II AB / III B	863	95.25	*	—		
	(4)	II B / III B	188	95.21	*	—	—	
	(5)	II A / III AB	99	92.93	**	—	—	—

† Genotype $\begin{matrix}\text{II AB}\\ \text{III AB}\end{matrix}$ means the genotype II A/II B, III A/III B.

— = Not significant.

* = Significant at 5% level.

** = Significant at 1% level.

TABLE 8. Differences of hatchability in strain 2 at the combination of loci II and III in 1966 and 1967

Year		Genotype†	Number of fertile eggs	Hatchability (%)	Significance of difference from			
					(1)	(2)	(3)	(4)
1966	(1)	II AB / III AB	64	95.31				
	(2)	II A / III B	277	90.61	—			
	(3)	II AB / III B	395	88.61	—	—		
	(4)	II B / III B	59	83.05	*	—	—	
1967	(1)	II A / III AB	92	89.13				
	(2)	II A / III B	467	82.01	—			
	(3)	II AB / III AB	135	81.48	—	—		
	(4)	II AB / III B	822	79.32	*	—	—	
	(5)	II B / III B	179	69.83	**	**	*	**

† Genotype $\begin{matrix}\text{II AB}\\ \text{III AB}\end{matrix}$ means the genotype II A/II B, III A/III B.

— = Not significant.

* = Significant at 5% level.

** = Significant at 1% level.

TABLE 9. Differences of fertility in strain 3 at the combination of loci II and III in 1966 and 1967

Year	Genotype†	Number of eggs set	Fertility (%)	Significance of difference from (1)	(2)	(3)
1966	(1) II AB / III AB	62	96.77			
	(2) II B / III B	87	94.25	—		
	(3) II A / III B	294	93.88	—	—	
	(4) II AB / III B	296	92.23	—	—	—
1967	(1) II B / III B	267	95.13			
	(2) II A / III B	426	92.96	—		
	(3) II AB / III B	552	92.21	—	—	
	(4) II AB / III AB	81	91.36	—	—	—

† Genotype $\frac{\text{II AB}}{\text{III AB}}$ means the genotype II A/II B, III A/III B.

— = Not significant.

TABLE 10. Differences of hatchability in strain 3 at the combination of loci II and III in 1966 and 1967

Year	Genotype†	Number of fertile eggs	Hatchability (%)	Significance of difference from (1)	(2)	(3)
1966	(1) II B / III B	82	92.68			
	(2) II A / III B	276	86.96	—		
	(3) II AB / III B	273	84.25	—	—	
	(4) II AB / III AB	60	83.33	—	—	—
1967	(1) II AB / III AB	74	85.14			
	(2) II AB / III B	509	80.53	—		
	(3) II B / III B	254	80.31	—	—	
	(4) II A / III B	396	79.29	—	—	—

† Genotype $\frac{\text{II B}}{\text{III B}}$ means the genotype II B/II B, III B/III B.

— = Not significant.

TABLE 11. Distribution of cocks' egg albumen genotypes in 1966 and 1967

Genotype	1966 Strain			1967 Strain		
	1	2	3	1	2	3
II A III B	4	3	0	10	10	3
II A III AB	0	0	0	1	2	0
II AB III B	12	3	5	11	6	3
II AB III AB	0	1	2	2	1	0
II B III B	2	2	1	1	2	3

and 1967. The effects of mating types were examined for locus II, locus III and the combination of loci II and III.

(1) Locus II

The effects of mating types at locus II on fertility and hatchability were examined on the basis of the differences of sire', dam' and offspring's genotypes. The effects of sire's genotypes were examined by the comparisons of mating types that dams have the same genotype but sire's genotypes are different. The effects of dam's genotypes were examined by the comparisons of mating types that sire's genotypes are the same but dam's genotypes are different. The effects of egg albumen types were examined by the comparisons of mating types that the theoretical segregation ratios of offspring's genotypes are the same but sire' and dam's genotypes are reciprocal. And the effects of offspring's genotypes were examined by the comparisons of mating types producing heterozygotes in the rate of 0, 50 and 100 percent of offspring.

Tables 12 and 13 show the fertility and hatchability of each mating type in 1966 and 1967.

The effects of sire's genotypes on fertility and hatchability were examined by the comparison types (1), (2) and (3).

For fertility, there were no significant differences in comparison types (1) and (3). However, in comparison type (2), there were significant differences in strains 2 and 3. In strain 2, although only the difference between mating types A×AB and AB×AB in 1967 was significant ($\chi^2=4.73$), mating type A×AB showed higher fertility than mating types AB×AB and B×AB both in 1966 and 1967. In strain 3, reversely, mating type A×AB was significantly less fertile than mating types AB×AB and B×AB in 1967 ($\chi^2=9.34$ and 8.97), though it is unknown whether in 1966 mating type A×AB also shows lower fertility than the other two mating types because of lacking mating type A×AB in 1966.

For hatchability, in comparison type (1), there were significant differences in strains 2 and 3. In strain 2, mating type AB×A showed significantly higher hatchability than mating type A×A in 1967 ($\chi^2=18.08$), and in 1966 mating type AB×A also showed the highest hatchability, though the differences were not significant. In strain 3, on the contrary, mating type A×A showed higher hatchability than mating types AB×A and B×A in 1967, and the difference between mating types A×A and B×A was significant ($\chi^2=6.17$). In comparison type (2), there were significant differences in the three strains. In strain 1, mating type B×AB showed lower hatchability than mating types A×AB and AB×AB in 1966, and the difference between mating types B×AB and AB×AB was significant ($\chi^2=4.10$). However, since there was none of

TABLE 12. Fertility of various mating types at locus II in 1966 and 1967

Number of comparison	Mating type		Strain 1 1966	Strain 1 '67	Strain 2 '66	Strain 2 '67	Strain 3 '66	Strain 3 '67
(1)	A ×A	N.E.S.[1]	85	398	54	291	0	81
		F (%)[2]	95.3	94.0	98.1	95.5	—	96.3
	AB×A	N.E.S.	290	404	80	232	103	75
		F (%)	96.2	93.1	92.5	96.6	93.2	90.7
	B ×A	N.E.S.	31	51	67	23	35	88
		F (%)	96.8	98.0	94.0	100.0	100.0	94.3
(2)	A ×AB	N.E.S.	104	340	60	529	0	99
		F (%)	97.1	95.9	98.3	97.0	—	79.8
	AB×AB	N.E.S.	230	456	96	272	98	83
		F (%)	95.7	96.1	93.8	93.8	95.9	95.2
	B ×A	N.E.S.	53	0	78	116	53	91
		F (%)	92.5	—	92.3	94.8	96.2	94.5
(3)	A × B	N.E.S.	37	152	11	98	0	54
		F (%)	97.3	96.7	100.0	96.9	—	96.3
	AB× B	N.E.S.	68	198	47	34	0	34
		F (%)	92.6	98.0	100.0	94.1	—	97.1
	B× B	N.E.S.	20	0	0	0	16	0
		F (%)	95.0	—	—	—	100.0	—
(4)	A ×A	F (%)	95.3	94.0	98.1	95.5	—	96.3
	A ×AB	F (%)	97.1	95.9	98.3	97.0	—	79.8
	A × B	F (%)	97.3	96.7	100.0	96.9	—	96.3
(5)	AB×A	F (%)	96.2	93.1	92.5	96.6	93.2	90.7
	AB×AB	F (%)	95.7	96.1	93.8	93.8	95.9	95.2
	AB× B	F (%)	92.6	98.0	100.0	94.1	—	97.1
(6)	B×A	F (%)	96.8	98.0	94.0	100.0	100.0	94.3
	B×AB	F (%)	92.5	—	92.3	94.8	96.2	94.5
	B× B	F (%)	95.0	—	—	—	100.0	—
(7)	AB×A	F (%)	96.2	93.1	92.5	96.6	93.2	90.7
	A ×AB	F (%)	97.1	95.9	98.3	97.0	—	79.8
(8)	AB× B	F (%)	92.6	98.0	100.0	94.1	—	97.1
	B×AB	F (%)	92.5	—	92.3	94.8	96.2	94.5

1) N.E.S. means number of eggs set.
2) F (%) means fertility (%).

TABLE 13. Hatchability of various mating types at locus II in 1966 and 1967

Number of comparison	Mating type		Strain 1		Strain 2		Strain 3	
			1966	'67	'66	'67	'66	'67
(1)	A ×A	N.F.E.[1]	81	374	53	278	0	78
		H (%)[2]	91.4	85.3	86.8	75.5	—	89.7
	AB×A	N.F.E.	279	376	74	224	96	68
		H (%)	92.2	87.8	91.9	90.2	90.6	78.0
	B×A	N.F.E.	30	50	63	23	35	83
		H (%)	96.7	88.0	88.9	95.7	94.3	74.7
(2)	A×AB	N.F.E.	101	326	59	513	0	79
		H (%)	93.1	88.0	91.5	77.6	—	63.2
	AB×AB	N.F.E.	220	438	90	255	94	79
		H (%)	94.1	83.8	88.9	84.3	81.9	83.5
	B×AB	N.F.E.	49	0	72	110	51	86
		H (%)	85.7	—	87.5	76.4	86.3	89.5
(3)	A × B	N.F.E.	36	147	11	95	0	52
		H (%)	100.0	82.3	100.0	76.8	—	86.5
	AB× B	N.F.E.	63	194	47	32	0	33
		H (%)	92.1	86.1	93.6	65.6	—	93.9
	B× B	N.F.E.	19	0	0	0	16	0
		H (%)	100.0	—	—	—	87.5	—
(4)	A ×A	H (%)	91.4	85.3	86.8	75.5	—	89.7
	A ×AB	H (%)	93.1	88.0	91.5	77.6	—	63.3
	A × B	H (%)	100.0	82.3	100.0	76.8	—	86.5
(5)	AB×A	H (%)	92.8	87.8	91.9	90.2	90.6	78.0
	AB×AB	H (%)	94.1	83.8	88.9	84.3	81.9	83.5
	AB× B	H (%)	92.1	86.1	93.6	65.6	—	93.9
(6)	B×A	H (%)	96.7	88.0	88.9	95.7	94.3	74.7
	B×AB	H (%)	85.7	—	87.5	76.4	86.3	89.5
	B× B	H (%)	100.0	—	—	—	87.5	—
(7)	AB×A	H (%)	92.8	87.8	91.9	90.2	90.6	78.0
	A ×AB	H (%)	93.1	88.0	91.5	77.6	—	63.3
(8)	AB× B	H (%)	92.1	86.1	93.6	65.6	—	93.9
	B ×AB	H (%)	85.7	—	87.5	76.4	86.3	89.5

1) N.F.E. means number of fertile eggs.

2) H (%) means hatchability (%).

mating type B×AB in 1967, it is unknown whether in 1967 mating type B×AB also shows the lowest hatchability. In strain 2, mating type AB×AB showed the highest hatchability in 1967, and the difference between mating types A×AB and AB×AB was significant ($\chi^2=4.79$), but in 1966 mating type A×AB showed the highest hatchability. In strain 3, mating type A×AB showed significantly lower hatchability than mating types AB×AB and B×AB in 1967 ($\chi^2=8.30$ and 16.01). However, since there was none of mating type A×AB in 1966, it was not ascertained that mating type A×AB was unfavorable for hatch. In comparison type (3), there were no significant differences in the three strains.

From these results, it is suggested that sire's genotypes influence on fertility and hatchability differently between the strains. In strain 1, it seems that sire's genotypes have little effects on fertility but sire's genotype II B/II B is unfavorable for hatch when dam's genotype is II A/IIB. In strain 2, it is suggested that sire's genotype II A/II A may be favorable for fertilization when dam's genotype is II A/II B, but sire's genotype II A/II A may be unfavorable for hatch when dam's genotype is II A/II A. In strain 3, although the data were not available in 1966, it is suggested that sire's genotype II A/II A may have superior effects on hatchability when dam's genotype is II A/II A, but, on the contrary, sire's genotype II A/II A may have inferior effects both on fertility and hatchability when dam's genotype is II A/II B.

The effects of dam's genotypes on fertility and hatchability were examined by the comparison types (4), (5) and (6).

For fertility, in comparison type (4), there were significant differences in strain 3. In 1967, mating type A×AB was significantly less fertile than mating types A×A and A×B ($\chi^2=10.88$ and 7.72). In comparison type (5), there was a significant difference in strain 1. In 1967, mating type AB×B showed significantly higher fertility than mating type AB×A ($\chi^2=6.36$). However, reversely, in 1966 mating type AB×A showed higher fertility than mating type AB×B, though the difference was not significant. In comparison type (6), there were no significant differences.

For hatchability, in comparison type (4), mating type A×AB showed always higher hatchability than mating type A×A in strains 1 and 2, though the differences were not significant. However, in strain 3, mating type A×AB showed, on the contrary, significantly lower hatchability than mating types A×A ann A×B in 1967 ($\chi^2=15.24$ and 8.51). In comparison type (5), there were significant differences in strain 2. In 1967, mating type AB×A showed significantly higher hatchability than mating types AB×AB and AB×B ($\chi^2=$ 6.78 and 14.99), but in 1966 mating type AB×B showed the highest hatchability.

In comparison type (6), there was a significant difference in strain 3. In 1967, mating type B×A showed significantly lower hatchability than mating type B×AB ($\chi^2=6.38$), but in 1966 the relation was reverse.

From these results, it is suggested that, although there were significant differences statistically, dam's genotypes have no definite effects on fertility and hatchability when sire's genotypes are II A/II B and II B/II B, but dam's genotypes may influence on fertility and hatchability differently between the strains when sire's genotype is II A/II A. Dam's genotype II A/II B may have superior effects on hatchability in strains 1 and 2 but, on the contrary, in strain 3 dam's genotype II A/II B may have inferior effects both on fertility and hatchability.

The effects of egg albumen types were examined by the comparison types (7) and (8).

For fertility, there was only a significant difference in strain 3. In 1967, mating type AB×A was significantly more fertile than mating type A×AB ($\chi^2=3.85$).

For hatchability, there was only a significant difference in strain 2. In 1967, mating type A×AB showed significantly lower hatchability than mating

TABLE 14. Fertility of the mating types at locus II producing heterozygotes in the rate of 0, 50 and 100 percent of offspring in 1966 and 1967

Offspring's genotypes in 1966	Strain 1		Strain 2		Strain 3	
	N.E.S.[1]	F (%)[2]	N.E.S.	F (%)	N.E.S.	F (%)
0 percent heterozygotes	105	95.24	50	98.15	16	100.00
50 percent heterozygotes	745	95.57	361	94.74	254	94.88
100 percent heterozygotes	68	97.06	78	94.87	35	100.00
Offspring's genotypes in 1967						
0 percent heterozygotes	398	93.97	291	95.53	81	96.30
50 percent heterozygotes	1398	95.42	1183	95.86	382	90.31
100 percent heterozygotes	203	97.04	121	97.52	142	95.07

1) N.E.S. means number of eggs set.
2) F (%) means fertility (%).

TABLE 15. Hatchability of the mating types at locus II producing heterozygotes in the rate of 0, 50 and 100 percent of offspring in 1966 and 1967

Offsprins's genotypes in 1966	Strain 1		Strain 2		Strain 3	
	N.F.E[1]	H (%)[2]	N.F.E.	H (%)	N.F.E.	H (%)
0 percent heterozygotes	100	93.00	53	86.79	16	87.50
50 percent heterozygotes	712	92.70	342	90.35	241	86.31
100 percent heterozygotes	66	98.49	74	90.54	35	94.29
Offspring's genotypes in 1967						
0 percent heterozygotes	374	85.29	278	75.54	78	89.74
50 percent heterozygotes	1334	86.28	1134	81.13	345	80.29
100 percent heterozygotes	197	83.76	118	80.51	135	79.26

1) N.F.E. means number of fertile eggs.
2) H (%) means hatchability (%).

type AB×A ($\chi^2=16.34$), but in 1966 the hatchabilities of these two mating types were almost the same.

From these results, it is suggested that egg albumen II A may be favorable for fertilization in strain 3, but egg albumen types have little effects on hatchability.

Tables 14 and 15 show the fertilities and hatchabilities of mating types producing heterozygotes in the rate of 0, 50 and 100 percent of offspring.

For fertility, there were no significant differences in the three strains, but for hatchability there were significant differences in strains 2 and 3. In strain 2, mating types producing only homozygotes showed lower hatchability, both in 1966 and 1967, than mating types producing 50 and 100 percent heterozygotes, and the difference in 1967 between mating types producing only homozygotes and 50 percent heterozygotes was significant ($\chi^2=4.37$). In strain 3, mating types producing only homozygotes showed, reversely, significantly higher hatchability than mating types producing 50 and 100 percent heterozygotes in 1967 ($\chi^2=3.85$ and 3.87).

These results suggest that offspring's genotypes influence on hatch differently between the strains.

In strain 1, it seems that offspring's genotypes have no effects on hatchability. In strain 2, it seems that the heterozygotes are superior to the homozygotes during the period of incubation. In strain 3, on the contrary, it seems that the homozygotes are superior to the heterozygotes.

(2) Locus III

The effects of mating types at locus III were examined in the same way at locus II. There were only the five comparison types because of lacking cocks and hens having genotype III A/III A. Since most of matings were III B×III B, the comparisons at locus III could not be done well. Tables 16 and 17 show the fertility and hatchability of each mating type, respectively.

TABLE 16. Fertility of various mating types at locus III in 1966 and 1967

Number of comparison	Mating type		Strain 1		Strain 2		Strain 3	
			1966	'67	'66	'67	'66	'67
(1)	AB×AB	N.E.S.	0	0	0	59	17	0
		F (%)	—	—	—	100.0	100.0	—
	B×AB	N.E.S.	93	134	78	158	20	33
		F (%)	95.7	93.3	100.0	95.6	95.0	93.9
(2)	AB× B	N.E.S.	0	232	49	122	34	0
		F (%)	—	98.3	91.8	97.5	100.0	—
	B× B	N.E.S.	825	1633	353	1256	234	572
		F (%)	95.6	95.0	94.3	95.6	94.9	92.1
(3)	AB×AB	F (%)	—	—	—	100.0	100.0	—
	AB× B	F (%)	—	98.3	91.8	97.5	100.0	—
(4)	B×AB	F (%)	95.7	93.3	100.0	95.6	95.0	93.9
	B× B	F (%)	95.6	95.0	94.3	95.6	94.9	92.1
(5)	AB× B	F (%)	—	98.3	91.8	97.5	100.0	—
	B×AB	F (%)	95.7	93.3	100.0	95.6	95.0	93.9

1) N.E.S. means number of eggs set.
2) F (%) means fertility (%).

The effects of sire's genotypes were examined by the comparison types (1) and (2).

For fertility, there was a significant difference in strain 1. In 1967, mating type AB×B was significantly more fertile than mating type B×B ($\chi^2=4.88$). For hatchability, there were no significant differences in the three strains.

From these results, it seems that sire's genotypes have little effects on

TABLE 17. Hatchability of various mating types at locus III in 1966 and 1967

Number of comparison	Mating type		Strain 1		Strain 2		Strain 3	
			1966	'67	'66	'67	'66	'67
(1)	AB×AB	N.F.E.[1]	0	0	0	59	17	0
		H (%)[2]	—	—	—	83.1	82.4	—
	B×AB	N.F.E.	89	125	78	151	19	31
		H (%)	92.1	91.2	98.7	83.4	73.7	96.8
(2)	AB× B	N.F.E.	0	228	45	119	34	0
		H (%)	—	85.1	84.4	78.2	85.3	—
	B× B	N.F.E.	789	1552	333	957	222	527
		H (%)	93.3	85.5	88.6	79.7	89.2	80.5
(3)	AB×AB	H (%)	—	—	—	83.1	82.4	—
	AB× B	H (%)	—	85.1	84.4	78.2	85.3	—
(4)	B×AB	H (%)	92.1	91.2	98.7	83.4	73.7	96.8
	B× B	H (%)	93.3	85.5	88.6	79.7	89.2	80.5
(5)	AB× B	H (%)	—	85.1	84.4	78.2	85.3	—
	B×AB	H (%)	92.1	91.2	98.7	83.4	73.7	96.8

1) N.F.E. means number of fertile eggs.
2) H (%) means hatchability (%).

fertility and hatchability except that in strain 1 sire's genotype III A/III B may be favorable for fertilization when dam's genotype is III B/III B.

The effects of dam's genotypes were examined by the comparison types (3) and (4).

For fertility, in comparison type (3), there were no significant differences in the three strains. In comparison type (4), there was a significant difference in strain 2. In 1966, mating type B × AB showed significantly higher fertility than mating type B × B ($\chi^2=4.64$), but in 1967 the fertilities of these two mating types were almost the same.

For hatchability, in comparison type (4), there was a significant difference in strain 2. Mating type B × AB showed higher hatchability than mating type B × B both in 1966 and 1967, and the difference in 1966 was significant ($\chi^2=7.56$).

From these results, it is suggested that in strain 2 dam's genotype III A/III B may be favorable for fertilization and hatch.

The effects of egg albumen III were examined by the comparison type (5).

For fertility, there were significant differences in strains 1 and 2. In

strain 1, mating type AB×B was significantly more fertile than mating type B×AB in 1967 ($\chi^2=6.18$). In strain 2, on the contrary, mating type AB×B showed significantly lower fertility than mating type B×AB in 1966 ($\chi^2=6.59$), but this relation was reverse in 1967.

TABLE 18. Fertility of the mating types at locus III producing heterozygotes in the rate of 50 and 0 percent of offspring in 1966 and 1967

Offspring's genotypes in 1966	Strain 1		Strain 2		Strain 3	
	N.E.S.[1]	F (%)[2]	N.E.S.	F (%)	N.E.S.	F (%)
50 percent heterozygotes	93	95.70	127	96.85	71	98.59
homozygotes only	825	95.64	353	94.33	234	94.87
Offspring's genotypes in 1967						
50 percent heterozygotes	366	96.45	339	97.05	33	93.94
homozygotes only	1633	95.04	1256	95.62	572	92.13

1) N.E.S. means number of eggs set.
2) F (%) means fertility (%).

TABLE 19. Hatchability of the mating types at locus III producing heterozygotes in the rate of 50 and 0 percent of offspring in 1966 and 1967

Offspring's genotypes in 1966	Strain 1		Strain 2		Strain 3	
	N.F.E.[1]	H (%)[2]	N.F.E.	H (%)	N.F.E.	H (%)
50 percent heterozygotes	89	92.13	123	93.50	70	81.43
homozygotes only	789	93.28	333	88.59	222	89.19
Offspring's genotypes in 1967						
50 percent heterozygotes	353	87.25	329	81.45	31	96.77
homozygotes only	1552	85.50	1201	76.68	527	80.46

1) N.F.E. means number of fertile eggs.
2) H (%) means hatchability (%).

TABLE 20. Differences among the mating types at the combination of loci II and III for fertility of strain 1 in 1966 and 1967

	Mating types in 1966	Number of eggs set	Fertility (%)	Significance of difference from (1)	(2)	(3)	(4)	(5)
(1)	II A III B × II AB III B	104	97.12					
(2)	II AB III B × II AB III B	164	96.34	—				
(3)	II AB III B × II A III B	266	95.86	—	—			
(4)	II A III B × II A III B	85	95.29	—	—	—		
(5)	II AB III B × II AB III AB	66	93.94	—	—	—	—	
(6)	II AB III B × II B III B	68	92.65	—	—	—	—	—

TABLE 20 (continued)

	Mating types in 1967	Number of eggs set	Fertility (%)	Significance of difference from (1)	(2)	(3)	(4)	(5)	(6)	(7)
(1)	II AB III AB × II AB III B	79	100.00							
(2)	II AB III B × II B III B	158	98.73	—						
(3)	II A III B × II AB III B	300	96.33	—	—					
(4)	II AB III B × II AB III B	377	95.23	—	—	—				
(5)	II A III B × II B III B	81	95.06	*	—	—	—			
(6)	II A III B × II A III B	398	93.97	*	*	—	—	—		
(7)	II AB III B × II A III AB	90	92.22	*	**	—	—	—	—	
(8)	II AB III B × II A III B	268	92.16	*	**	*	—	—	—	—

— = Not significant.

* = Significant at 5% level.

** = Significant at 1% level.

For hatchability, there was a significant difference in strain 2. Mating type AB × B showed lower hatchability than mating type B × AB both in 1966 and 1967, and the difference in 1966 was significant ($\chi^2=9.54$).

These results suggest that egg albumen type III B is superior to III AB for fertilization in strain 1, and that in strain 2 egg albumen type III AB may be favorable for embryos.

Tables 18 and 19 show the fertilities and hatchabilities of wating types producing 50 percent heterozygotes and no heterozygotes, respectively.

There were no significant differences in strains 1, 2 and 3. However, in strain 2, mating types producing 50 percent heterozygotes showed higher fertility and hatchability than mating types producing no heterozygotes. Therefore, in strain 2, heterozygous offspring may be favorable for fertilization and hatch.

(3) Combination of loci II and III

The comparisons of mating types at the combination of loci II and III were carried out for the mating types that the numbers of eggs set were above sixty.

(a) Strain 1

Tables 20 and 21 show the comparison of the fertility and hatchability of each mating type, respectively.

There were no significant differences for fertility and hatchability in 1966, but in 1967 there were significant differences and definite tendencies.

For fertility, it seems that dam's genotype II A/II B is superior to dam's genotype II A/II A.

For hatchability, on the contrary, it seems that dam's geno-type II A/II A is superior to dam's genotypes II A/II B and II B/II B.

(b) Strain 2

The comparisons of mating types are given in Tables 22 and 23. There were also no significant differences in 1966, but there were significant differences in 1967.

For fertility, mating type II AB III B × II A III B is superior to mating types II AB III B × II AB III B and II AB III B × II A III AB, but there was no tendency for sire' and dam's genotypes.

For hatchability, mating types II AB III B × II A III B, II AB III B × II A III B and II AB III B × II AB III B are superior to mating types II A III B × II AB III B, II A III B × II B III B, II B III B × II AB III B and II A III B × II A III B, and there was no definite tendency for dam's genotypes, but for sire's

TABLE 21. Differences among the mating types at the combination of loci II and III for hatchability of strain 1 in 1966 and 1967

	Mating types in 1966	Number of fertile eggs	Hatchability (%)	Significance of difference from (1)	(2)	(3)	(4)	(5)	(6)	(7)
(1)	II AB III B × II AB III AB	62	95.16							
(2)	II AB III B × II AB III B	158	93.64	—						
(3)	II AB III B × II A III B	255	93.33	—	—					
(4)	II A III B × II AB III B	101	93.07	—	—	—				
(5)	II AB III B × II B III B	63	92.06	—	—	—	—			
(6)	II A III B × II A III B	81	91.36	—	—	—	—	—		
	Mating types in 1967									
(1)	II AB III B × II A III AB	83	92.77							
(2)	II AB III B × II A III B	247	87.85	—						
(3)	II A III B × II AB III B	289	87.20	—	—					
(4)	II A III B × II A III B	374	85.29	—	—	—				
(5)	II AB III B × II B III B	156	85.26	—	—	—	—			
(6)	II AB III B × II AB III B	359	84.40	*	—	—	—	—		
(7)	II AB III AB × II AB III B	79	81.01	*	—	—	—	—	—	
(8)	II A III B × II B III B	77	76.62	**	*	*	—	—	—	—

—, *, ** See Table 20.

TABLE 22. Differences among the mating types at the combination of loci II and III for fertility of strain 2 in 1966 and 1967

	Mating types in 1966	Number of eggs set	Fertility (%)	Significance of difference from (1)	(2)	(3)	(4)	(5)	(6)
(1)	II A III B × II AB III B	60	98.33						
(2)	II B III B × II AB III B	78	92.31	—					
(3)	II AB III B × II A III B	61	90.16	—	—				
	Mating types in 1967								
(1)	II AB III B × II A III B	144	98.61						
(2)	II A III B × II B III B	98	96.94	—					
(3)	II A III B × II AB III B	412	96.60	—	—				
(3)	II A III B × II A III B	222	95.05	—	—	—			
(4)	II B III B × II AB III B	101	94.06	*	—	—	—		
(5)	II AB III B × II AB III B	222	92.34	**	*	—	—	—	
(7)	II AB III B × II B III AB	67	91.04	**	*	—	—	—	—

—, *, ** See Table 20.

genotypes there was a definite tendency that genotype II A/II B is superior to genotypes II A/II A and II B/II B.

From these results, it is suggested that mating type II AB III B × II A III B is favorable for fertilization and hatch and that heterozygous sire at locus II is superior to homozygous sire for hatch.

(c) Strain 3

The comparisons of mating types are given in Tables 24 and 25. There were also no significant differences in 1966, but there were significant differences in 1967.

For fertility, mating type II A III B × II AB III B is significantly inferior to the other four mating types.

TABLE 23. Differences among the mating types at the combination of loci II and III for hatchability of strain 2 in 1966 and 1967

	Mating types in 1966	Number of fertile eggs	Hatchability (%)	Significance of difference from (1)	(2)	(3)	(4)	(5)	(6)
(1)	II A III B × II AB III B	59	91.53						
(2)	II AB III B × II A III B	55	89.09	—					
(3)	II B III B × II AB III B	72	87.50	—	—				
	Mating types in 1967								
(1)	II AB III B × II A III B	142	90.14						
(2)	II AB III B × II A III AB	61	86.89	—					
(3)	II AB III B × II AB III B	205	84.39	—	—				
(4)	II A III B × II AB III B	398	78.89	**	—	—			
(5)	II A III B × II B III B	95	76.84	**	—	—	—		
(6)	II B III B × II AB III B	95	75.79	**	—	—	—	—	
(7)	II A III B × II A III B	211	72.99	**	*	**	—	—	—

—, *, ** See Table 20.

For hatchability, mating types II AB III B × II A III B, II B III B × II A III B and II A III B × II AB III B were inferior to mating types II B III B × II AB IIIB and II AB IIIB × II AB III B.

From these results, it seems that mating type II A III B × II AB III B has inferior effects both on fertility and hatchability.

DISCUSSION

Sometimes it has been reported that in mammals blood groups or serum proteins were associated with fertility and embryonic death. For example, the incompatibility of the ABO and/or Rh blood group systems in man may cause death of fetuses or new borns (SHEPPARD and D. PHIL, 1959, (15), LEVINE *et al*, 1941, (10)). Serum transferrins in cattle and pigs were also associated with

TABLE 24. Differences among the mating types at the combination of loci II and III for fertility of strain 3 in 1966 and 1967

	Mating types in 1966	Number of eggs set	Fertility (%)	Significance of difference from (1)	(2)	(3)	(4)
(1)	II AB III B × II AB III B	62	95.16				
(2)	II AB III B × II A III B	68	89.71	—			
	Mating types in 1967						
(1)	II AB III B × II AB III B	73	97.26				
(2)	II B III B × II AB III B	91	94.51	—			
(3)	II B III B × II A III B	88	94.32	—	—		
(4)	II AB III B × II A III B	75	90.67	—	—	—	
(5)	II A III B × II AB III B	99	79.80	**	**	**	*

TABLE 25. Differences among the mating types at the combination of loci II and III for hatchability of strain 3 in 1966 and 1967

	Mating types in 1966	Number of fertile eggs	Hatchability (%)	Significance of difference from (1)	(2)	(3)	(4)
(1)	II AB III B × II A III B	61	90.16				
(2)	II AB III B × II AB III B	59	88.14	—			
	Mating types in 1967						
(1)	II B III B × II AB III B	86	89.53				
(2)	II AB III B × II AB III B	71	81.69	—			
(3)	II AB III B × II A III B	68	77.94	*	—		
(4)	II B III B × II A III B	83	74.70	*	—	—	
(5)	II A III B × II AB III B	79	63.29	**	*	—	—

—, *, ** See Table 20.

embryonic mortality (ASHTON and FALLON, 1962, (4), KRISTJANSSON, 1964, (9)). Since domestic fowls are not viviparous, the relationship between dam and embryo seems to be different from that in mammals. However, there are some studies suggesting that blood groups are also associated with fertility and hatchability in domestic fowl (BRILES and KRUEGER, 1955, (6), ALLEN, 1962, (1), ALLEN and GILMOUR, 1962, (2), DE SILVA, 1965, (8)). Since egg albumen is a necessary substance for maintaining embryo's growth, it will be quite possible that the interactions of egg albumen types and sperm' or embryo's genotypes have some effects on fertility and hatchability. MORTON *et al.* (1965, (12)) and BUVANENDRAN (1967, (7 a)) examined the associations between maternal egg albumen genotypes and embryonic mortality in domestic fowls and found that there were significant associations between them.

With respect to maternal egg albumen genotypes at locus II, II B/II B was superior to II A/II A in the investigation by MORTON *et al.* 1965), 12)), but, on the contrary, II A/II A was superior to the other two genotypes in the investigation by BUVANENDRAN (1967, (7 a)). He suggested that this difference may be brought by chance associations or the different expressions of genes at locus II on the different genetic backgrounds in the two populations.

In the present study, with respect to maternal egg albumen genotypes at loci II and III, there were found the different effects of genotypes among the three strains. At locus II, genotype II A/II A was inferior for fertility in strain 1. However, on the contrary, it was superior for either fertility or hatchability in strain 2, and no significant effect in strain 3. At locus III, maternal genotype III A/III B in strain 2 had significantly higher hatchability than maternal genotype III B/III B for two years studied, though there were no significant effects in strains 1 and 3. At the combination of loci II and III, maternal genotype II A III B was unfavorable for fertilization in strain 1, and maternal genotype II B III B was also unfavorable for fertilization and hatch in strain 2, but there were no significant differences in strain 3.

Thus, the effects of the genotypes at these loci on the reproductive fitness were different in each strain. These results suggest that genes at egg albumen loci interact with genes at other loci and exhibit different effects according to their genetic backgrounds.

The two similar investigations by MORTON *et al.* (1965, (12)) and BUVANENDRAN (1967, (7 a)) examined only the association of maternal egg albumen genotypes and embryonic mortality, but in the present study, the comparisons of mating types were carried out by estimating sire's genotypes. With respect to the effects of sire' and dam's genotypes in mating types on fertility and hatchability, there were found significant effects at locus II in each strain.

For the effects of sire's genotypes, when dam's genotype is II A/II B, sire's genotype II B/II B had inferior effects on hatchability in strain 1, and in strain 2 II A/II A had supertor effects on fertility, but in strain 3 II A/II A had inferior effects both on fertility and hatchability. For the effects of dam's genotypes, when sire's genotype is II A/II A, dam's genotype II A/II B was superior for hatchability in strains 1 and 2, but, on the contrary, it was inferior for either fertility or hatchability in strain 3.

Thus, sire' and dam's genotypes have apparent effects when dam's genotype is II A/II B and sire's genotype II A/II A, and the effects were different among the three strains. These results suggest that sire' and dam's genotypes also influence differently among the three strains according to their genetic backgrounds.

Another point of interest was a comparison of homozygotes versus heterozygotes. In chickens, heterozygous superiority on fertility and hatchability has sometimes been reported for blood group loci (BRILES and KRUEGER, 1955, (6), DE SILVA, 1965, (8)). In the present study, the effects of mating types differing in expected percentage of heterozygous offspring were also compared for fertility and hatchability. For locus II, there were differences in hatchability among mating types producing heterozygotes in the rate of 0, 50 and 100 percent of offspring, but the differences did not show a consistent tendency among the three strains. In strain 2, heterozygous offspring seem to be more suitable for hatch than homozygous offspring. However, on the contrary, in strain 3 homozygous offspring seem to be more suitable for hatch than heterozygous offspring. In strain 1, there were no significant differences. The different effects of mating types on hatchability among the three strains seem to be due to different genetic backgrounds. However, in the present study, it is impossible to draw conclusions about the effects of mating types on fertility and hatchability because of the comparatively small number of data and of the inconsistency among the strains. It is necessary to reexamine by increasing the number of each mating type.

SUMMARY

The effects of egg albumen genotypes were examined, using three New Hampshire strains.

For the effects of maternal egg albumen genotypes, genotype II A/II A had inferior effects on fertility in strain 1, but it had superior effects on fertility and hatchability in strain 2. Maternal genotype III A/III B had superior effects on hatchability in strain 2, but it had no significant effects in strains 1 and 3.

The effects of sire', dam' and offspring's genotypes were also examined by the comparison of mating types.

For the effects of sire's genotypes, when dam's genotype is II A/II B, sire's genotype II B/II B had inferior effects on hatchability in strain 1, and in strain 2 II A/II A had superior effects on fertility, but in strain 3 II A/II A had inferior effects both on fertility and hatchability.

For the effects of dam's genotypes, when sire's genotype is II A/II A, dam's genotype II A/II B had superior effects on hatchability in strains 1 and 2, but it had inferior effects both on fertility and hatchability in strain 3.

For the effects of offspring's genotypes at locus II, heterozygous offspring were superior to homozygous offspring for hatchability in strain 2, but, on the contrary, in strain 3 homozygous offspring were superior to heterozygous offspring.

Thus, the effects of egg albuman genotypes at loci II and III on fertility and hatchability seemed to be different in each strain according to their genetic backgrounds.

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