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INHERITANCE OF THYROID RESPONSE TO THIOURACIL FEEDING IN NEW HAMPSHIRE CHICKENS AND ITS RELATIONSHIP TO SOME ECONOMIC CHARACTERISTICS

by

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INTRODUCTION

The chicken thyroid gland is a bi-lobed endocrine gland located at the base of the neck and lies in close proximity to the sub-clavian and common carotid arteries. The two lobes are completely separated and have a rich blood supply from the carotid arteries. Each lobe consists of a collection of closed vesicles which are lined with epithelium and are filled with colloid. Among the vesicles is connective tissue which contains the many small blood vessels. The metabolites of the thyroid gland are released into the blood of the jugular vein from which they are carried to all parts of the body.

The thyroid gland has a close relationship with the anterior pituitary gland, the so-called 'master' gland of the body. The anterior pituitary gland secretes thyrotrophin, otherwise known as thyroid stimulating hormone or TSH, which has a stimulatory action upon the thyroid gland. The thyroid gland in turn produces a hormone called thyroxine which influences the metabolism of body tissues. The relationship between the anterior pituitary gland and the thyroid gland is similar to that between a thermostat and a furnace. If the level of thyroxine in the blood falls below the level required by the anterior pituitary gland, additional TSH is produced which stimulates the thyroid gland to increase its production of thyroxine.

It is now well known that the feeding of thiouracil inhibits the normal production of thyroxine by the thyroid gland. The anterior pituitary gland then produces additional thyrotrophic hormone which causes the thyroid gland to increase in weight. Considerable variation in the magnitude of the response to thiouracil has been observed. Presumably, the individual variations in response are due to differences in the amount of thyrotrophic hormone released by the anterior pituitary gland, and/or a difference in the ability of the thyroid gland to respond to thyrotrophic hormone. If either of these fuctions is genetically controlled it should be possible to develop strains of animals differing in their response to thiouracil.

Lines of chickens exhibiting differences in thyroidal activity would be valuable, not only to further the study of the inheritance of this characteristic, but also to furnish experimental material for the study of other characteristics known to be influenced by thyroidal activity. Such lines would be useful in studying variations in rates of growth, feathering, reproduction, disease resistance, and other factors.

REVIEW OF LITERATURE

Inheritance of Thyroid Response to Thiouracil

<u>The Population</u>

The fact that the thyroid gland of the fowl becomes enlarged when thiouracil is administered is well known. This phenomenon was observed by Astwood, Bissell, and Hughes (1944), Mixner, Reineke, and Turner (1944), Schultze and Turner (1945), Andrews and Schnetzler (1946), and later by many others. The enlargement of the thyroid gland was shown to be the result of an increase in production of thyrotrophic hormone following the cessation of thyroxine production brought about by the action of thiouracil upon the thyroid gland. Maximum enlargement was shown to occur when thiouracil was given as 0.1 percent of the feed by weight, and practically the same response was obtained with 0.2 percent thiouracil. Toxicity was produced with high levels of thiouracil but not at the 0.2 percent level.

Frequency distributions of thyroid gland weights have been observed to follow a positive skewed pattern. Hollander and Riddle (1946) presented this type of distribution for a population of pigeons in which goiter was common. A similar distribution was reported by Mulligan and Francis (1951) in a population of normal male dogs. El-Ibiary and Shaffner (1951) reported two positive skewed distributions for thyroid weights of New Hampshire chickens. For one distribution the chicks had been fed thiouracil as 0.2

percent of the ration from hatching time until 10 weeks of age, while the other distribution was for 10 week old controls. The distribution for the thiouracil fed birds was skewed to a much greater degree than that for the controls.

The variability of thyroid weight was shown to be quite high by Juhn and Mitchell (1929) who noted that the thyroid gland weights of Brown Leghorns were more variable than body weights and weights of the brain, kidneys, spleen, hypophysis, and parathyroids. Aberle and Landauer (1935) computed thyroid weight as a percentage of body weight in day old White Leghorn and Frizzle chicks. The coefficients of variation were 32.2 ± 1.23 percent for males and 31.5 ± 1.21 percent for females. Bergman and Turner (1939) observed considerable variation in the thyroid weights of White Leghorn chicks. The coefficient of variation of thyroid glands of normal male dogs computed from the data of Mulligan and Francis (1951) was 38.95 ± 4.66 percent.

Juhn and Mitchell (1929) reported that the left lobe of the thyroid gland of adult Brown Leghorn chickens had a tendency toward greater development than the right lobe.

The relation of the thyroid gland to sex has been examined by numerous workers, and the majority of reports indicate that the female thyroid is larger than the male gland, particularly if examined on a body weight basis. Latimer (1924) reported no apparent sex difference in thyroid weights of White Leghorns on a normal diet except in the larger chickens, in which case the males were superior. Juhn and Mitchell (1929) found the thyroids of male adult Brown Leghorns were larger than female glands, both on an actual weight and a relative weight basis. Breneman (1941) reported the thyroid glands of 30-day-old White Leghorn male chicks were larger than those of females, whereas El-Ibiary and Shaffner (1951) found the male thyroids of 10 week old New Hampshires to be slightly larger than female glands. On the other hand, female thyroid glands were found to be larger than male glands by Aberle and Landauer (1935) in White Leghorns and Frizzles; Bergman and Turner (1939) in White Leghorns; Crile and Quiring (1940) in White Leghorns; Breneman (1941) in Rhode Island Reds; Munro, Kosin, and McCartney (1943) in White Leghorns, New Hampshires, Light Sussex, White Plymouth Rocks, and White Wyandottes; Andrews and Schnetzler (1946) in Barred Plymouth Rocks; El-Ibiary and Shaffner (1951) in New Hamphires; and Hoffmann, Shaffner, and Comstock (1953) in New Hamphires, White Plymouth Rocks, Rhode Island Reds, Columbians, and Crossbreds from White Plymouth Rock x Rhode Island Red matings.

Chaudhuri (1928) examined the iodine content of thyroid glands from Old English Game birds. The percentage iodine per gland was higher in females than in males, but only seven birds of each sex were examined and the difference was not significant.

Bergman and Turner (1939), and Munro, Kosin, and McCartney (1943) found that the female thyroid gland responded more than the male gland to the administration of thyrotrophic hormone.

Hutt (1930) reported that females were better able to withstand large doses of desiccated thyroid than males.

Wheeler and Hoffmann (1948b) reported that female chicks had significantly larger thyroid glands than male chicks at hatching time, when their dams were fed 10 grams of thyroprotein per 100 pounds of feed from the day they were hatched.

Although thyroid weight response to thiouracil feeding was greater in males than in females, according to Andrews and Schnetzler (1946), a greater response of females over males was obtained by Mixner, Reineke, and Turner (1944), Schultze and Turner (1945), Glazener and Jull (1946a), and El-Ibiary and Shaffner (1951).

Although Allee and Lutherman (1940) found no effect on thyroid weight of White Leghorn pullets by subjecting them to a temperature of 6° C. for more than 100 days, indications of environmental effects on thyroid weight were reported by Cruickshank (1929), and Cruickshank (1930) when she noted marked seasonal differences in thyroid weights of laying females. The thyroid was 35 percent smaller from April to July than from January to March. Galpin (1938) also noted the thyroids of laying hens were large in winter and decreased in size up to midsummer, after which they increased again in size. Reineke and Turner (1945) showed that thyroxine secretion of White Plymouth Rock chicks was highest in October and November and was low from March to August. Turner (1948a) found that the daily thyroxine secretion rate of two year old hens was highest from November to March and had declined at least 15 percent by May. Hoffmann and Shaffner (1950) found that seven week old New Hampshire cockerels with a 45° F. environmental temperature for three or four weeks had larger thyroid glands than similar birds held at 80° F. for like periods.

The great variability in thyroid weights led Aberle and Landauer (1935) to suggest that the factors responsible for this variability "are to be looked for in the composition of the eggs from which they hatched as well as in genetic factors affecting thyroid size". It is of interest at this point that Scharrer and Schropp (1932) were able to increase the iodine content of eggs more than 100 times that contained in ordinary eggs by feeding two milligrams of iodine daily to their White Leghorn hens for more than a year. Asmundson, Almquist, and Klose (1936) noted that the iodine content of the egg varied according to the source of the iodine in the hen's diet. Andrews and Schnetzler (1945) produced evidence that thiouracil fed to laying hens was transmitted to their eggs and that goiterous chicks were produced therefrom.

The heritability of thyroid weight in domestic fowl apparently has been reported only by El-Ibiary and Shaffner (1951). The heritability of thyroid weights in 10 week old New Hampshires on a normal ration was 62.7 percent in females and 43.8 percent in males as estimated from the effectx of sires and dams combined. The estimate from sires alone was 13.9 percent for females and 8.1 percent for males. In similar birds fed a diet containing 0.2 percent thiouracil the heritability estimates based on sires and dams combined were 0.61 percent in females and 0.71 percent in males, while the estimates based only on sires was zero for both sexes.

Effects of Selection

Apparently, the only previous selection experiments involving the thyroid gland in birds were conducted by Riddle and his associates with pigeons and doves and summarized by Riddle (1947), and by El-Ibiary and Shaffner (1950) with New Hampshire chickens. Riddle (1947) was able to select races of pigeons and doves differing in the weights of untreated thyroid glands. However, goiter became fairly common in most of his doves and practically all his pigeons. It was concluded that one or more genes were involved in the susceptibility to goiter. El-Ibiary and Shaffner (1950) were able to select two lines of New Hampshire chickens which, after one generation of selection, differed significantly in their thyroid weight response to the feeding of thiouracil as 0.2 percent of the ration from one day of age to 10 weeks of age.

Evidence for a differential thyroid activity of birds and mammals was presented by Chaudhuri (1928) who reported that the average percentage iodine content of thyroid glands in ducks and fowls was significantly higher than that in dogs, goats and rabbits.

Genetic variations in weight of the untreated thyroid gland were reported indirectly by Landauer (1929) and by Mayhew and Upp (1932), Upp (1932) and Upp (1934) Landauer (1929) reported a type of dwarfism in Rhode Island Reds associated with abnormal, enlarged thyroid glands. Mayhew and Upp (1932), Upp (1932), and Upp (1934) reported the occurrence of a type of dwarfism due to an autosomal recessive gene. They did not report an examination of the thyroids but they concluded their cases of dwarfism were the same type as that of Landauer (1929).

Cruickshank (1930) reported a difference in average weight of untreated thyroids of Brown Leghorns and White Leghorns, although the thyroid weight per kilogram of body weight was the same. Munro, Kosin, and McCartney (1943) found no significant differences in thyroid gland weights among White Leghorn, New Hampshire, Light Sussex, White Plymouth Rock and White Wyandotte Chicks at 18 days of age; but Aberle and Landauer (1935) and Landauer and Aberle (1935) found the thyroid glands of Frizzle fowl were significantly larger than those of Leghorns. Hoffmann, Shaffner, and Comstock (1953) found highly significant breed differences among the thyroid weights of 12 week old broilers of New Hampshires, Rhode Island Reds, White Plymouth Rocks, Columbians, and White Plymouth Rock x Rhode Island Red crossbreds.

Danforth (1933) produced evidence that the nature of the response of the plumage of any particular breed of fowl to thyroxine depends, primarily, not on the hormone itself, but on the genetic nature of the breed in question.

Thyrotrophin was found by Bates, Riddle and Lahr (1941) to elicit a markedly different thyroid response in two strains of White Leghorn cockerels. Chicks from one source re uired four times as much thyrotrophin as those from the other source to produce an equivlent thyroid weight increase. Munro, Kosin, and McCartney (1943) found significant differences among White Leghorn, New Hampshire, Light Sussex, White Plymouth Rock and White Wyandotte chicks in their thyroid response to injections of an anterior pituitary extract containing thyrotrophic fractions.

Breed or strain differences in the thyroid response to the feeding of thiouracil have been reported by Mixner, Reineke, and Turner (1944), Schultze and Turner (1945), Mixner and Upp (1947), Glazener, Shaffner, and Jull (1949), Andrews (1950), Boone, Davidson, and Reineke (1950), and El-Ibiary and Shaffner (1950).

The Crossing of High and Low Lines

Aberle and Landauer (1935) and Landauer and Aberle (1935) reported that thyroid glands of Frizzle Fowl were larger than those of White Leghorns, and in reciprocal crosses, the F_1 with the Frizzle as the male parent had much larger glands than either parent variety. The F_1 from the other cross produced glands which were practically the same size as those of the Leghorns. Riddle (1947) reported the results of crossing races of pigeons and doves which had been selected for large and small thyroid glands. In general, measurements made on F_1 hybrids tended to show metabolic levels which wereintermediate to those of the parental races. However, a few pigeon and dove hybrids apparently tended to have a higher metabolic rate than had either of the respective parental races. These results indicate that heterosis as well as dominance or epistasis may be a factor in the weight of the thyroid gland.

Thyroid Weight and Function

The weight of the thyroid gland has been shown by Smelser (1937), and by Bergman and Turner (1939) to vary in proportion to the amount of exogenous thyrotrophin. It would seem that the thyroid glands enlarged in this manner would have greater function than smaller glands, but some controversy has occurred concerning this problem.

Galpin (1938) found that the chick embryo seemed to have the highest metabolic rate in the summer at the time that thyroid size in the hen was smallest. She assumed that thyroid function was inversely proportional to its mass, an opinion shared by Hutt and Gowe (1948). However, the bulk of evidence in the literature favors the view that normally the size of the thyroid gland is proportional to its function. Winchester (1940) reported that the thyrotrophic hormone content of hens' pituitaries was highest during the month of February, and that heat production was maximum in February or March and was at its low point in late summer. Reineke and Turner (1945) observed that the thyroxine secretion rate of White Plymouth Rock chicks was highest in October and November and was low from March to August, and greater thyroid weights have been observed in winter than in summer in laying hens by Cruickshank (1929) and Cruickshank (1930), Galpin (1938), and Turner

(1948a). It would seem that greater demands would be placed on the thyroid glands in the winter months than in summer for body heat production and greater activity.

Aberle and Landauer (1935) found that Frizzle fowls had larger thyroid glands than White Leghorns. Frizzle fowls have an abnormal feather structure and were found by Landauer and Aberle (1935) to have a higher loss of body heat and higher metabolic rates than normal chickens at low environmental temperatures. Munro, Kosin, and McCartney (1943) noted that, in general, the breed with the largest thyroid glands under normal conditions exhibited the greatest thyroid weight response to anterior pituitary extract and vice versa. This did not occur in all cases, however. Schultze and Turner (1945) observed that the thyroid weight increased in about the same proportion as thyroxine secretion rate in growing fowl, and Hansborough and Kahn (1951) noted the same trend in chick embryos from the eleventh day of incubation to hatching time. Although Allee and Lutherman (1940) found no effect on thyroid weight of White Leghorn pullets when subjected to temperatures of 6° C. for more than 100 days, Hoffmann and Shaffner (1950) found larger thyroids in New Hampshire cockerels exposed to environmental temperatures of 45° F. for three or four weeks than in similar birds held at 80° F. for like periods.

Relationship to Economic Characteristics

Sexual Maturity

Chaudhuri (1928) found that the iodine content of thyroid glands from sexually immature White Wyandotte cockerels was lower than in those of the sexually mature.

Crew and Huxley (1923) found no noticeable difference in sexual maturity between controls and experimental birds which were fed two grams of desiccated thyroid per bird daily from three months of age until seven months of age. However, desiccated thyroid was reported by Turner, Irwin and Reineke (1944) and Glazener and Jull (1946a) to decrease the testis weight of males.

Scharrer and Schropp (1932) fed approximately two milligrams of iodine daily to White Leghorn hens and noted that "breeding tendency" occurred earlier than in controls.

Thyroprotein has had variable results on sexual maturity. Wheeler and Hoffmann (1948a) reported that the feeding of thyroprotein as 10 grams per 100 pounds of feed during the growing period to Rhode Island Red pullets retarded the onset of egg production from the 20th to the 25th week whereas McCartney and Shaffner (1950) recorded a significant increase in comb area of New Hampshire pullets fed a similar level of thyroprotein. Wheeler, Hoffmann, and Graham (1948) fed 10 grams of thyroprotein per 100 pounds of feed to Rhode Island Red chicks from one day of age to 12 weeks of age and found the control males had adopted "cocky" behavior whereas the treated males had not. The testes of treated males were only ¼ as heavy as those of controls. On the other hand, Kumaran and Turner (1949) found a slight stimulation of spermatogensis in White Plymouth Rock cockerels fed 0.08 percent thyroprotein in the feed.

McCartney and Shaffner (1950) fed thiouracil as 0.1 percent of the ration to New Hampshire pullets and found a slight, but non-significant decrease in comb area. Schultze and Turner (1945) noted no significant change in the weight of the testes of 15 weeks old Barred Plymouth Rock cockerels fed with 0.1 percent thiouracil for the last three weeks, but in 12 weeks old White Leghorn cockerels fed with 0.1 percent thiouracil for the last two weeks the testes decreased significantly in weight. Decreased development of combs or testes or both in male chicks of various breeds and varieties were noted by Astwood, Bissell, and Hughes (1944), Glazener and Jull (1946a), Briggs and Lillie (1946), Andrews and Schnetzler (1946), Shaffner and Andrews (1948), Jaap (1948), and Kumaran and Turner (1949).

Thyroidectomy of Brown Leghorn cockerels was reported by Greenwood and Chu (1939) to cause a marked regression of comb and testis development. However, thyroidectomized pullets were not affected as to age of sexual maturity on the basis of age at first egg. Winchester, Comar, and Davis (1949) reported the destruction of thyroid glands of New Hampshire pullets with radioactive iodine, and the age of first egg was not adversely affected when thyroid replacement therapy was used.

Egg Production

Welch (1928) reported that poultry in goiter districts in Montana seemed to have normal egg production, even though the thyroid was frequently as large as the thumb. Wilgus, Gassner, Patton, and Harshfield (1948) reported the experimental production of goiter by iodine deficiency, but egg production was not improved by the addition of iodine to the ration.

The thyroid weight of adult female White Leghorns was reported by Cruickshank (1929), and Cruickshank (1930) to be maximum immediately prior to the period of maximum egg production. Cruickshank (1929) and Galpin (1938) found that the weight of the thyroid gland of laying fowls decreased following the period of maximum egg production. Cruickshank (1929) reported that histological appearance of the thyroid gland suggested a state of relative inactivity in laying birds compared to that of growing birds, and Galpin (1938) suggested that an inverse relationship existed between thyroid size and reproductive activity in the fowl. Booker and Sturkie (1950) found that White Leghorn pullets laying four egg cycles secreted more thyroxine than those laying in two egg cycles, and suggested that the rate of thyroxine secretion may play a role in the determination of cycle length, but not the interval between cycles.

The feeding of iodine has occasionally resulted in an increase in egg production, although this has not always been true. Forbes, Karns, Bechdel, Williams, Keith, Callenbach, and Murphy (1932), and Johnson, Pilkey, and Edson (1935) observed no consistent results from the feeding of iodine; but Simpson and Strand (1930) observed greater egg production than expected of their two and three year old hens. Following the feeding of iodine increases in egg production of 3.5 percent were noted by Scharrer and Schropp (1932), 25 percent by Klein (1933), and 12 percent by Zajtay (Zaitschek) (1934).

Desiccated thyroid has given variable results when fed to laying fowls, probably because of different dosages and differences in laying condition of the birds. Crew (1925) reported a marked stimulation of egg production in aged females fed large doses of desiccated thyroid, but no effect on egg production of hens was observed by Cole and Hutt (1927). Egg production was only slightly reduced by large doses of desiccated thyroid according to Crew and Huxley (1923), whereas egg production was greatly reduced or even stopped by large amounts of desiccated thyroid as reported by Sainton and Peynet (1926), Asmundson (1931), Asmundson and Pinsky (1935) and Asmundson, Almquist and Klose (1936).

The feeding of 0.45 grams of thyroxine daily to New Hampshire pullets from August to February was reported by Glazener and Jull (1946b) to have no effect on egg production when compared with controls.

The feeding of thyroprotein, usually at the rate of 10 grams per 100 pounds of feed, has received much treatment in the literature in regard to egg production. Practically all the reports of increased egg production have originated at the Missouri Agricultural Experiment Station in the papers of Schultze and Turner (1945), Turner, Irwin, and Reineke (1945), Turner, Kempster, Hall and Reineke (1945), Turner, Kempster, and Hall (1946), Reineke (1946), Turner and Kempster (1947), Turner (1948c), Turner and Kempster (1948), and Turner and Kempster (1949). Apparently the only exceptions to the above statement are the reports of De Man and Bos (1946) who reported that the feeding of 20 grams of iodinated casein per 100 kilograms of mash raised the egg production by 20 percent in Rhode Island Reds, this stimulation being obtained in spite of the fact that articicial lights had already brought egg production to a higher level than normal; and of Moore and Rees (1948) who fed 10 grams of iodized casein per 100 pounds of feed to laying Rhode Island Red yearling hens and reported that average egg production was 25.4 percent higher than that of controls. No effect of thyroprotein on egg production was noted by Gutteridge and Pratt (1946), Gutteridge and Novikoff (1947), McCartney and Shaffner (1950), Savage, Turner, Kempster, and Hogan (1952), and Lillie, Sizemore, Milligan, and Bird (1952). Wilson (1949) found that the feeding of iodinated casein did not prevent the decline in egg production of White Leghorn, Rhode Island Red and New Hampshire pullets subjected to high ambient temperatures. On the other hand, decreases in egg production in response to thyroprotein feeding were recorded by Temperton and Dudley (1947), Hutt and Gowe (1948), Hoffmann and Wheeler (1948), Berg and Bearse (1948), Godfrey (1949), and Berg and Bearse (1951). Booker and Sturkie (1950) noted that the egg production of the control birds used by the Missouri group was rather low compared to that of control birds used by Hutt and Gowe (1948), for example, and suggested that iodinated casein might increase egg production of low producing hens but have no effect on high producing hens.

The feeding of thiouracil was observed to produce no effect on egg production by Andrews and Schnetzler (1945), and Glazener and Jull (1946b). McCartney and Shaffner (1950) observed no effect on egg production when thiouracil was 0.1 percent of the ration but when the dosage was increased to 0.3 percent, egg production decreased. Decreases in egg production in response to thiouracil feeding were also noted by Berg and Bearse (1948), and Berg and Bearse (1951).

Thyroidectomy was reported by Winchester (1939), and Winchester (1940) to reduce the egg production from 3.77 ± 0.39 eggs per hen per week to 0.42 ± 0.18 eggs. Injections of thyroxine brought the egg production back up to 40 to 60 percent of that of controls. Egg production declined when excess thyroxine was administered. Taylor and Burmester (1940) reported that thyroidectomy reduced egg production by 2/3 to 3/4, while production of incompletely thyroidectomized birds was reduced by 1/3. They were unable to raise egg production of thyroidectomized birds by thyroxine injections, but their dosages and timings were different from those of Winchester (1939) and Winchester (1940). Winchester, Comar and Davis (1949) reported the destruction of thyroids of New Hampshire chicks by radioactive iodine and noted no adverse effects on egg production of the few females which reached maturity.

Fertility

Crew (1925) found that senile females were markedly stimulated to egg production by large doses of desiccated thyroid, and the aged cocks in the pen were able to fertilize these eggs by natural matings.

Potasium iodide was fed to White Leghorns by Johnson, Pilkey, and Edson (1935) and no consistent effects on fertility were found.

Thyroxine was fed by Hays (1948) to Rhode Island Red males varying in age from 12 months to 48 months of age, but there were no significant differences in fertility. However, the thyroxine treatment prevented a seasonal decline in fertility experienced by the control males. Gowe and Howes (1951) added thyroxine to semen samples and noted a lowered survival time in the oviducts of females, but the decrease was not significant.

Shaffner (1948) reported that the feeding of thyroprotein to Barred Plymouth Rock males reduced the fertilizing capacity of sperm, but no effects of thyroprotein on fertility were noted by Wheeler and Hoffmann (1948b), Wheeler and Hoffmann (1948c), Huston and Wheeler (1949), Wilson (1949), and McCartney and Shaffner (1950).

No effect of thiouracil feeding on fertility was noted by Andrews and Schnetzler (1945) and McCartney and Shaffner (1950). Shaffner and Andrews (1948) fed thiouracil as 0.2 and 0.5 percent of the ration to Barred Rock males and reported a significant reduction in actual male fertility at both levels. However, Kumaran and Turner (1949) fed thiouracil to White Plymouth Rock cockerels from one day of age and noted precocious development of spermatogenesis, although some disorganization was evident. They suggested that the reduced fertilizing capacity of the cockerels of Shaffner and Andrews (1948) may have been due to lack of maturity of the spermatids at the time they passed from the tubules of the testes, and to the reduction in the secretion of male sex hormone.

Hatchability

The feeding of iodine supplements to White Leghorn hens was reported to improve hatchability eight to 12 percent by Scharrer and Schropp (1932), and 13 to 14 percent by Zajtay (Zaitschek) (1934). However, no effect was noted by Johnson, Pilkey, and Edson (1935), Asmundson, Almquist, and Klose (1936), Wheeler and Hoffman (1949a); and Wilgus, Gassner, Patton, and Harshfield (1948) reported that hatchability was unfavorably affected by large amounts of iodine in the hen's diet.

Although the addition of thyroprotein to the diet was reported by Gutteridge and Novikoff (1947) to increase hatchability, no effect was noted y Wheeler and Hoffmann (1948c), Godfrey (1949), Huston and Wheeler (1949), Wheeler and Hoffmann (1949a), McCartney and Shaffner (1950), and Lillie, Sizemore, Milligan, and Bird (1952).

Hanan (1928a), and Hanan (1928b) reported reduced hatchability in eggs in which large doses of thyroxine were introduced into the air cell on the seventh day of incubation.

Thiouracil in the ration had no effect on hatchability when fed by Andrews and Schnetzler (1945) to White Leghorn hens as 0.2 percent of the ration. Similarly, no effect on hatchability was noted by McCartney and Shaffner (1950) when the drug was fed at the 0.1 percent level to New Hampshire pullets, but when the dose was 0.3 percent, hatchability was decreased about 25 percent. When the females on the 0.3 percent ration were placed on a 0.1 percent ration, hatchability increased to within 10 percent of that obtained during the pretreatment period. In order to obtain maximum hatchability, it was necessary to keep the eggs from thiouracil-fed females in the incubator for two extra days.

Incubation Period

Wheeler and Hoffmann (1949a), and Wheeler and Hoffmann (1949b) concluded from unpublished data of Brooke and Wheeler that the feeding of desiccated thyroid to hens failed to alter the incubation time of their eggs. Their own data showed a delay in the hatching time of chicks from hens fed potassium iodide.

The feeding of thyroprotein to hens resulted in a delayed incubation period according to the reports of Wheeler and Hoffmann (1948a), Wheeler and Hoffmann (1948b), Wheeler and Hoffmann (1948c), Wheeler and Hoffmann (1948d), Wheeler and Hoffmann (1949a), McCartney and Shaffner (1949a), McCartney and Shaffner (1949b), and Savage, Turner, Kempster, and Hogan (1952).

Hanan (1928a), and McCartney and Shaffner (1949b) reported that the injection of thyroxine into the air cell did not appreciably modify the incubation period. However, Beyer (1952) injected thyroxine into Barred Columbian eggs prior to incubation and noted a decrease in the incubation period of from one to one and a half days.

The feeding of thiouracil delayed the incubation period of eggs according to reports of McCartney and Shaffner (1949a), McCartney and Shaffner (1949b), Romijn, Fung, and Lokhorst (1952), and Adams and Buss (1952).

Delays in hatching time by the administration of thiourea were reported by Grossowicz (1946), and Adams and Buss (1952).

Hoffmann and Shaffner (1950) modified the incubation temperature and found that chicks hatched from eggs incubated at 96.8° F. had markedly heavier thyroid glands and required four more days to hatch than chicks from eggs incubated at 102.2° F.

Body Weight

Much has been written about the relationship of the thyroid gland to growth and body weight. Positive correlations between thyroid weight and body weight have been reported by Latimer (1924), Cruickshank (1929), Brody and Kibler (1941), Schultze and Turner (1945), and El-Ibiary and Shaffner (1951). A negative correlation between thyroid weight and body weight was inferred in the case of dwarfism reported by Landauer (1929), in which large thyroid glands were found. This case was quite abnormal, however.

Willier (1924) successfully implanted small pieces of thyroid gland of the fowl on the chorio-allantoic membrane of the developing chick at seven to ten days of incubation. When examined at 17 to 18 days of incubation the body of the chick was emaciated and small, and the segments of the wings and legs shortened.

The administration of desiccated thyroid to fowls has produced various results, usually reducing growth and body weight, depending upon the dosage of thyroid material and the age of the bird. Cole and Hutt (1927) and Upp (1932) observed no effect on body weight when desiccated thyroid was fed whereas Crew and Huxley (1923) recorded a decreased growth rate which was of doubtful significance. However, reduced growth or body weights were reported from the feeding of desiccated thyroid by Giacomini (1924), Sainton and Peynet (1926), Martin (1929), Hutt (1930), Asmundson (1931), Asmundson and Pinsky (1935), Asmundson, Almquist and Klose (1936), and Taylor and Burmester (1940).

Somewhat diverse results were obtained by the use of thyroxine. Hanan (1928b) reported that growth of chick embryos was not affected in hen eggs injected in the air cell with small doses of thyroxine on the seventh day of incubation, whereas Beyer (1952) injected thyroxine into the eggs prior to incubation and noted an increase in weight of treated embryos over the controls. Markowitz and Yater (1932) studied the effect of thyroxine on cultures of pulsating fragments of heart muscle removed from two-day old chick embryos and reported an increase in frequency of pulsations of from 150 permminute to 226 per minute, thus demonstrating the fact that thyroxine operates directly upon tissues without the aid of nerves, which are absent from chick heart tissue at that early age. Danforth (1933) observed that the administration of thyroxine to fowls of various genotypes was followed by a slight loss in weight, but this was quickly regained. No effect on body weight was noted by Radi and Warren (1938) following the injection of thyroxine into the pectoral muscles of three week old Rhode Island Red chicks.

Variable results were also obtained when iodine or iodides were administered. Forbes, Karns, Bechdel, Williams, Keith, Callenbach, and Murphy (1932) observed no certain effect on the growth of Single Comb White Leghorn pullets fed iodine at a rate of 50 milligrams per 100 pounds live weight from hatching time until 32 weeks of age. Zajtay (Zaitschek) (1934) reported slightly greater body weights of 110 Leghorn hens fed small quantities of potassium iodide for 365 days than of controls, whereas Asmundson, Almquist, and Klose (1936) reported a loss of body weight among White Leghorn hens receiving large amounts of sodium iodide.

When thyroprotein or iodinated casein was fed to young growing chickens in small or moderate amounts, increased growth rate was usually obtained. Parker (1943), Irwin, Reineke, and Turner (1943), Wheeler, Hoffmann, and Graham

(1948), Quisenberry and Kreuger (1948), Glazener and Shaffner (1948) and Kumaran and Turner (1949) were among those who reported growth increases. No effects were noted by Boone, Davidson, and Reineke (1950), or by Ackerson, Borchers, Temper, and Mussehl (1950), whereas,reductions in growth rate were reported by Turner, Irwin, and Reineke (1944), Glazener, Shaffner, and Jull (1949), and by Boone, Davidson, and Reineke (1950) who used very high levels of thyroprotein.

When thyroprotein or iodinated casein was fed to adult chickens, the result was more often that of reduction in body weight, probably from the metabolism of stores of fat in the body. Among the workers who reported decreases in weights of adult birds fed thyroprotein or iodinated casein were Turner, Irwin, and Reineke (1945), Turner, Kempster, and Hall (1946), Boone, Reineke, and Davidson (1947), Hoffmann and Wheeler (1948), Shaffner (1948), Berg and Bearse (1948), Turner (1948c), Turner and Kempster (1949), McCartney and Shaffner (1950), Berg and Bearse (1951), Savage, Turner, Kempster, and Hogan (1952), and Lillie, Sizemore, Milligan, and Bird (1952). No effects were observed by Temperton and Dudley (1947), Hutt and Gowe (1948), Turner and Kempster (1948), Wilson (1949), Kumaran and Turner (1949), and Godfrey (1949); whereas Turner, Kempster, Hall, and Reineke (1945), Turner and Kempster (1947), and Huston and Wheeler (1949) reported increases in body weight from the use of thyroprotein or iodinated casein. Wheeler and Hoffmann (1948b) fed thyroprotein to hens and noted that chicks hatched from their eggs had enlarged thyroid glands, but no differences in post-hatching growth were noted when compared with controls.

The feeding of thiouracil has invariable decreased the growth rate of growing chickens as reported by Astwood, Bissell, and Hughes (1944), Mixner, Reineke, and Turner (1944), Schultze and Turner (1945), Kempster and Turner (1945) Andrews and Schnetzler (1946), Glazener and Jull (1946a), Briggs and Lillie (1946), Andrews and Bohren (1947), Moreng and Shaffner (1948), Moreng and Shaffner (1949), Kumaran and Turner (1949), and El-Ibiary and Shaffner (1951). The injection of thiouracil into White Plymouth Rock chick embryos retarded growth within seven days according to Adams and Buss (1952).

On the other hand, the feeding of thiouracil to adult birds usually resulted in increased body weight. No effect was noted by Glazener and Jull (1946b), but increases in body weight were recorded by Mixner, Tower, and Upp (1946), Shaffner and Andrews (1948), McCartney and Shaffner (1950), and Berg and Bearse (1951).

Partial or complete thyroidectomy was reported by Winchester (1940) and Morris (1951) to reduce body weight. Winchester (1940) found that the effect of thyroxine administration on body weight in throidectomized hens was a function of the dosage. Winchester, Comar and Davis (1949) and Winchester and Davis (1952) reported that New Hampshire chickens with their thyroids destroyed by radioactive iodine could be maintained at near normal growth rates by injections of suitable amounts of thyroxine.

Rate of Feathering

The effect of the thyroid gland on rate of feathering has been examined by numerous investigators. An abnormal case of "thyrogenous dwarfism" in a six month old Rhode Island Red pullet was described by Landauer (1929). The thyroid gland of this dwarf was much larger than normal and a general retardation in feather regeneration was noted. Schultze and Turner (1945) reported that White Leghorns have a higher thyroid secretion rate and are more rapid feathering than White Plymouth Rocks. However, Boone, Reineke and Davison (1947), contrary to expectations, found no significant difference in the thyroid secretion rate of fast and slow feathering strains of Rhode Island Reds.

The administration of desiccated thyroid generally resulted in accelerated feather growth, although this was not invariably true. Horning and Torrey (1923a), and Horning and Torrey (1923b) reported a delayed feather growth, while Crew and Huxley (1923) found no effect from feeding desiccated thyroid. Stimulation of feather growth from feeding desiccated thyroid was noted by Cole and Reid (1924), Torrey and Horning (1925a), Torrey and Horning (1925b) and Cole and Hutt (1927). Feather growth was also stimulated by feeding fresh thyroid according to Giacomini (1924), and Cole and Hutt (1927), although the latter workers stated that fresh thyroid was not as effective as desiccated thyroid of approximately equal thyroid activity.

The injection of thyroxine was reported by Fraps (1936) to increase the frequency of barb formation in the back and saddle feathers of the Brown Leghorn capon, and Radi and Warren (1938) reported an increase in the feathering of Rhode Island Red chicks injected with thyroxine from three to seven weeks of age. Winchester, Comar and Davis (1949) destroyed the thyroid glands of New Hampshire chicks with radio-active iodine, and Blivaiss (1951) thyroidectomized Brown Leghorn hens and noted that feather development was quickly resumed after the initiation of thyroxine therapy in these birds.

The feeding of iodine and its compounds to adult male Brown Leghorn fowl was reported by Cole and Reid (1924) to produce no effect on feather growth. Radi and Warren (1938) reported a slight increase in rate of feathering in Rhode Island Red chicks by the feeding of potassium iodide. Thyroprotein feeding has resulted in increased rate of feathering according to the reports of Parker (1943), Irwin, Reineke, and Turner (1943), Turner, Irwin, and Reineke (1944), Turner, Irwin, and Reineke (1945), Boone, Reineke, and Davidson (1947), Wheeler, Hoffmann, and Graham (1948), Quisenberry and Kreuger (1948), Glazener, Shaffner, and Jull

(1949), and Boone, Davidson, and Reineke (1950).

The feeding of thiouracil, on the other hand, has produced a decreased rate of feathering as reported by Astwood, Bissell, and Hughes (1944), and Briggs and Lillie (1946).

Mortality

Welch (1928) noted that goiter was very common in poultry in goiterous areas, but no bad effect on the health of these fowls was observed.

The addition of iodine to the ration had no effect on the mortality of chickens according to Forbes, Karns, Bechdal, Williams, Keith, Callenbach, and Murphy (1932), Klein (1933), Scharrer and Schropp (1932), and Wilgus, Gassner, Patton, and Harshfield (1948). Simpson and Strand (1930) stated that two and three year old White Leghorn hens fed potassium iodide appeared to be healthier than expected of hens of that age, but Johnson, Pilkey, and Edson (1935) fed potassium iodide to Single Comb White Leghorns and concluded there were no differences in mortality compared to the control group.

Hutt (1930) fed large doses of four milligrams of thyroid iodine per 1,000 and 2,000 grams of body weight to Black Minorca pullets and cockerels and found that this dosage proved lethal to both sexes.

Irwin, Reineke and Turner (1943) found severe mortality resulted from the feeding of thyroprotein at high levels to White Rock chicks. However, low levels of thyroprotein in the diet produced no effect on mortality according to Turner, Irwin and Reineke (1945), Turner and Kempster (1947), Temperton and Dudley (1947), Hutt and Gowe (1948), Moore and Rees (1948), Wheeler, Hoffmann, and Graham (1948), Wheeler and Hoffmann (1948a), Turner and Kempster (1949), Savage, Turner, Kempster, and Hogan (1952), and Lillie, Sizemore, Milligan, and Bird (1952).

Thiouracil feeding, on the other hand, was reported by McCartney and Shaffner (1950) to increase the embryonic mortality in eggs laid by hens fed thiouracil as 0.3 percent of the ration.

Disease Resistance

Parhon and Parhon (1914) fed thyroid powder to fowls and noted increased resistance to fowl cholera. Two out of five treated birds survived the outbreak while only one out of nine non-treated birds survived.

Wheeler, Hoffmann, and Graham (1948) reported an outbreak of coryza in which higher mortality occurred among a group of Rhode Island Reds receiving thyroprotein than among controls. Moreng and Shaffner (1950) altered the metabolism of New Hampshires with thiouracil, thyroprotein, or thyroxine before inoculating the birds with the fowl cholera organism, and concluded that thyroid activity had little or no influence on resistance to fowl cholera. Mayhew and Upp (1932) reported a type of dwarfism in Single Comb Rhode Island Reds which seemed to have a low resistance to the common diseases of poultry. They concluded their dwarfs were the same type as that reported by Landauer (1929) which was characterized by a large abnormal tyroid gland. However, the relationship of disease resistance to thyroid activity is quite indirect and questionable in this case.

Wheeler and Hoffmann (1948c) reported that mortality following outbreaks of "colds" was much less among birds fed thyroprotein than among controls, and suggested the possibility that thyroprotein may increase resistance to colds. Wheeler, Hoffmann, and Barber (1948), and Todd, Culton, Kelley, and Hanses (1949) reported that the rate of gain of growing chicks infected with coccidiosis was greater in groups fed thyroprotein than in groups fed control rations. Todd (1948) reported that the rate of gain of chicks infected with round-worms wasgreater when fed thyroprotein than in infected controls. Shaffner and Andrews (1948) reported that Barred Rock males fed thiouracil appeared to be more susceptible than controls to common poultry diseases such as respiratory disturbances and Newcastle disease. Francis and Kish (1952) reported that chickens of different genetic constitutions reacted differently to Newcastle disease. They suggested that "some other inherent factor controlled by heredity may be present that has a function in causing the time at which the birds die after challenge."

MATERIALS AND METHODS

Various matings of New Hamoshire chickens at the University of Maryland poultry farm produced the chicks used in this investigation. No pedigree records of the parents were available, and the amount of inbreeding in the flock was unknown. Eggs were incubated at two week intervals and were held at temperatures of 50° to 60° F. until incubated. The chicks were maintained in conventional five-deck broiler growing batteries equipped with wire screen floors. Each deck was heated by an electric element in a hover in the center of each deck. The chicks were fed the Maryland Experiment Station chick starting mash except that it contained thiouracil as 0.2 percent of the diet by weight. Thiouracil as 0.1 percent of the ration has been shown by Astwood, Bissell, and Hughes (1944), Mixner, Reineke, and Turner (1944), Schultze and Turner (1945), and Andrews and Schnetzler (1946) to produce maximum thyroid enlargement. However, toxicity was not produced when the level was as high as 0.2 percent. The higher level was used in these experiments in order to reduce probability that some chicks might be able to resist the effects of the drug. The thiouracil was thoroughly mixed with the mash frequently and in small lots of 100 pounds or less in a small mechanical mixer in order to insure a fresh supply at all times. Fresh water was kept before the birds and lights were on continuously.

At four weeks of age the chicks were weighed on a Toledo scale to the nearest gram and were sacrificed by dislocating the cervical vertebrae in the region of the atlas and epistropheus. Due to the large number of chicks in each experiment, it was necessary to preserve them by freezing. Small groups were then thawed out and the thyroid glands removed, care being taken to trim away all fat and surplus tissue. The glands were then weighed immediately with a Roller-Smith torsion balance to the nearest tenth of a milligram. Each lobe of the gland was weighed separately. Chicks treated in this manner until four weeks of age will hereafter be referred to as "thiouracil treated" chicks.

Except for such natural selection factors as egg production, fertility, hatchability and viability, the sole basis for selection was the average thyroid weights of full-sib families. Since it was necessary to sacrifice chicks to obtain the thyroid weights, additional hatches were obtained for breeding purposes from the matings which produced extremes in thyroid weight. The families whose average thyroid weights were largest were designated as the high line. A low line was established with the families whose thyroid weights were smallest. The chicks to be used for breeding were reared in brooder houses in which a radiant heating system was used. At approximately 10 weeks of age the chicks were placed on range, and were moved to breeding pens at approximately 20 weeks of age. Matings within lines were made on a rotation system designed to keep inbreeding at a minimum.

The analysis of variance for percentages based on unequal numbers as described by Cochran (1943) was used as an aid to interpreting disease resistance data. Estimates of heritability were made by use of techniques described by Lush (1940), Lush (1948), Lush (1949), and Lerner (1950). Other methods of analysis were based on techniques described by Snedecor (1946).

In June 1950 a plan was initiated designed to produce two lines of chickens, one with a high and one with a low thyroidal response to the feeding of thiouracil. Only 21 birds were available from the high and low response groups described by El-Ibiary and Shaffner (1950). They consisted of four cockerels and seven pullets from the high response group and four cockerels and six pullets from the low response group. Matings within each line were made by artificial insemination, and a limited number of offspring was obtained. All offspring were raised for breeding purposes, and none were used for determining thyroidal response to thiouracil. Thus, one generation was produced without selection. However, because of the small number of breeding stock available and because of the inbreeding which would have resulted from mating these individuals, it was decided to reinitiate the work and establish new families from the New Hampshire flock maintained at the University of Maryland.

In November 1950 six breeding pens were set up at the University of Maryland Poultry Farm. Six sires were mated to eight dams each. Three hatches were fed a mash containing 0.2 percent thiouracil to four weeks of age, at which time the chicks were sacrificed and their thyroid glands weighed. Two additional hatches fed normal diets were raised to maturity and high and low families based on the thyroid weights of their full sibs were retained for breeding stock.

Later in the hatching season the six sires were replaced by six other sires, four of them being unselected progeny of the original two lines described by El-Ibiary and Shaffner (1950). Two of these four sires were from the high thyroid families, the other two from low thyroid families.

In the fall of 1951 six mating pens were made up for the high and low line matings selected from the University of Maryland New Hampshire flock the preceding season. Males for each pen were selected in such a manner that inbreeding was kept as low as possible. Later, four additional pens were made available for the birds whose pedigrees contained ancestors selected by El-Ibiary and Shaffner (1950). These males were also distributed so that inbreeding was kept low. Thus a total of 10 breeding pens were available for the project during this season.

During the spring of 1952 an opportunity to study the relationship of thyroid response to thiouracil and resistance to Newcastle disease presented itself when the University of Maryland poultry flock was accidently exposed to this disease. Two hatches of selected replacement chicks from the high and low thyroid response lines were two and four weeks of age, respectively, when the disease outbreak occurred. The usual symptoms of Newcastle disease were noted such as the wave of mortality, paralysis, etc. Furthermore, several of the chicks which succumbed to the disease were examined by the pathological service of the University, and the causative agent of Newcastle disease was found to be present.

Ten breeding pens were made available for this project in the fall of 1952. Breeding birds selected from the previous generation were housed in August. Males were placed in the pens in such a manner that the chicks produced were crosses between high and low lines. One large hatch of crossbred chicks was obtained and given the usual thiouracil treatment. Then the males were moved to other pens so that the selection for high and low lines was continued. Matings again were made so that inbreeding was kept low. Due to the large number of chicks produced in each hatch a variation from the usual procedure was followed in brooding and sacrificing the chicks for assay. All chicks for assay were reared on the floor in a typical broiler house until four weeks of age. The feed was prepared in the usual way so that it contained thiouracil as 0.2 percent by weight. The chicks were sacrificed by administering overdoses of ether rather than by dislocating the cervical vertebrae. Body weights were taken at the time the thyroid glands were weighed.

RESULTS AND DISCUSSION

Inheritance of Thyroid Response to Thiouracil

The Population

The frequency distribution of thyroid gland weights from 472 chicks from an unselected population of New Hampshire chickens fed thiouracil as 0.2 percent of the ration until four weeks of age is given in Figure 1. The figure was prepared by arbitrarily grouping the thyroid gland weights into groups of 20 milligrams each. It will be noticed that the distribution is asymetrical or skewed, with the majority of observations to the left of the mean and toward the small sized gland. This type of distribution is known as a positive skewed distribution and seems characteristic of thyroid weights in chickens and other animals. Similar distributions were shown by Hollander and Riddle (1946) in pigeons, Mulligan and Francis (1951) in normal male mongrel dogs, and El-Ibiary and Shaffner (1951) in 10 week old New Hampshire chickens. In the latter report distributions were given for chicks on a normal diet, and on the same diet containing thiouracil as 0.2 percent of the ration. The authors stated that the distribution on the control ration was normal, but a critical examination shows an obvious, although slight, positive skewness. However, the skewness was much more extreme in the thiouracil fed birds than in the normal birds.

Figure 1. Frequency distribution of thyroid gland weights of the unselected population of thiouracil treated chicks.

The first moment of the population of thyroid weights, otherwise known as the mean or average, was 135 milligrams. The median, or central observation, was 120 milligrams, and the mode, or most frequent weight was estimated as 108 milligrams. These statistics aid in describing the skewness of the distribution, since they would all coincide if the distribution were normal, or symmetrical.

The second moment, or variance, of the population was 5,032 milligrams and the standard deviation was 70.9 milligrams. These statistics are descriptive of the variation of the population.

The third moment of the population produced another measure of skewness and totaled 508,137 milligrams. This quantity, when divided by the variance and multiplied by the standard deviation, produced a quantity known as g_1 which was equal to + 1.4474 in this case. The fact that g_1 was positive is confirmation that the distribution was skewed in the positive direction and that the mode was to the left of the mean. The degree of skewness of this distribution was highly significant with a t value of 12.87. The 1% level of t with infinite degrees of freedom is only 2.576.

Table 1 presents the thyroid weights of the original population of thiouracil treated birds grouped according to sire families, the overall average being 135 ± 2 milligrams. The variation among thyroid weights was quite high as shown by

TABLE 1. Thyroid gland weights, coefficients of variations, and standard errors of sire families of thiouracil treated chicks in the unselected population.

Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
8	100	149 ± 6	42.7 ± 3.0
9	59	156 ± 10	51.4 ± 4.7
10	101	120 ± 4	36.4 ± 2.6
11	60	148 ± 10	50.9 ± 4.6
12	83	142 ± 9	58.0 ± 4.5
13	68	96 ± 8	70.2 ± 6.0
	471	135 ± 3	52.4 ± 1.7

the coefficients of variation. The coefficient of variation for the entire population was 52.4 ± 1.7 percent. This is somewhat higher than the 32.2 ± 1.23 percent for males and 31.5 ± 1.21 percent for females reported by Aberle and Landauer (1935). However, their chicks were killed at hatching time, were not fed thiouracil, and the thyroid weights were considered as percentages of body weight. Considerable variation in chicken thyroid weights was also noted by Juhn and Mitchell (1929), and Bergman and Turner (1939).

An analysis of variance of the main effects of the unselected population considering the individual lobe as the smallest unit of measurement is given in Table 2. Only the main effects were considered in this analysis. In order to estimate all the interactions accurately it would have been necessary for each dam to have progeny of each sex represented

TABLE 2. Analysis of variance of thyroid gland weights of thiouracil treated chicks in the unselected population.

Source of variation	Degrees of freedom	Mean square
Total	941	
Between lobes	1	5,888**
Between sexes	1	30,898**
Among hatches	2	6,539**
Among battery tiers	3	5,217**
Among sires	5	18,373*
Among dams w/in sires	31	7,141**
Error	898	999

in every battery tier in each hatch. The chicks were not sexed at hatching time and this requirement was not met. Therefore, it was impossible to estimate the effects of interactions accurately, and all interactions were included in the experimental error.

The right lobes of the thyroid glands averaged 65 milligrams while the left lobes weighed 70 milligrams. The difference was highly significant as shown in Table 2. This is in harmony with the observation of Juhn and Mitchell (1929) that the left lobe of the thyroid gland of adult Brown Leghorns had a tendency toward greater development than the right lobe.

A highly significant sex difference was noted also, the female thyroid glands weighing 146 milligrams compared to 123 milligrams for the males. Andrews and Schnetzler (1946) found a greater thyroid response to thiouracil in males than in females, but results more in accordance with those reported here were found by Mixner, Reineke, and Turner (1944), Schultze and Turner (1945), Glazener and Jull (1946a), and El-Ibiary and Shaffner (1951).

That the weight of the thyroid gland is easily influenced by various environmental conditions was evidenced by the highly significant variations among hatches and among battery tiers. There were no consistent trends in thyroid weights of the different hatches, the weights being 126, 144, and 131 milligrams for the first, second, and third hatches, respectively. Nor was there a real trend in battery tiers since the averages were 121, 136, 143, and 138 milligrams from the top tier to the bottom. This is evidence that research workers should take care that differences due to different hatches are controlled in their experimental designs, especially when working with a characteristic as easily influenced by different environmental conditions as the thyroid gland. This is probably true for different rooms and for different batteries within a room, since it was true for different tiers within the same battery in these experiments. It will be noted in the analysis of variance given in Table 3 that the statistical significance due to various factors is not the same as that given in Table 2. This is due, principally, to the increased number of degrees of freedom in Table 2 produced when each lobe was considered separately, which brought about a marked decrease in the error mean square.

An apparent paradox to the large environmental effects described above appears in the comparatively high heritability estimates obtained for thyroid gland weights at four weeks of

TABLE 3. Analyses of variance of right, left, and combined lobes of the thyroid glands of thiouracil treated chicks in the unselected population.

Source of variation	Degrees of freedom	Mean squares: Left lobe	Mean squares: Right lobe	Mean squares: Combined	Composition of mean squares
Total	470				
Between sexes	1	22,233**	9,897**	61,796**	
Among hatches	2	1,668	5,409**	13,078**	
Among battery tiers	3	3,137*	2,158	10,434*	
Among sires	5	9,189*	9,774*	36,745*	Q + 12.73 D + 78.54 S
Among dams w/in sires	31	3,608**	3,659**	14,232**	Q + 12.73 D
Error	428	1,073	1,000	3,783	Q

age given in Table 4. The heritability estimates were computed according to the method of intra-class correlations among full sibs and half sibs as described by Lerner (1950).

TABLE 4. Estimates of heritability for right, left, and combined lobes of the thyroid glands of thiouracil treated chicks in the unselected population.

Basis of estimate	Heritability (%) Left lobe	Right lobe	Combined lobes
4D/Q + D + S	59.3	64.9	67.4
4S/Q + D + S	21.2	24.2	23.4
2(D + S)/Q + D + S	40.2	44.6	45.4

Taking the right and left lobes separately, the heritability estimates for the left lobe were 59.3, 21.2, and 40.2 percent depending on the method used for obtaining the estimates. For the right lobe the estimates were 64.9, 24.2, and 44.6 percent. When the two lobes for each chick were pooled into a single thyroid gland weight per chick, the heritability estimates were 67.4, 23.4, and 45.4 percent .

The difference between the first and second estimates in each case may be due to (1) non-additive gene action, or (2) maternal effects, or (3) sex-linked effects. It will be shown later that non-additive gene action has very little, if any, effect on the thyroid response to thiouracil at four weeks of age. And since sex linkage would tend to make the second estimate larger than the first, we may assume that the differences between the first and second estimates are largely due to maternal effect, which is estimated as 38.1 percent for the left lobe, 40.7 percent for the right lobe, and 44.0 percent for the two lobes combined. It is not surprising that a large maternal effect should persist to four weeks of age, since Simpson and Strand (1930), Scharrer and Schroop (1932), and Asmundson, Almquist, and Klose (1936) showed that the iodine content of the egg varied according to the amount and source of iodine in the hen's diet. Andrews and Schnetzler (1945) produced evidence that thiouracil fed to laying hens was transmitted to their eggs, and numerous investigators have reported the production of goiterous chicks by the feeding of thyroprotein or thiouracil to the dams.

It would appear from the heritability estimates that the right lobe of the thyroid gland would have produced slightly better results than the left lobe as a basis of selection, and almost as good results as the combined lobes. The reasons for this are not clear. One can imagine a greater blood supply to one lobe than to the other, thus permitting the favored lobe to receive more stimulation from thyrotrophic hormone. This argument becomes untenable when it is recalled that the left lobe is larger than the right. However, these differences in heritability estimates are quite small and may easily be due to sampling error.

At any rate, it is apparent that one could save time and/or assay more birds by weighing only the right or the left lobe of the thyroid gland, rather than weighing both lobes. Very little, if any, greater accuracy is obtained by using both lobes combined. However, since the data for both lobes combined are available for the entire experiment, and since it appears this value may have a slight advantage over one lobe or the other alone, the values for combined lobes are used throughout this report in the various analyses.

Effects of Selection

The selection experiment began quite late in the 1950 breeding season with only 21 birds available from the high and low response groups described by El-Ibiary and Shaffner (1950). These birds consisted of four cockerels and seven pullets from the high response group and four cockerels and six pullets from the low response group. They had been selected on the basis of average thyroid weights of their full sibs which had been fed a mash containing thiouracil as 0.2 percent of the ration from the time of hatching until 10 weeks of age. These averages ranged from 2.86 to 4.68 grams for the high response group and from 0.21 to 0.85 grams for the low response group .

Matings within each line were made by artificial insemination and only a few offspring were obtained. All offspring were raised for breeding purposes and none were used for determining thyroidal response to thiouracil. Thus, one generation was produced without selection. From this generation, only two females from the low line and three from the high line produced enough progeny for testing. One low line male was mated to the two low line females and one high line male was mated to the three high line females with the results given in Table 5.

TABLE 5. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated progeny of birds selected by El-Ibiary and Shaffner (1950).

High line				Low line			
Dam	No. of chicks	Thyroid wt.(mg.)	C. of V. (%)	Dam	No. of chicks	Thyroid wt.(mg.)	C. of V. (%)
A6	15	199 ± 42	82.0 ± 15.0	A 3	2	37 ± 13	48.0 ± 24.0
A12	8	342 ± 123	101.4 ± 25.4	A 5	5	64 ± 6	19.7 ± 6.2
A14	7	453 ± 181	106.1 ± 28.3				
	30	296 ± 58	107.4 ± 13.9		7	56 ± 7	32.1 ± 8.6

The average thyroid gland weight of the high line was 296 ± 58 milligrams, almost six times more than that of the low line which averaged 56 ± 7 milligrams, but the variation was large and the number of individuals quite small. The difference between the two lines was not statistically significant, as shown in Table 6, even though the two means were quite different in magnitude. The variability of the high line was much larger than that of the low line, and [illegible] 6. Analysis of variance of thyroid [illegible] thiouracil [illegible] of birds selected [illegible] (1950).

Source of variation	Degrees of freedom	Mean square
Total	36	
Between sexes	1	[illegible],1[illegible]5
Between [illegible]	1	[illegible]4,[illegible]12*
Among battery tiers	3	[illegible],964
Between lines (sires)	1	3[illegible]7,[illegible]62
[illegible] within lines	3	10,[illegible]60
Error	27	7[illegible],[illegible]6

[illegible] of the high line [illegible] the interesting [illegible] situation in which the coefficient of variation [illegible] greater than 100 percent. However, the standard error is also quite large, [illegible] true [illegible] variation [illegible] well below 100 percent. The differences between [illegible] significant, [illegible] demonstrating the [illegible] in [illegible] effect [illegible] thyroid gland. [illegible] factors [illegible]

In November 1950 [illegible] breeding [illegible] the University of Maryland Poultry Farm. [illegible] sires were [illegible] to eight [illegible] each. Three hatches of chicks were [illegible] thiouracil [illegible] at four weeks of age [illegible] thyroid [illegible] were removed [illegible] weighed.

Later in the hatching season [illegible] matings were made, [illegible] 4, 9, 1[illegible], [illegible] 11 were [illegible] by [illegible], two of which were [illegible] of [illegible] and the other two progeny of low response birds produced by El-Ibiary and Shaffner (1950). These sires were of the same breeding as those which produced the progeny described in Table 5. The dams were entirely free from selection for thyroidal response to thiouracil.

Table 7 shows results of the diallel matings. Most of the data in the left half of this table were given in Table 1, but are repeated here for ease in comparison. The average thyroid weight of the second series was higher than in the first series whether high or low line sires were used. The second series was produced from one to three months after the first, and it was at first suspected that environmental factors raised the level of all pens in the second series. However, an examination of pens 12 and 13 which contained unselected, and different, males for both series showed that this was not the case. In fact, the second series of these two pens gave lower thyroid gland weights than the first series. The possibility remains, however, that the differences between series in pens 8 and 9, or 12 and 13 were due to unfortunate sampling errors in the choice of males. The low response males lowered the variability while the high response males raised the variability of progeny of dams to which they were mated.

Although no selection had been practiced on the generation in which they were hatched, the high response

TABLE 7. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks produced by diallel matings.

First series				Second series		
Progeny of unselected males				**Progeny of low response males**		
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
8	100	149 ± 6	42.7 ± 3.0	105	166 ± 8	51.2 ± 3.5
9	59	156 ± 10	51.4 ± 4.7	70	180 ± 10	48.6 ± 4.1
	159	151 ± 6	46.2 ± 2.6	175	171 ± 5	39.0 ± 2.1
Progeny of unselected males				**Progeny of high response males**		
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
10	101	120 ± 4	36.4 ± 2.6	107	236 ± 14	62.8 ± 4.3
11	60	148 ± 10	50.9 ± 4.6	54	169 ± 16	71.6 ± 6.9
	161	130 ± 5	45.1 ± 2.5	161	213 ± 11	67.1 ± 3.7
Progeny of unselected males				**Progeny of unselected males**		
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
12	83	142 ± 9	58.0 ± 4.5	106	117 ± 9	79.0 ± 5.4
13	68	96 ± 8	70.2 ± 6.0	52	94 ± 7	52.3 ± 5.1
	151	121 ± 6	65.2 ± 3.8	158	109 ± 6	74.2 ± 4.2

males raised the progeny of the dams to which they were mated much more than did the low response males. The difference between the thyroid weights of progeny of the high and low response males was not significant as seen in Table 8.

TABLE 8. Analysis of variance of thyroid gland weights of thiouracil treated chicks in the second series presented in Table 7.

Source of variation	Degrees of freedom	Mean square
Total	493	
Between sexes	1	34,294*
Between hatches	1	420,726**
Among battery tiers	3	71,739**
Among sires		
Selected vs. unselected	1	727,001
Sires 8-11		
Between lines	1	146,574
Among sires w/in lines	2	83,690
Sire 12 vs. sire 13	1	17,307
Among dams w/in sires	32	33,095**
Error	451	8,442

This is not surprising when it is noted that the high response males were mated to females whose progeny by other sires were lower than the progeny of females to which the low response males were mated. Male thyroid glands averaged 157 milligrams while those from females averaged 173 milligrams, the difference being significant. The differences among hatches and battery tiers were highly significant which confirms the conclusions from Table 3. Heritability estimates from these data are presented in Table 9 and are quite similar to those given in Table 4.

TABLE 9. Heritability estimates for thyroid gland weights computed from Table 8.

Basis of estimate	Heritability (%)
4D/Q + D + S	74.1
4S/Q + D + S	13.3
2(D + S)/ Q + D + S	43.7

From this point until the end of the experiment the project was conducted in two parts. The first part consisted of a simple selection experiment whereas the second part was complicated by the fact that the birds selected by El-Ibiary and Shaffner (1950) were represented in pedigrees of the breeding birds. Hereafter these two different experiments will be designated A and B, respectively. That is, the pedigrees of birds in experiment B possessed as ancestors some of the birds selected by El-Ibiary and Shaffner (1950), while those in experiment A did not.

Selection was continued during the 1951-1952 season by choosing families with highest thyroidal response for the high line and lowest response for the low line. Results obtained in the spring of 1952 for experiment A after one generation of selection are shown in Table 10. Thyroid glands

TABLE 10. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks in Experiment A after one generation of selection.

High line				Low line			
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
12	64	153 ± 16	84.8 ± 7.5	13	63	102 ± 7	55.4 ± 4.9
19	81	154 ± 9	55.2 ± 4.3	25	65	131 ± 13	78.4 ± 6.9
24	17	265 ± 32	49.8 ± 3.5	26	121	145 ± 9	67.2 ± 4.3
	162	165 ± 9	69.0 ± 3.8		249	130 ± 6	70.6 ± 3.2

of the low line averaged 130 ± 6 milligrams and those of the high line averaged 165 ± 9 milligrams. These are weighted means, and the high and low lines would actually be higher and lower, respectively on an unweighted mean basis. At this stage of selection the coefficients of variation were practically the same for both lines. This is shown graphically by the frequency distributions in Figure 2. The analysis of variance in Table 11 shows that the difference between lines

TABLE 11. Analysis of variance of thyroid gland weights of thiouracil treated chicks in Experiment A after one generation of selection.

Source of variation	Degrees of freedom	Mean square
Total	410	
Between sexes	1	11,415
Between hatches	1	240,278**
Between lines	1	118,969
Among sires w/in lines	4	64,783**
Among dams w/in sires	53	16,014**
Error	350	8,107

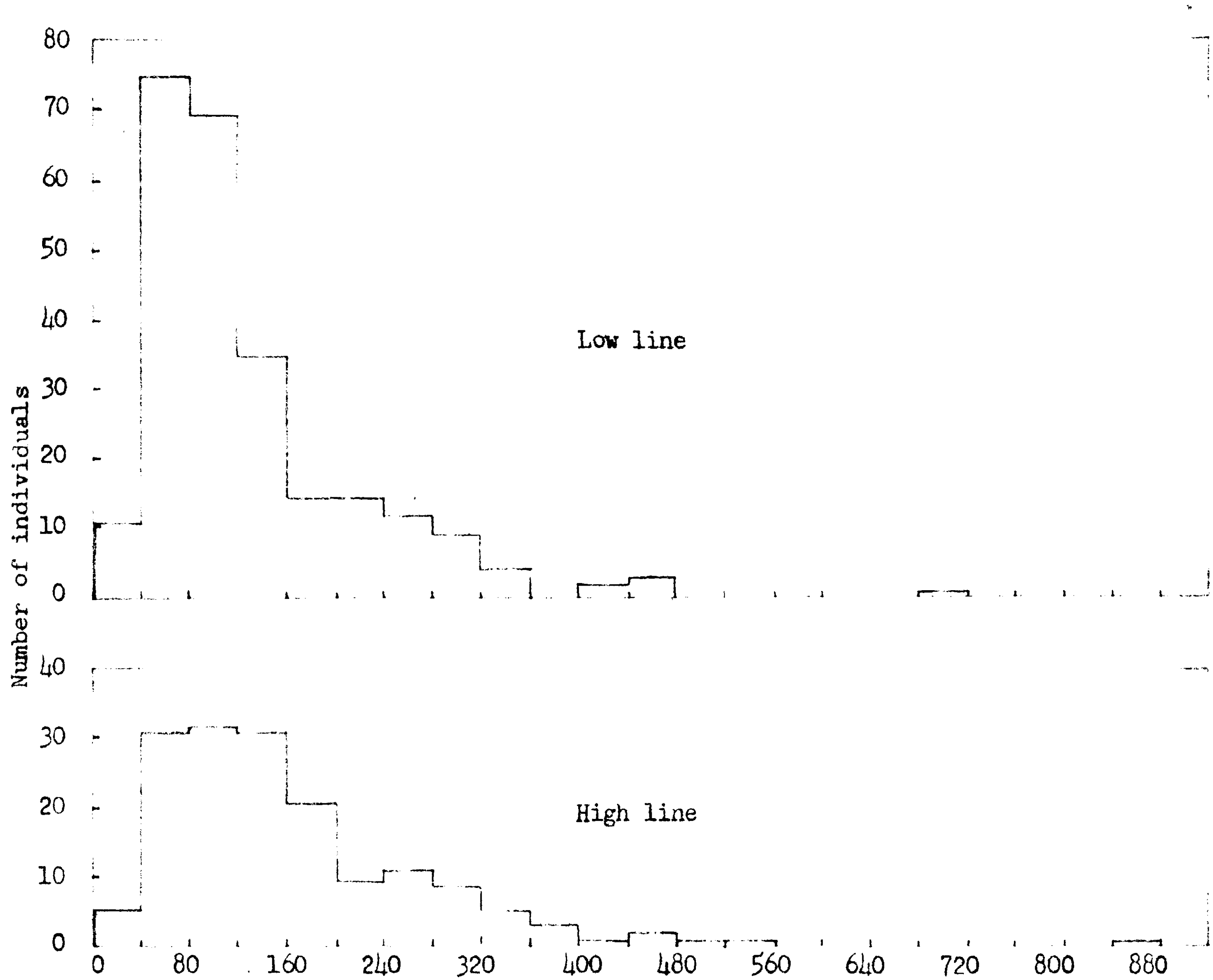

Figure 2. Frequency distributions of thyroid gland weights of thiouracil treated chicks of Experiment A after one generation of selection.

is not significant at this stage of selection. Male thyroid glands averaged 139 milligrams whereas those of females averaged 150 milligrams, but the difference was not significant. The difference between hatches was highly significant and the differences among sires within lines and among dams within sires were highly significant. The heritability estimates in Table 12 are much the same as in previous generations.

TABLE 12. Heritability estimates of thyroid gland weights of thiouracil treated chicks in Experiment A after one generation of selection.

Basis of estimate	Heritability (%)
4D/Q + D + S	45.6
4S/Q + D + S	28.6
2(D + S)/Q + D + S	37.1

Selection of Experiment A continued into the 1952-1953 season with the results given in Table 13. At this stage of selection the progeny of the high line averaged slightly more than twice that of the low line with thyroid weights of 214 ± 10 milligrams and 100 ± 4 milligrams respectively. As in the previous generation, the variability in the two lines was practically the same, with coefficients of variation of 52.7 ± 3.2 percent for the

TABLE 13. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks in Experiment A after two generations of selection.

High line				Low line			
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
12	28	263 ± 27	54.8 ± 7.3	13	107	107 ± 5	44.8 ± 3.1
19	58	193 ± 14	53.8 ± 5.0	25	49	94 ± 9	66.2 ± 6.7
24	49	208 ± 14	48.5 ± 4.7	26	61	93 ± 6	51.9 ± 4.7
	135	214 ± 10	52.7 ± 3.2		217	100 ± 4	51.6 ± 2.5

high line and 51.6 ± 2.5 percent for the low line. This is shown graphically in the frequency distributions in Figure 3.

The analysis of variance in Table 14 shows the difference between lines is now highly significant. The difference between

TABLE 14. Analysis of variance of thyroid gland weights of thiouracil treated chicks in Experiment A after two generations of selection.

Source of variation	Degrees of freedom	Mean square
Total	351	
Between sexes	1	51,455**
Between lines	1	1,058,418**
Among sires w/in lines	4	25,592
Among dams w/in sires	48	12,484**
Error	297	5,177

sexes is also highly significant with the male glands weighing 131 milligrams and the female glands 155. The heritability

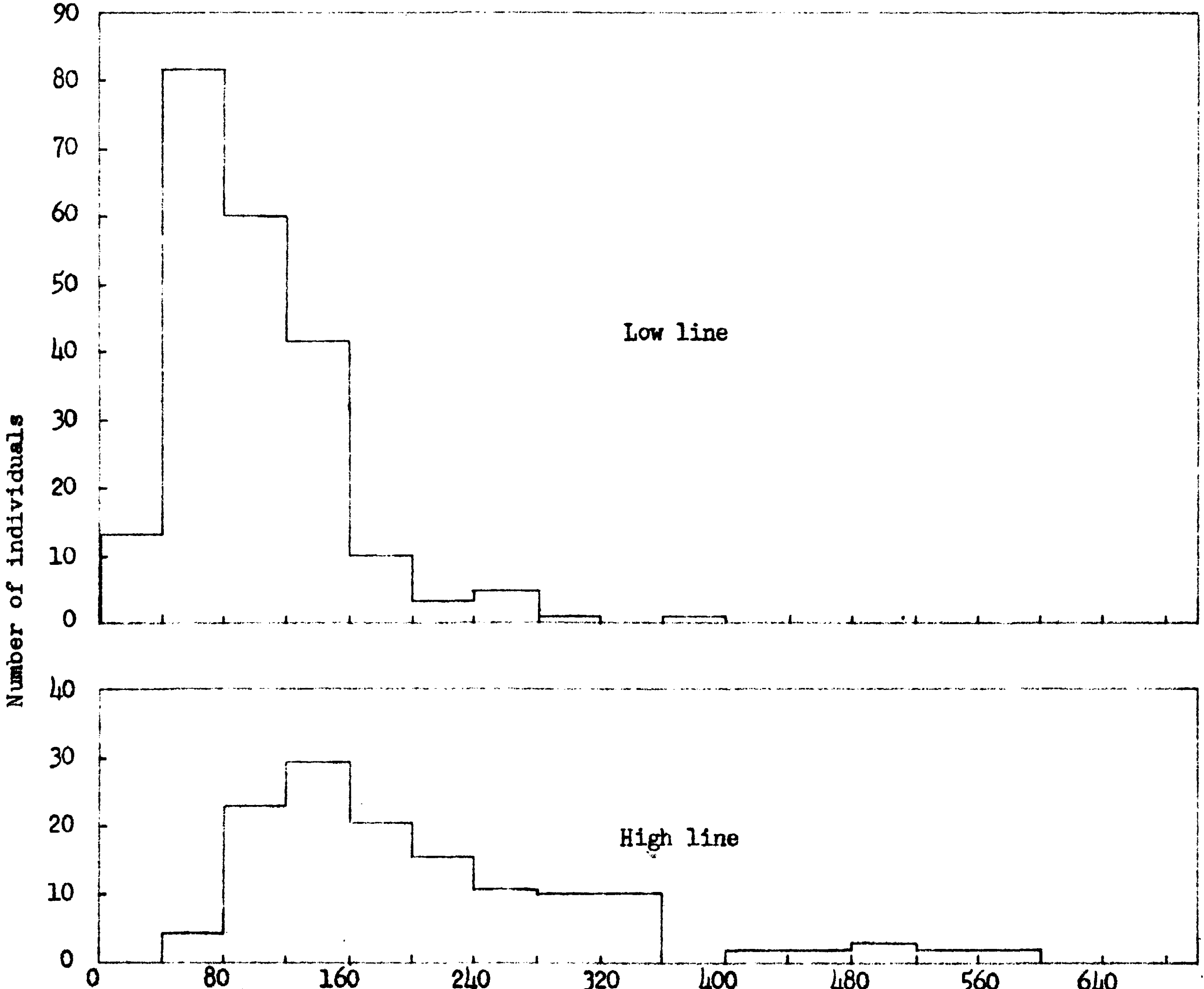

Figure 3. Frequency distribution of thyroid gland weights of thiouracil treated chicks of Experiment A after two generations of selection.

estimates in Table 15 continue to be much the same as before.

TABLE 15. Heritability estimates of thyroid gland weights of thiouracil treated chicks in Experiment A after two generations of selection.

Basis of estimate	Heritability (%)
4D/Q + D + S	68.74
4S/Q + D + S	13.70
2(D + S)/Q + D + S	41.22

Results of Experiment B for the 1951-1952 season are presented in Table 16. After approximately two generations of selection the average thyroid weights of the chicks from the high line were almost four times larger than those of the chicks from the low line with thyroid weights of 426 ± 28 milligrams, and 111 ± 4 milligrams respectively. The analysis of variance is shown

TABLE 16. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks in Experiment B after approximately two generations of selection.

High line				Low line			
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
22	75	438 ± 36	70.4 ± 5.8	20	57	92 ± 6	48.3 ± 4.5
23	72	415 ± 44	89.2 ± 7.4	21	147	119 ± 5	51.8 ± 3.0
	147	426 ± 28	79.5 ± 4.6		204	111 ± 4	52.6 ± 2.6

in Table 17 and the differences between the two lines is highly significant. The difference between sexes is also highly significant, the average thyroid weight for males being 196 milligrams and for females 288 milligrams. The

TABLE 17. Analysis of variance of thyroid gland weights of thiouracil treated chicks in Experiment B after approximately two generations of selection.

Source of variation	Degrees of freedom	Mean square
Total	350	
Between sexes	1	750,082**
Between hatches	1	9,887
Between lines	1	8,489,511**
Among sires w/in lines	2	23,714
Among dams w/in sires	41	55,905
Error	304	47,150

frequency distributions of the thyroid glands for the two lines are given in Figure 4. Each line exhibits the same type of skewed distribution as the original population shown in Figure 1, but the variability is much greater in the high line than in the low line. The greater variability of the high line is also shown in Table 16, the coefficient of variability of the high line being 79.5 ± 4.6 and that for the low line 52.6 ± 2.6. The difference between the coefficients of variation for the two lines is highly significant. The estimates of heritability shown in Table 18 have reduced considerably.

Selection in Experiment B was carried on into the 1952-1953 season and the results are shown in Table 19. The high

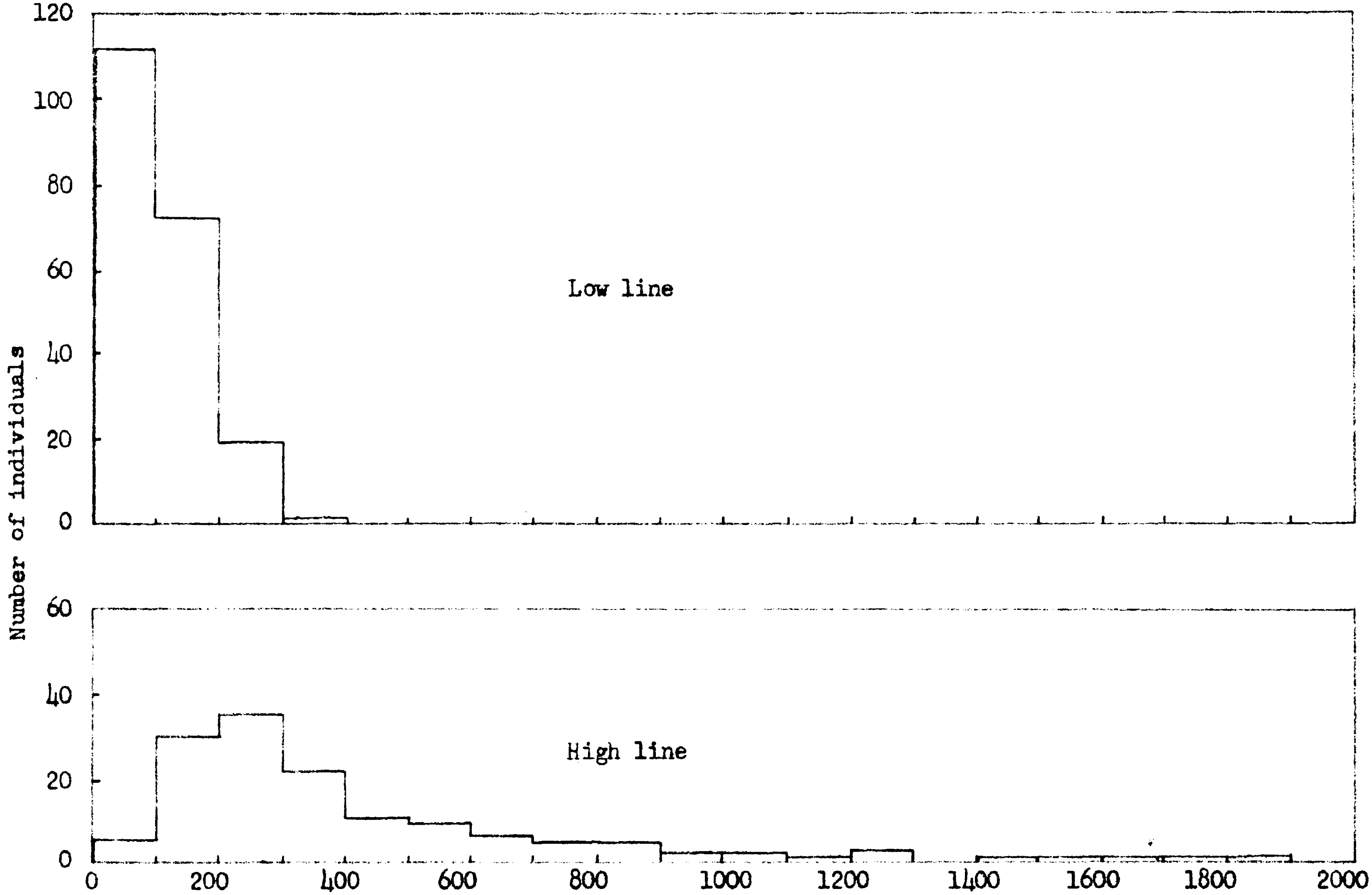

Figure 4. Frequency distributions of thyroid gland weights of thiouracil treated chicks from Experiment B after approximately two generations of selection.

TABLE 18. Heritability estimates of thyroid gland weights of thiouracil treated chicks in Experiment B after approximately two generations of selection.

Basis of estimate	Heritability (%)
4D/Q + D + S	8.90
4S/Q + D + S	0.00
2(D + S)/Q + D + S	4.45

TABLE 19. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks in Experiment B after approximately three generations of selection.

High line				Low line			
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
22	23	540 ± 57	50.2 ± 7.4	20	56	104 ± 8	55.1 ± 5.2
23	24	446 ± 59	65.2 ± 9.6	21	77	107 ± 5	43.2 ± 3.5
	47	492 ± 41	57.3 ± 5.9		133	106 ± 4	48.2 ± 3.0

line has attained a thyroid weight almost five times greater than the low line with weights of 492 ± 41 and 106 ± 4 milligrams respectively. The high line is also more variable than the low line, the coefficients of variation being 57.3 ± 5.9 and 48.2 ± 3.0 percent, respectively. The analysis of variance is given in Table 20, and the difference between lines is highly significant. The male thyroid

TABLE 20. Analysis of variance of thyroid gland weights of thiouracil treated chicks in Experiment B after approximately three generations of selection.

Source of variation	Degrees of freedom	Mean square
Total	179	
Between sexes	1	14,671
Between lines	1	5,187,721**
Among sires w/in lines	2	51,750
Among dams w/in sires	26	34,151*
Error	149	20,133

glands averaged 200 milligrams and the females 217, but the difference between sexes was not significant. The frequency distributions are given in Figure 4. The heritability estimates continue to be low, as shown in Table 21.

TABLE 21. Heritability estimates of thyroid gland weights of thiouracil treated chicks in Experiment B after approximately three generations of selection.

Basis of estimate	Heritability (%)
4D/Q + D + S	40.88
4S/Q + D + S	6.84
2(Q + D)/Q + D + S	23.86

It is apparent that El-Ibiary and Shaffner (1950) were able to make greater progress in selecting for high and low

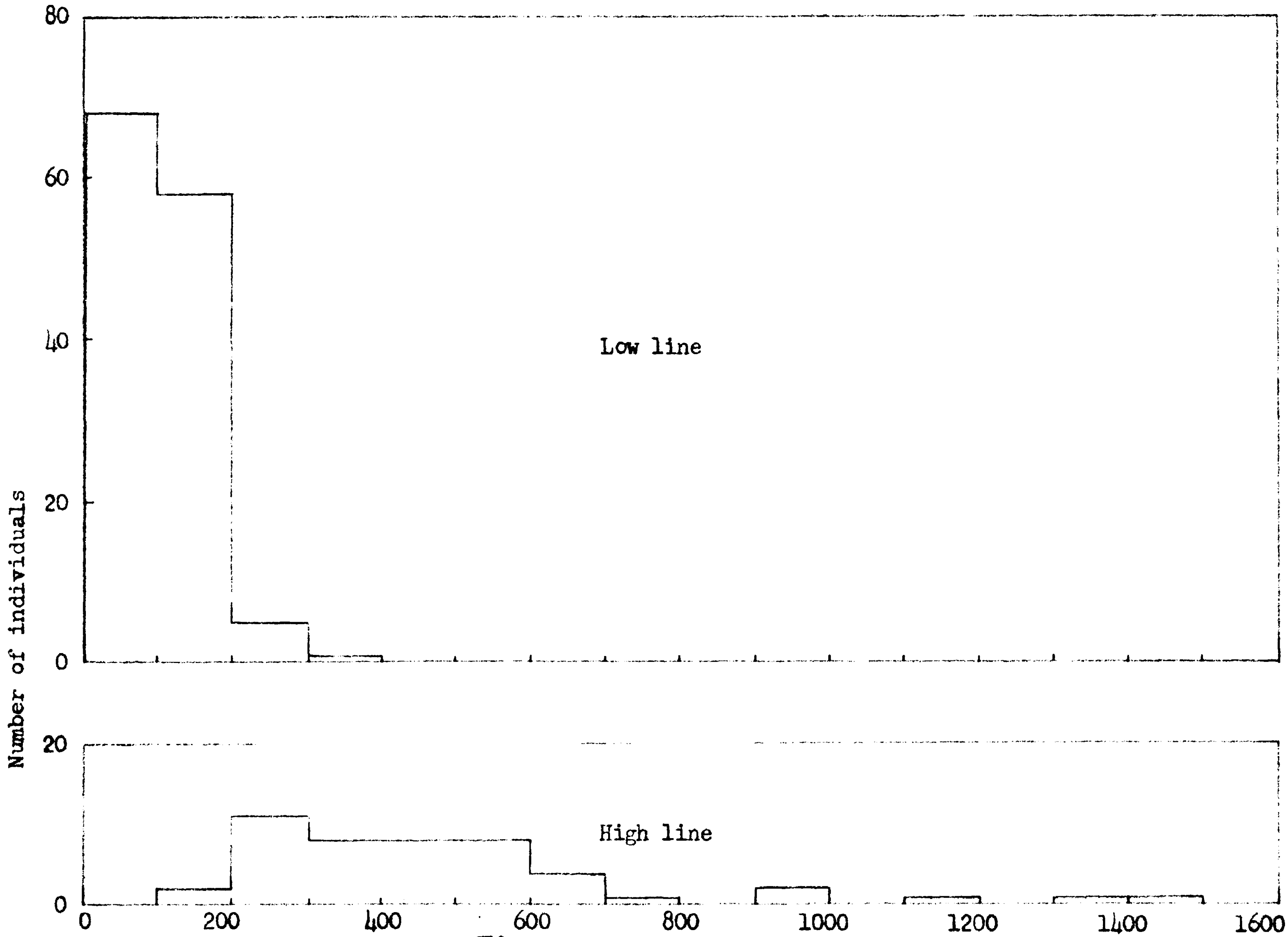

Figure 5. Frequency distributions of thyroid gland weights of thiouracil treated chicks from Experiment B after approximately three generations of selection.

thyroidal response to thiouracil than was attained in experiment A. There are three possible reasons for this. In the first place their selections were made on the basis of thyroid weights at 10 weeks of age, whereas in this experiment, four week weights were used. It would seem that any non-genetic maternal effects would be more likely to affect thyroid weights at four weeks than at 10 weeks of age. As a matter of fact, an increase in heritability with increased age was indicated by the heritability estimates of 60 to 70 percent for the 2(D + S)/Q + D + S method of estimation by El-Ibiary and Shaffner (1951) for 10 week old chicks, which were much larger than the estimate of approximately 45 percent arrived at here for four week old chicks. Also, it has been shown by Baker, Hazel, and Reinmiller (1943) that the heritability of body weight in pigs increases gradually from zero at birth to a maximum at 112 days of age, and El-Ibiary and Shaffner (1951) showed that heritability of body weight of New Hampshire chickens was higher at 10 weeks of age than at six or eight weeks. Thus it seems reasonable to expect lower heritability and consequently less progress from selection at four weeks than at 10 weeks of age.

Secondly, the experiment conducted by El-Ibiary and Shaffner (1950) utilized a larger number of families for the initial experiment. In their experiment eight sires were mated to eight dams each, whereas in the present experiment only six sire matings were available.

Finally, chance may have been a factor in the final choice of sires and dams used to produce the high and low lines. The great variability in thyroid weight would make it unlikely that the sires and dams in each experiment would have comparable genotypes for thyroid gland weight.

As suggestions for future experimentation, it would be desirable to determine the age at which heritability of thyroid response to thiouracil is highest, and use that age for assaying the families. However, the four week age has an advantage over later ages in early testing, and a much greater age might have the disadvantage of lengthening the generation interval so that rate of progress actually would be reduced.

The crossing of high and low lines

It was decided that a control would be desirable when the time came for crossing the two lines. Therefore pens 13 and 26 of the low line and pens 19 and 24 of the high line were mated so that the sires were the same for the two hatches used for assay during the 1952-1953 season. In all other pens, the sires of chicks hatched during the first hatch were placed with females of the other line. That is, the sires which had been selected to head pens 20, 21, and 25 were placed in pens 22, 23, and 12, respectively, for producing the crosses. After one hatch was obtained the sires were replaced in the pens containing pullets from their respective lines, a clearing period of two weeks was allowed, and eggs were saved for producing chicks for assay for another generation of selection.

The controls were used for two reasons. In the first place, the controls would show up any large difference between hatches, and secondly, they could be used as a basis for computing correction factors if a large difference between hatches occurred. The results are presented in Table 22.

TABLE 22. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks from two hatches of Experiment A after two generations of selection.

High line

	First hatch			Second hatch		
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
19	60	218 ± 13	45.6 ± 4.2	58	193 ± 14	53.8 ± 5.0
24	67	226 ± 15	55.3 ± 4.8	49	208 ± 14	46.5 ± 4.7
	127	222 ± 10	51.3 ± 3.2	107	200 ± 10	50.0 ± 3.4

Low Line

	First hatch			Second hatch		
Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
13	102	102 ± 6	56.6 ± 4.0	107	107 ± 5	44.8 ± 3.1
26	66	106 ± 6	48.0 ± 4.2	61	93 ± 6	51.9 ± 4.7
	168	103 ± 4	53.1 ± 2.9	168	102 ± 4	47.4 ± 2.6

The data in the right half of this table were presented previously in Table 13 but are repeated here for purposes of comparison. The thyroid weights of the first hatch were slightly greater than those of the second hatch, particularly in the high line. The difference between hatches was significant, but only at the five percent level of probability as shown in Table 23. Apparently the unknown factors which reduced the thyroid weights of the second hatch below those of the

TABLE 23. Analysis of variance of thyroid gland weights of thiouracil treated chicks from two hatches of Experiment A after two generations of selection.

Source of variation	Degrees of freedom	Mean square
Total	569	
Between sexes	1	83,624**
Between hatches	1	29,956*
Between lines	1	1,653,514**
Among sires w/in lines	2	83,195
Among dams w/in sires	47	20 11,093**
Error	517	5,752

first hatch affected the high line much more than the low line. Therefore any correction of the crosses for differences between hatches should be approximately midway between the corrections for the two lines. It is estimated that such a correction would amount to little, if any, more than five percent, and since this small amount would have little effect on the final results, no correction factors were computed.

The difference between sexes was highly significant, thus confirming the conclusions arrived at from Table 14 when only one hatch was considered.

Aberle and Landauer (1935) reported that in reciprocal crosses between Frizzle fowl and White Leghorns, which have large and small thyroid glands, respectively, the cross in which the male parent was Frizzle produced thyroid glands which were larger than the Frizzle parent, whereas the other cross produced thyroid glands which were the same size as those of White Leghorns. El-Ibiary and Shaffner (1951) concluded that "none of the additive variance is concerned with the goiterogenic capacity of the gland and that dominance is to be suspected" in the genetic control of thyroid gland weight of thiouracil treated 10-week-old New Hampshire chickens. Figure 6 is not in agreement with either of the works cited above. If non-additive genes completely controlled thyroid weight, the crossing of two lines differing in goiterogenic capacity should produce results approximately the same as either one or the other parent stock. On the other hand, if the goiterogenic capacity were controlled only by additive genes thyroid weights of the crosses would be expected to lie midway between those of the two parent stocks. In Figure 6 the mid-point between the parent stocks would be 162 milligrams which is quite near the observed value of 169 milligrams. However, in Experiment B the thyroid weights of the crosses were nearer those of the low line than of the high line parent. The mid-parent value would be 300 milligrams while the observed

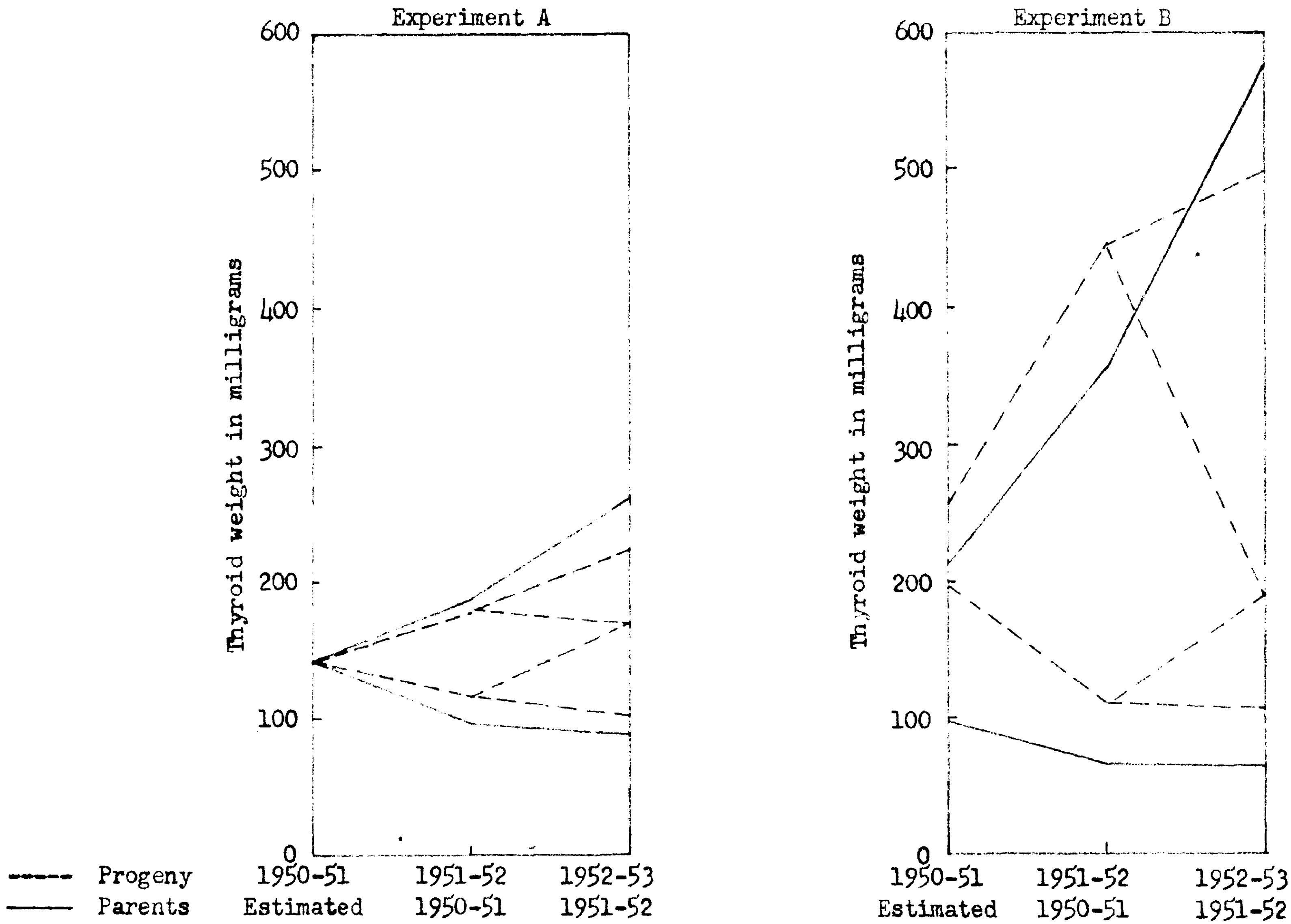

Figure 6. Results of selection for high and low thyroid response to thiouracil treatment.

value was 188 milligrams. The difference between the observed value and the value expected on an assumption that all genes affecting thyroid response to thiouracil are additive produced a chi square value of 8.36 which is highly significant. This may be taken as evidence that some dominant or epistatic genes for small thyroid size are involved. Although an undetermined amount of this difference may be found in the difference between the first and second hatches discussed previously in connection with Table 22, and although it would seem that if a transformation could be found which would make the frequency distribution symmetrical the crosses would be more nearly centered between the two parent stocks, it must be concluded from the available evidence that thyroid response to thiouracil feeding was affected by dominant or epistatic genes in Experiment B.

It is interesting that the offspring of the high line in Experiment B produced larger thyroid responses to thiouracil in 1950-51 and in 1951-52 than full sibs of their parents. This could be due to different environmental conditions for these years, or the parents chosen for the high line may have been genetically disposed toward higher response to thiouracil than their full sibs which were used for assay. This could easily occur with the large natural variation which affects this trait.

The crossing data for Experiment A are given in Table 24. The cross using the high line male on low line females produced

TABLE 24. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks from reciprocal crosses between the high and low lines of Experiment A.

High line male x low line females				Low line male x high line females			
Pen	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	Pen	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
25	71	187 ± 15	66.4 ± 5.6	12	23	116 ± 13	54.6 ± 8.0

larger thyroid glands than the reciprocal cross, but the difference between reciprocal crosses was not significant as shown in Table 25.

TABLE 25. Analysis of variance of thyroid gland weights of reciprocal crosses between the high and low lines of Experiment A.

Source of variation	Degrees of freedom	Mean square
Total	93	
Between sexes	1	10,105
Between sires (crosses)	1	86,357
Among dams w/in sires	16	34,217**
Error	75	8,111

Furthermore, in this case only one sire was used for each cross and the sire effects were confounded with the effects of the different types of cross. Therefore, the large glands resulting from the high line male crossed with low line females may be entirely due to chance differences between the two sires used, regardless of the line from which they came. For reason, the heritability estimate for the sire component given in Table 26 has little meaning. However, it is noted that the heritability estimates in general are much larger

TABLE 26. Heritability estimates of thyroid gland weights of reciprocal crosses between the high and low lines of Experiment A.

Basis of estimate	Heritability (%)
4D/Q + D + (S + L)	140.67
4(S + L)/Q + D + (S + L)	31.20
2 [D + (S + L)] /Q + D + (S + L)	85.93

among the crossed progeny than among their half sibs which resulted from two generations of selection.

Table 27 presents the data for reciprocal crosses of Experiment B. Here it is noted that there is very little

TABLE 27. Thyroid gland weights, coefficients of variation, and standard errors of thiouracil treated chicks from reciprocal crosses between high and low lines of Experiment B.

High line ♂ X low line ♀♀				Low line ♂ x high line ♀♀			
Pen	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	Pen	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
20	26	236 ± 28	61.4 ± 8.5	22	48	137 ± 23	116.3 ± 11.9
21	36	164 ± 17	62.3 ± 7.3	23	25	273 ± 39	71.1 ± 10.1
	62	194 ± 16	64.9 ± 5.8		73	183 ± 16	74.2 ± 6.1

difference between the reciprocal crosses, but there are great differences among sires with regard to the thyroid gland weights of their progeny. This is emphasised statistically in Table 28 when the mean square for between reciprocal crosses is even less than the mean square for error. On the other hand, the differences between sires within crosses in highly significant. This confirms

TABLE 28. Analysis of variance of thyroid gland weights of reciprocal crosses between high and low lines of Experiment B.

Source of variation	Degrees of freedom	Mean square
Total	134	
Between sexes	1	10,856
Between crosses	1	3,980
Among sires w/in crosses	2	191,659**
Among dams w/in sires	27	18,637
Error	103	13,614

the suggestion made previously that the differences between reciprocal crosses in Experiment A may have been due largely to differences between sires. The high heritability estimates in Table 29 confirm the expectation that heritability is higher in

TABLE 29. Heritability estimates of thyroid gland weights of reciprocal crosses between high and low lines of Experiment B.

Basis of estimate	Heritability (%)
4D/Q + D + S	23.21
4S/Q + D + S	103.16
2(D + S)/Q + D + S	63.19

crossed populations obtained by mating individuals from stocks in which selection has been practiced.

Thyroid Weight and Function

When a number of full sibs of the high and low lines were fed a control ration during the 1951-1952 season, the high line was found to have smaller thyroid glands than the low line at four weeks of age. Table 30 shows that the high

TABLE 30. Thyroid gland weights, coefficients of variation, and standard errors of untreated and thiouracil treated chicks in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

		Control ration			Thiouracil ration		
	Sire	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)	No. of chicks	Thyroid wt. (mg.)	C. of V. (%)
	12	37	25.3 ± 1.2	28.3 ± 3.5	64	153 ± 16	84.8 ± 7.5
igh	19	42	27.8 ± 1.3	30.8 ± 3.4	81	154 ± 9	55.2 ± 4.3
ine	24	27	25.4 ± 1.4	30.2 ± 4.1	17	263 ± 32	49.8 ± 8.5
		106	26.3 ± 0.8	30.0 ± 2.1	162	165 ± 9	69.0 ± 3.8
	13	33	27.3 ± 1.1	15.4 ± 2.6	63	102 ± 7	55.4 ± 4.9
ow	25	18	29.3 ± 0.9	19.3 ± 2.4	65	131 ± 13	78.4 ± 6.9
ine	26	73	29.8 ± 0.9	25.1 ± 2.1	121	145 ± 9	67.2 ± 4.3
		124	24.8 ± 0.6	22.7 ± 1.4	249	130 ± 6	70.6 ± 3.2

line thyroids averaged 26.3 ± 0.8 milligrams while those of the low line averaged 28.8 ± 0.6 milligrams. The data in the right half of the table represent the thiouracil fed full sibs and were presented previously in Table 10. It will be noted that for sire family averages within each line the negative relationship between types of rations does not hold, and within the low line there is a direct positive correlation between thyroid size of birds on thiouracil and those on control rations.

Table 31 shows that the difference between lines is not

TABLE 31. Analysis of variance of thyroid gland weights of untreated and thiouracil treated chicks in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

Source of variation	Degrees of freedom	Mean square
Total	229	
Between sexes	1	152
Between hatches	1	699**
Between lines	1	414
Among sires w/in lines	4	84
Among dams w/in sires	28	89**
Error	194	43

significant, and the evidence presented here is not sufficient to justify any conclusions regarding thyroid weight and function. Thus, this problem, about which there is so much confusion in the literature, remains unsolved. It will be noted that here, as in thiouracil fed birds, environmental conditions are important as shown by the highly significant difference between hatches.

RELATIONSHIP TO ECONOMIC CHARACTERISTICS

Sexual Maturity

Very few data on sexual maturity were collected during this investigation. The first indications of a difference in sexual maturity of the two lines occurred when a few pullet offspring from the high and low lines selected by El-Ibiary and Shaffner (1950) were raised in batteries late in 1950. Only four pullets from the high line and three from the low line were available for this study. The data are presented in Table 32. The low line averaged seven days less than the high line in age at first egg. It should be noted that two of the low line

TABLE 32. Age at first egg of progeny of high and low lines selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Pullet	Sexual Maturity (days)	Pullet	Sexual maturity (days)
A 6	149	A 3	158
A 11	155	A 5	[illegible]
A 12	149	A 22	136
A 14	170		
	156		149

pullets, A3 and A5, were penalized by not receiving the benefit of lights until they were 149 days old. All other birds were 131 days of age when lights were applied. Thus, it is reasonable to assume that the difference between lines would have been greater if lights had been applied to all birds at the same age. However, the number of pullets was quite small, and the difference between lines was not significant.

No sexual maturity data were obtained for the pullets hatched in the spring of 1951. The difference referred to in the previous paragraph was not confirmed by the pullets hatched in the spring of 1952. The data are presented in Tables 33 and 34 as the ages at which the first egg was recorded. However, egg production records were not obtained until pullets from the two hatches were 185 and 172 days of age, respectively, and many of the birds had already been in production for some time. Thus, these data are more indicative of late sexual maturity than of early sexual maturity. The data in the tables are averages for the two hatches. In Experiment A, shown in Table 33, the average age at which the first egg was recorded was 183 days and was the same in both lines. In

TABLE 33. Modified estimate of age at sexual maturity of untreated pullets in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Sexual maturity (days)	Pen	No. of pullets	Sexual maturity (days)
12	9	185	13	18	179
19	14	182	25	13	182
24	16	184	26	13	188
	39	183		44	183

TABLE 34. Modified estimate of age at sexual maturity of untreated pullets in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Sexual maturity (days)	Pen	No. of pullets	Sexual maturity (days)
22	14	182	20	14	200
23	11	192	21	11	190
	25	186		25	196

Experiment B, shown in Table 34, the high line averaged 186 days compared to 196 days to maturity for the low line. The difference was in favor of the high line, but this difference was not significant.

Although the literature contains evidence that sexual maturity may be affected by differences in thyroid activity, these data provide no consistent evidence for a difference in sexual maturity between the two lines.

Egg Production

The egg production of the New Hampshire pullets which produced the unselected population of Experiment A in 1950-1951 was recorded for the period from December 1950 to June 1951. The average percent production for each of the six pens is given in Table 35.

TABLE 35. Percent egg production of untreated pullets in the unselected population.

Pen	No. of pullets	Production (%)
8	8	59.9
9	7	55.1
10	7	60.8
11	7	41.3
12	8	51.5
13	8	42.6
	45	51.8

After one generation of selection for thyroid response to thiouracil, the high line averaged 56.1 percent egg production whereas the low line averaged 53.7 percent as shown in Table 36. The difference between lines was not significant. The period of egg production was somewhat different from that of the unselected population, having been recorded during the period from October 1951 to May 1952.

After two generations of selection the low line was found to be superior to the high line in egg production as shown in Table 37. Egg production was recorded from August 1952 to February 1953. In this case, the high line averaged 43.0 percent and the low line 53.0 percent production, but the difference between lines was not significant.

TABLE 36. Egg production of untreated pullets in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Production (%)	Pen	No. of pullets	Production (%)
9	10	56.2	10	11	51.5
14	14	54.1	11	13	57.5
19	9	58.0	13	11	52.1
	33	56.1		35	53.7

TABLE 37. Egg production of untreated pullets in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Production (%)	Pen	No. of pullets	Production (%)
12	9	39.4	13	16	59.4
19	14	41.8	25	13	54.9
24	16	47.8	26	13	44.7
	39	43.0		42	53.0

The egg production in experiment A during this period of selection is presented graphically in Figure 7.

The data on egg production of the pullets selected by El-Ibiary and Shaffner (1950) are very few and are given in Table 38. The production of the high line during July 1950 was 39.1 percent compared with 30.4 percent for the low line,

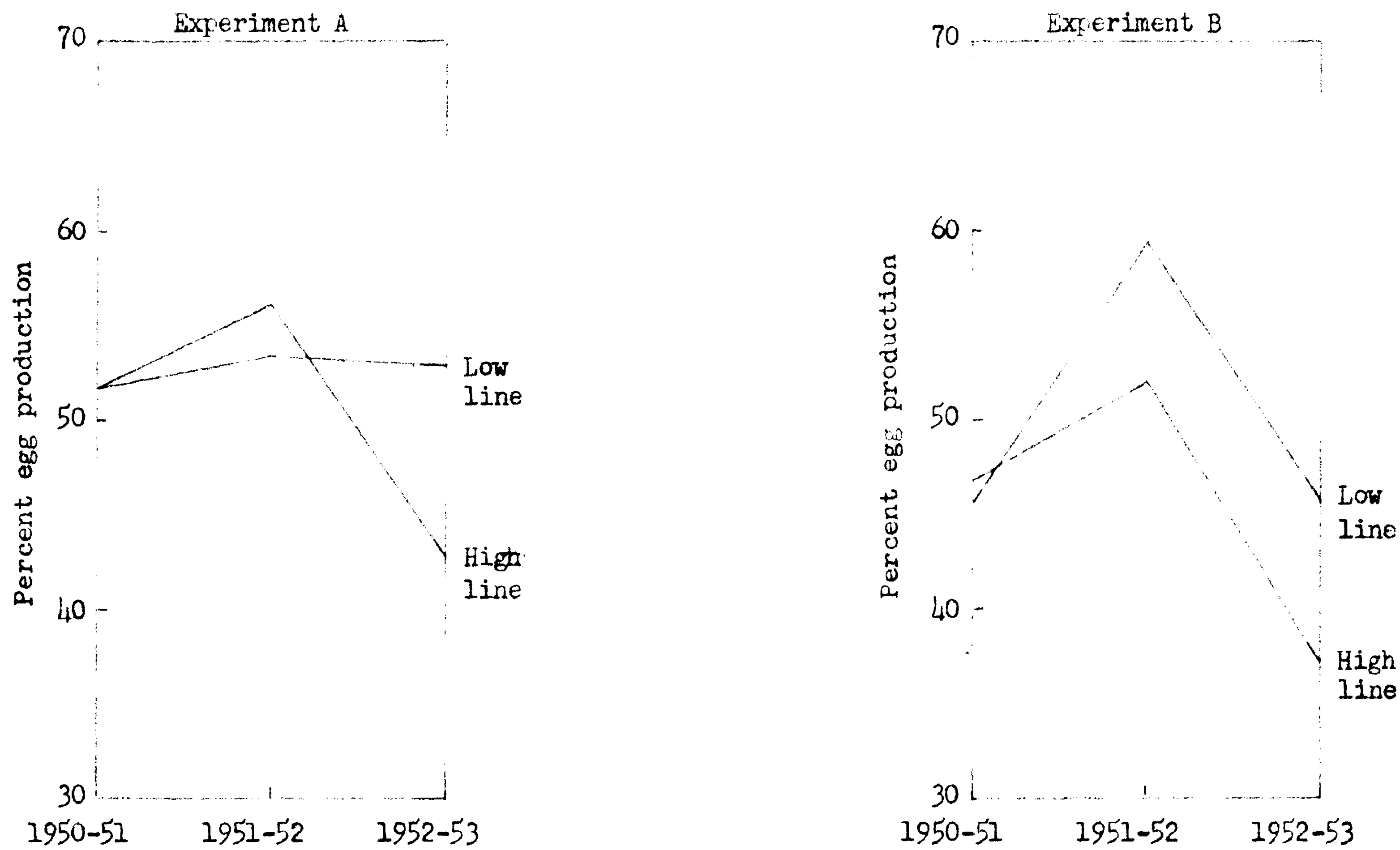

Figure 7. Egg production of pullets selected for high and low thyroid weight response to thiouracil.

TABLE 38. Egg production of high and low lines selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Hen	Production (%)	Hen	Production (%)
633	60.9	632	39.1
617	21.7	629	21.7
630	34.8	634	30.4
	39.1		30.4

but the number of pullets was quite small and the difference between lines was not significant.

The egg production of female progeny of the pullets described in Table 38 is presented in Table 39. The egg production from

TABLE 39. Egg production of progeny of high and low lines selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Hen	Production (%)	Hen	Production (%)
A 6	60.6	A 3	26.0
A11	12.5	A 5	43.3
A12	51.9	A22	47.1
A14	42.3		
	41.8		38.8

January to April of 1951 was 3.0 percent higher in the high line than in the low line. Again the number of pullets was small and the difference between lines was not significant. Other than these pullets, Experiment B had no egg production data for

1950-1951 since most of the pullets were the same as reported in Table 35.

After approximately two generations of selection for thyroid response to thiouracil in Experiment B, the egg production of high line pullets averaged 52.2 percent for the months of January, April and May 1952 as shown in Table 40, while that of low line

TABLE 40. Egg production of untreated pullets in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High Line			Low line		
Pen	No. of pullets	Production (%)	Pen	No. of pullets	Production (%)
22	11	58.5	20	13	60.6
23	12	45.8	21	14	57.6
	23	52.2		27	59.1

pullets was 59.1 percent. The difference between lines was not significant.

Table 41 shows that after approximately three generations of selection, the low line was again superior to the high line, with averages of 45.8 and 37.3 percent production, respectively. The situation is shown graphically in Figure 7. Evidence in the literature indicates that egg production may be affected by differences in thyroid activity. However, in no case was the

TABLE 41. Egg production of untreated pullets in Experiment B after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Production (%)	Pen	No. of pullets	Production (%)
22	14	37.5	20	15	40.7
23	12	37.2	21	12	50.8
	26	37.3		27	45.8

difference between lines significant in percent egg production, and the evidence presented here is not sufficient to justify concluding that the low line had greater egg production than the high line.

Fertility

The fertility was not recorded for the original population, but in Experiment A the percent fertility was slightly higher in the low line than in the high line after one generation of selection for thyroid response to thiouracil. The high line averaged 92.5 percent fertility while the low line averaged 95.4 percent as shown in Table 42. However, in the following generation the high line had slightly better fertility than the low line with 93.8 percent and 92.8 percent fertility, respectively, as shown in Table 43. In neither case was the difference between lines significant. These results are shown graphically in Figure 8.

TABLE 42. Fertility in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Fertility (%)	Pen	No. of pullets	Fertility (%)
12	14	96.8	13	10	97.0
19	9	97.0	25	9	98.5
24	10	79.5	26	13	93.2
	33	92.5		32	95.4

TABLE 43. Fertility in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Fertility (%)	Pen	No. of pullets	Fertility (%)
12	6	91.9	13	16	92.5
19	11	92.5	25	13	93.3
24	11	97.1	26	10	92.7
	28	93.8		39	92.8

In Experiment B, the fertility of the high line seemed to be superior to that of the low line in most cases. However, among the six females selected by El-Ibiary and Shaffner (1950) the high line pullets averaged only 41.3 percent fertility compared to 50.5 percent for the low line under conditions of artificial insemination. These results are presented in Table 44. Among the seven female progeny of these birds, the high line averaged 92.5 percent fertility while the low line averaged

TABLE 44. Fertility of eggs laid by high and low line pullets selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Hen	Fertility (%)	Hen	Fertility (%)
633	48.8	632	41.6
617	16.7	629	100.0
630	58.4	634	10.0
	41.3		50.5

70.6 percent as shown in Table 45.

TABLE 45. Fertility of eggs laid by progeny of high and low line birds selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Hen	Fertility (%)	Hen	Fertility (%)
A 6	97.8	A 3	73.7
A11	50.0	A 5	89.7
A12	97.4	A22	54.1
A14	90.0		
	92.5		70.6

The same trend held true when full brothers of the pullets described in Table 45 were used in matings with unselected pullets. Table 46 shows the high line males produced 95.8 percent fertility while the low line males were able to produce only 92.2percent fertility. In the following generation the average fertility of the high line was 81.9 percent and of the lowline was 73.8 percent. These data are shown in Table 47.

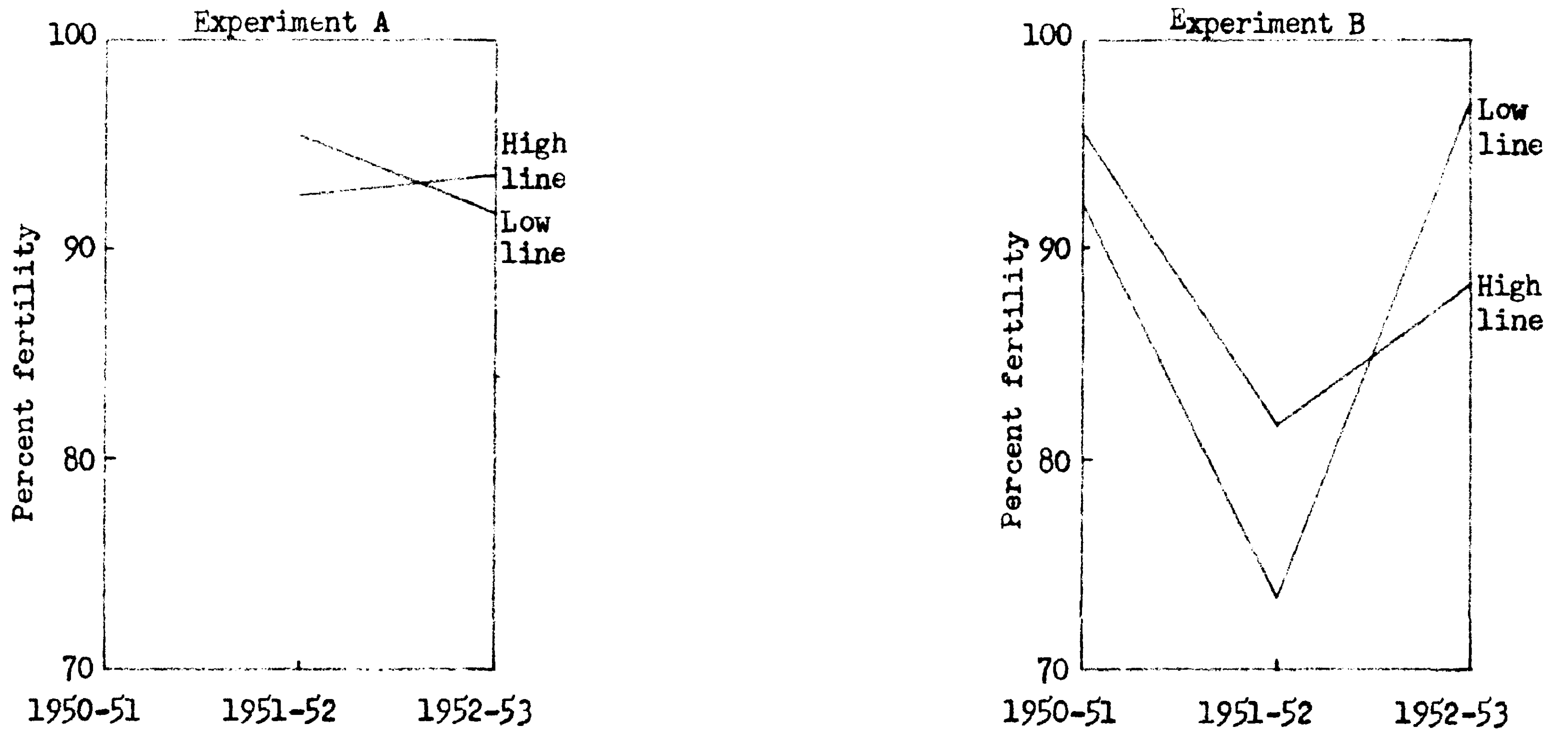

Figure 8. Fertility of birds selected for high and low thyroid weight response to thiouracil.

TABLE 46. Fertility when high and low line males were mated to unselected females.

High line			Low line		
Pen	No. of pullets	Fertility (%)	Pen	No. of pullets	Fertility (%)
10	7	91.6	8	7	93.1
11	7	100.0	9	6	91.2
	14	95.8		13	92.2

TABLE 47. Fertility in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Fertility (%)	Pen	No. of pullets	Fertility (%)
22	11	68.5	20	13	49.1
23	12	95.3	21	14	98.4
	23	81.9		27	73.8

However, after approximately three generations of selection, this trend was reversed as shown in Table 48. The high line averaged only 88.6 percent while the low line averaged 97.6 percent. The results are shown graphically in Figure 8. The literature contains evidence that differences in thyroid activity may affect fertility in chickens. However, it must be concluded that there were no consistent differences in fertility between high and low lines in the present experiments.

TABLE 48. Fertility in Experiment B after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Fertility (%)	Pen	No. of pullets	Fertility (%)
22	12	82.1	20	9	96.0
23	11	95.1	21	7	99.3
	23	88.6		16	97.6

Hatchability

Hatchability of fertile eggs was not recorded separately for Experiment A in the original population, but after one generation of selection the low line had better hatchability with 95.0 percent than the high line with 90.4 percent. The data are presented in Table 49. After two generations of

TABLE 49. Hatchability of fertile eggs in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Hatchability (%)	Pen	No. of pullets	Hatchability (%)
12	14	86.8	13	10	92.5
19	9	93.1	25	10	97.1
24	10	91.2	26	13	95.6
	33	90.4		33	95.0

selection the hatchability was again better in the low line than in the high line. This is shown in Table 50, and the low line had a hatchability of 91.9 percent of fertile eggs compared to 84.8 percent for the high line. These results are shown graphically in Figure 9.

TABLE 50. Hatchability of fertile eggs in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Hatchability (%)	Pen	No. of pullets	Hatchability (%)
12	6	76.5	13	16	93.9
19	12	90.4	25	13	87.6
24	13	87.5	26	12	94.3
	31	84.8		41	91.9

In Experiment B, the high line was usually superior to the low line in hatchability of fertile eggs until the last year when the trend was reversed. However, among the six females selected by El-Ibiary and Shaffner (1950) the low line pullets produced a hatchability of 100 percent compared with 66.7 percent for the high line, as shown in Table 51. The hatchability of the female progeny of these birds is shown in Table 52. In this case the high line had a hatchability of 66.1 percent compared with 53.3 percent for the low line.

TABLE 51. Hatchability of fertile eggs laid by high and low line pullets selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Hen	Hatchability (%)	Hen	Hatchability (%)
633	100.0	632	100.0
617	0.0	629	100.0
630	100.0	634	100.0
	66.7		100.0

TABLE 52. Hatchability of fertile eggs of progeny of high and low line birds selected by El-Ibiary and Shaffner (1950).

High line		Low line	
Hen	Hatchability (%)	Hen	Hatchability (%)
A 6	75.6	A 3	85.7
A11	100.0	A 5	65.4
A12	59.5	A22	15.0
A14	51.9		
	66.1		53.3

When full brothers of the females described in Table 52 were mated to unselected pullets the results were as shown in Table 53. The high line had greater hatchability with 94.9 percent of fertile eggs compared to 86.0 percent for the low line. The following year, after approximately two generations of selection for thyroid response to thiouracil, the high line was again superior to the low line in hatchability of fertile eggs. The results are shown in Table 54, and the high line produced a hatchability of 94.9 percent of fertile eggs compared

TABLE 53. Hatchability of fertile eggs when high and low line males were mated to unselected females.

High line			Low line		
Pen	No. of pullets	Hatchability (%)	Pen	No. of pullets	Hatchability (%)
10	7	96.0	8	7	86.9
11	7	93.8	9	6	85.1
	14	94.9		13	86.0

TABLE 54. Hatchability of fertile eggs in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Hatchability (%)	Pen	No. of pullets	Hatchability (%)
22	11	98.4	20	13	60.3
23	12	91.5	21	14	96.7
	23	94.9		27	78.6

to 78.6 percent for the low line. However, in the 1952-1953 season shown in Table 55, this trend was reversed and the low line had 84.9 percent hatchability compared to 67.2 percent for the high line. These results are shown graphically in Figure 9. Although there is evidence in the literature that differences in thyroid activity may influence hatchability, it must be concluded that no consistent results were produced.

TABLE 55. Hatchability of fertile eggs in Experiment B after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Hatchability (%)	Pen	No. of pullets	Hatchability (%)
22	12	70.9	20	9	80.8
23	11	[illegible].6	21	7	89.0
	23	67.2		16	84.9

in the present experiments concerning hatchability of fertile eggs.

Incubation Period

The first indication that the high and low lines might differ in length of incubation period occurred during the 1951-1952 hatching season. Normally, the chicks were removed from the incubator on the 22nd day of incubation, at which time practically all those which were strong enough to do so had emerged from the shell. However, during the second replacement hatch of this season it was decided to remove the chicks on the 21st day of incubation. This was done, but a large number of eggs remained unhatched. These eggs were left in the incubator until the next day, at which time several more chicks had hatched. The results of Experiment A are presented in Table 56. It will be noted that 23.2 percent of

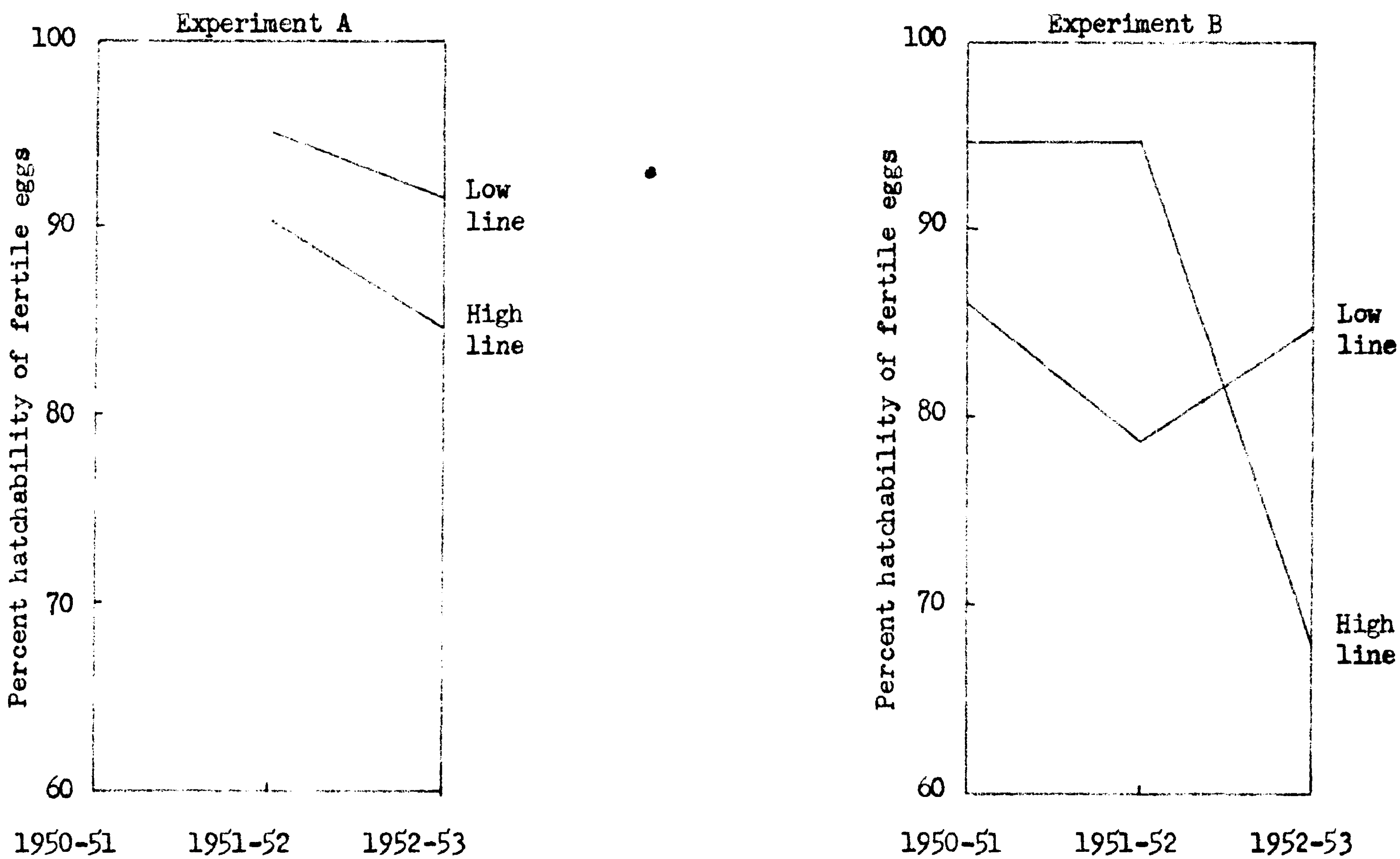

Figure 9. Hatchability of fertile eggs of birds selected for high and low thyroid weight response to thiouracil.

TABLE 56. Percent of chicks which hatched at 21 and 22 days of incubation after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	Incubation period		Sire	Incubation period	
	21 days	22 days		21 days	22 days
12	54.9	26.5	13	68.4	10.5
19	89.1	7.3	25	72.7	12.1
24	58.9	35.7	26	88.8	9.9
	67.6	23.2		76.6	10.8

the high line chicks hatched late, whereas only 10.8 percent of the low line chicks were late in hatching. In Experiment B the results were even more extreme as shown in Table 57. In the

TABLE 57. Percent of chicks which hatched at 21 and 22 days of incubation after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	Incubation period		Sire	Incubation period	
	21 days	22 days		21 days	22 days
22	74.6	23.8	20	50.9	9.4
23	67.1	24.4	21	92.6	4.1
	70.8	24.1		71.8	6.8

high line 24.1 percent of the chicks hatched late while only 6.8 percent of the low line chicks were late.

In order to investigate this point further, an experiment was designed the following season to measure the extent to which the low line hatched earlier than the high line. The chicks which had hatched completely were counted at six hour intervals during the hatching process, and the results are given in Table 58 for Experiment A and in Table 59 for Experiment

TABLE 58. Incubation period in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line		Low line	
Sire	Incubation period (days)	Sire	Incubation period (days)
12	21.20	13	21.26
19	21.17	25	21.48
24	21.34	26	21.29
	21.26		21.32

B. In Experiment A the incubation period of the high line was actually less than that of the low line with 21.26 and 21.32 days, respectively. These results were incompatible with the theory that the low line was earlier hatching than the high line. In Experiment B the low line hatched slightly earlier than the high line with 21.38 and 21.58 days, respectively. The difference between lines was not significant.

Experiments reported in the literature indicate that length of incubation period is increased by both hypothyroidism and hyperthyroidism in the dams.

The evidence presented here does not justify a conclusion that the high and low lines differ in length of incubation period. However, no chicks from unselected stock were included in this investigation and it is not known whether the incubation period was normal, or was perhaps retarded to the same extent in both lines.

TABLE 59. Incubation period in Experiment B after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line		Low line	
Sire	Incubation period (days)	Sire	Incubation period (days)
22	21.61	20	21.52
23	21.55	21	21.26
	21.58		21.39

Body Weight

Body weights were taken at four weeks of age on all birds assayed for thyroid weight response to thiouracil. For the unselected population the results are presented in Table 60, the average body weight being 205 grams. The analysis of variance is given in Table 61. The differences among hatches, sexes, sires, and dams within sires were all highly significant. Only the differences among battery tiers were not significant. This is interesting in view of the fact that the thyroid glands removed from the same bird at the same age exhibited highly significant differences among battery tiers.

TABLE 60. Four week body weights of thiouracil treated chicks in the unselected population.

Sire	No. of chicks	Body wt. (gm.)
8	100	229
9	59	210
10	101	212
11	60	205
12	83	193
13	68	170
	471	205

TABLE 61. Analysis of variance of four week weights of thiouracil treated chicks in the unselected population.

Source of variation	Degrees of freedom	Mean square
Total	470	
Between sexes	1	13,184**
Among hatches	2	39,900**
Among battery tiers	3	981
Among sires	5	31,905**
Among dams w/in sires	31	2,219**
Error	428	648

An analysis of covariance between body weight and thyroid weight at four weeks of age is given in Table 62. This technique allows the comparison of the various effects on one variable with the other variable held constant. In this case, with thyroid weight held constant, body weight was still found to be significantly affected by different hatches, sires, and dams within sires. However, the mean square for between sexes was almost reduced to zero by this treatment. The correlation coefficient between thyroid weight and body weight was + 0.3284 which was highly significant.

TABLE 62. Analysis of covariance between thyroid weight and body weight at four weeks of age of thiouracil treated chicks in the unselected population.

Source of variation	Degrees of freedom	Errors of estimate Mean square
Total	469	
Between sexes	1	1
Among hatches	2	35,452**
Among battery tiers	3	745
Among sires	5	17,607**
Among dams w/in sires	31	2,621**
Error	427	710

In view of the highly significant positive correlation between thyroid weight and body weight on a thiouracil ration it would be expected that selection for high and low thyroid response to thiouracil would result in correspondingly raising and lowering the four week body weights. In fact, this result was obtained in Experiment A. After one generation of selection the high line averaged 223 grams compared to 205 grams for the low line as shown in Table 63. In the following generation

TABLE 63. Four week body weights of thiouracil treated chicks in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Body wt.(gm.)	Sire	No. of chicks	Body wt.(gm.)
12	64	218	13	63	206
19	81	228	25	65	200
24	17	224	26	121	208
	162	223		249	205

the high line averaged 193 grams and the low line 160, as shown in Table 64. These results are shown graphically in Figure 10.

TABLE 64. Four week body weights of thiouracil treated chicks in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Body wt.(gm.)	Sire	No. of chicks	Body wt.(gm.)
12	28	200	13	107	168
19	58	190	25	49	150
24	49	189	26	61	162
	135	193		217	160

However, the fact that this trend does not necessarily follow is demonstrated by Experiment B. The high line averaged 220 grams compared to 218 grams when male progeny of the birds selected by El-Ibiary and Shaffner (1950) were mated to unselected females as shown in Table 65. The following generation the high line was again slightly heavier than the low line at four weeks of age with averages of 202 and 196 grams respectively as shown in Table 66. However, after approximately three generations of selection the high line weighed slightly less than the low line with average weights of 166 and 172 grams respectively, as shown in Table 67. These results are summarized graphically in Figure 10. The four week body weights showed no consistent

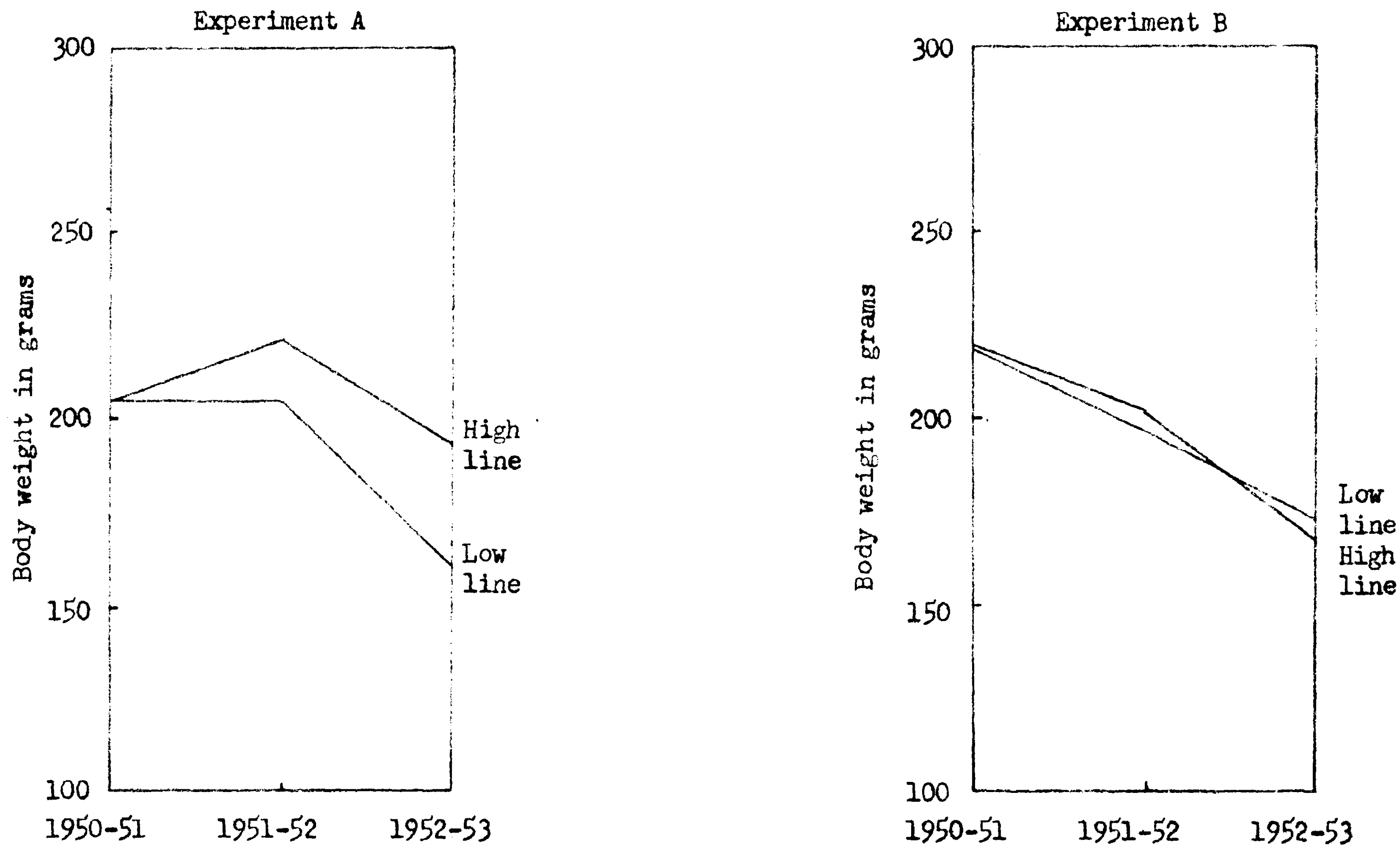

Figure 10. Four week body weights of chicks selected for high and low thyroid weight response to thiouracil.

TABLE 65. Four week body weights of thiouracil treated chicks in Experiment B when male progeny of birds selected by El-Ibiary and Shaffner (1950) were mated to unselected females.

High line			Low line		
Sire	No. of chicks	Body wt. (gm.)	Sire	No. of chicks	Body wt. (gm.)
10	107	215	8	105	217
11	54	224	9	70	220
	161	220		175	218

TABLE 66. Four week body weights of thiouracil treated chicks in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Body wt.(gm.)	Sire	No. of chicks	Body wt.(gm.)
22	75	220	20	57	197
23	72	185	21	147	195
	147	202		204	196

differences between the high and low lines.

In the winter of 1951 a broiler experiment was conducted using one hatch of the high and low lines. At ten weeks of age the chicks were weighed and sexed. The results presented in Table 68 show that the high line chicks were somewhat heaver than the low line chicks. High line males weighed 1204 grams compared to 1177 grams for low line males. Female weights were 981 and 967 grams for the high and low lines, respectively. However, the difference between linex was not

TABLE 67. Four week body weights of thiouracil treated chicks in Experiment D after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Body wt. (gm.)	Sire	No. of chicks	Body wt. (gm.)
22	23	161	20	56	180
23	24	172	21	77	165
	47	166		133	172

TABLE 68. Ten week body weights of untreated birds in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line					Low line				
Sire	Body weight (gm.)				Sire	Body weight (gm.)			
	Males		Females			Males		Females	
	No.	wt.	No.	wt.		No.	wt.	No.	wt.
12	39	1240	42	1003	13	25	1156	34	1010
19	29	1150	30	950	25	34	1189	26	965
24	4	1254	7	989	26	61	1179	41	936
	72	1204	79	981		120	1177	101	967

significant.

Three months later, 10 week body weights of the two replacement hatches of Experiment A were recorded and are presented in Table 69. These chicks were full sibs of those described in Table 68. High line males weighed 1118 grams

TABLE 69. Ten week body weights of untreated birds in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line					Low line				
	Body weight (gm.)					Body weight (gm.)			
Sire	Males		Females		Sire	Males		Females	
	No.	wt.	No.	wt.		No.	wt.	No.	wt.
12	72	1172	59	955	13	47	1222	47	992
19	27	1040	28	884	25	31	1135	19	918
24	51	1143	43	902	26	86	1219	79	950
	150	1118	130	914		164	1192	145	953

and low line males weighed 1192 grams, whereas females of the high and low lines weighed 914 and 953 grams, respectively. In this case the low line birds were somewhat larger than those from the high line. This may be the result of an outbreak of Newcastle disease which occurred when these birds were two to four weeks of age. As will be noted later, the high line chicks were more severely affected than the low line chicks, and the deleterious effects may have persisted to affect 10 week body weight.

In Experiment B the low line chicks were again superior to the high line chicks in 10 week body weight, as shown in Table 70. These birds had also been affected by Newcastle disease at the same time as those of Experiment A. However the differences between lines were not significant in either

TABLE 70. Ten week body weights of untreated birds in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line					Low line				
	Body weight (gm.)					Body weight (gm.)			
Sire	Males		Females		Sire	Males		Females	
	No.	wt.	No.	wt.		No.	wt.	No.	wt.
22	52	1021	49	846	20	49	1061	38	876
23	57	946	51	705	21	104	1068	106	834
	109	984	100	776		153	1064	144	855

experiment.

It must be concluded that no consistent difference in 10 body weight existed between the two lines.

The pullets of Experiment A hatched in the spring of 1951 after one generation of selection were weighed at approximately 20 weeks of age to get a measure of the adult body weight. The results are presented in Table 71, and

TABLE 71. Adult body weights of untreated pullets in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Body wt. (gm.)	Pen	No. of pullets	Body wt. (gm.)
12	10	2497	13	8	2665
19	7	2638	25	3	2306
24	9	2729	26	12	2574
	26	2615		23	2570

the high line had a slight advantage over the low line in adult body weight with an average of 2620 grams compared to 2515 grams for the low line.

In the spring of 1952 after two generations of selection the high line pullets of Experiment A again weighed somewhat more than those of the low line with averages of 2415 and 2356 grams, respectively, as shown in Table 72.

TABLE 72. Adult body weights of untreated pullets in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Body wt.(gm.)	Pen	No. of pullets	Body wt.(gm.)
12	10	2438	13	17	2597
19	14	2465	25	13	2388
24	15	2356	26	14	2193
	39	2415		44	2356

In neither year were the differences between lines significant.

In Experiment B after approximately two generations of selection the low line pullets were slightly heavier than the high line pullets with weights of 2252 and 2188 grams, respectively, as shown in Table 73. However, the following year pullets of the high line exceeded those of the low line in adult body weight, as shown in Table 74. The average

TABLE 73. Adult body weights of untreated pullets in Experiment B after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Body wt. (gm.)	Pen	No. of pullets	Body wt. (gm.)
22	12	2302	20	13	2438
23	12	2079	21	14	1957
	24	2188		27	2252

TABLE 74. Adult body weights of untreated pullets in Experiment B after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Body wt. (gm.)	Pen	No. of pullets	Body wt. (gm.)
22	15	2102	20	15	2084
23	14	2088	21	12	1748
	29	2097		27	1934

weight of high line pullets was 2097 grams compared to 1934 grams for the low line.

In all cases, the differences between lines were small, and these data do not furnish convincing evidence of a difference between lines with regard to adult body weight. The evidence in the literature indicates that body weight may be affected by thyroid activity. However, in spite of a highly significant positive correlation between thyroid weight and body weight at four weeks of age, the evidence is not consistent enough to justify concluding that the high and low lines differ in body weight at four weeks of age, 10 weeks of age, or at maturity.

Rate of Feathering

An estimate of the rate of feathering of Experiment A was obtained after two generations of selection for high and low thyroid response to thiouracil by removing the longest feather from the tail of the four week old bird and measuring the feather from one extreme to the other. Tail feathers of the high line were longer than those of the low line, being 3.57 and 2.52 centimeters, respectively, as shown in Table 75.

TABLE 75. Tail feather lengths of thiouracil treated chicks in Experiment A at four weeks of age after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Feather length (cm.)	Sire	No. of chicks	Feather length (cm.)
12	28	3.42	13	107	3.10
19	58	3.31	25	49	3.11
24	49	3.96	26	61	1.01
	135	3.57		217	2.52

The difference between the two lines was not significant.

In Experiment B an estimate of feathering was obtained two different years. In the 1951-1952 season, after approximately two generations of selection for high and low thyroid response to thiouracil, this estimate was obtained by measuring the longest tail feathers without removing them from the bird. The measurement was taken by placing one end of the rule at the tip of the pygostyle and recording the measurement at the tip of the longest feather. These results are given in Table 76. The high line

TABLE 76. Tail feather length of thiouracil treated chicks in Experiment B at four weeks of age after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Feather length (cm.)	Sire	No. of chicks	Feather length (cm.)
22	75	3.60	20	57	2.38
23	72	3.14	21	147	2.69
	147	3.38		204	2.60

again had the longest feathers with averages of 3.38 centimeters compared to 2.60 centimeters for the low line but the difference was not significant. The following year, after approximately three generations of selection, the feather lengths were taken after the feathers had been removed from the chicks and the results are shown in Table 77. The high

TABLE 77. Tail feather lengths of thiouracil treated chicks in Experiment B at four weeks of age after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Feather length (cm.)	Sire	No. of chicks	Feather length (cm.)
22	23	3.30	20	56	3.38
23	24	3.66	21	77	3.21
	47	3.49		133	3.28

line again had longer tail feathers than the low line with averages of 3.49 and 3.28 centimeters, respectively. Again, the difference between lines was not significant.

At first glance it would seem that the high line definitely had longer tail feathers at four weeks of age than the low line. However, in the last generation of Experiment B when the thyroid gland weight of the high line was almost five times greater than that of the low line, the tail feather lengthx were practically the same. Therefore, it must be concluded that selection for high and low thyroid weight response to thiouracil had no consistent effect on tail feather length.

Disease Resistance

During the spring of 1952 an opportunity to study the relationship between thyroid activity and resistance to

Newcastle disease presented itself when an outbreak of this disease occurred in the University of Maryland poultry flock. Two hatches of replacement chicks from the high and low response lines were two and four weeks of age, respectively, when the disease outbreak occurred. The high response line was represented by 606 chicks and the low response line by 666 chicks. The usual symptoms of Newcastle disease were noted such as the wave of mortality, paralysis, etc. Furthermore, several of the affected chicks were examined by the pathological service of the University of Maryland, and the causative agent of Newcastle disease was found to be present.

The mortality percentages of both hatches of the two lines of Experiment A are presented in Table 78. The pooled

TABLE 78. Mortality of untreated chicks in Experiment A following an outbreak of Newcastle disease after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
12	157	15.9	13	97	3.1
19	88	36.4	25	59	15.3
24	106	11.3	26	177	6.2
	351	21.2		333	8.2

mortality for both hatches was 21.2 percent for the high line and 8.2 percent for the low line.

In Experiment B the low line again had less mortality than the high line as shown in Table 79. The mortality of

TABLE 79. Mortality of untreated chicks in Experiment B following an outbreak of Newcastle disease after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
22	122	16.4	20	99	11.1
23	133	17.3	21	234	9.8
	255	16.8		333	10.4

the high line was 16.8 compared to 10.4 for the low line. In neither experiment was the difference between lines significant, nor were the differences between lines significant when the results for the two experiments were pooled. Thus, although these results suggest that the low line is more resistant to Newcastle disease than the high line, the evidence is not sufficient to justify such conclusions. In fact, if resistance to Newcastle disease were closely related to thyroid response to thiouracil, one would expect wider differences between lines in Experiment B than in Experiment A, but the reverse was true. More research on this point would be desirable since the literature contains evidence that disease resistance may be affected by differences in thyroid activity.

Mortality

Mortality data of chicks from the unselected population reared to four weeks of age on thiouracil as 0.2 percent of the ration are presented in Table 80. The average mortality

TABLE 80. Mortality of thiouracil treated chicks in the unselected population to four weeks of age.

Sire	No. of chicks	Mortality (%)
8	105	4.76
9	62	4.84
10	103	1.94
11	66	9.09
12	88	5.68
13	69	1.45
	493	4.63

was 4.63 percent. After one generation of selection in Experiment A the mortality of the high line was zero while that of the low line was 0.47 percent as shown in Table 81.

TABLE 81. Mortality of thiouracil treated chicks in Experiment A to four weeks of age after one generation of selection.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
12	64	0.00	13	64	0.90
19	81	0.00	25	65	0.00
24	17	0.00	26	122	0.50
	162	0.00		251	0.47

The low line continued with the highest mortality the next generation with 7.71 percent compared to 1.23 percent for the high line as shown in Table 82. This is also shown

TABLE 82. Mortality of thiouracil treated chicks in Experiment A to four weeks of age after two generations of selection.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
12	28	0.00	13	112	4.46
19	59	1.69	25	58	15.51
24	50	2.00	26	63	3.17
	137	1.23		233	7.71

graphically in Figure 11.

In Experiment B the situation was reversed in the early generations. At first the chicks sired by male progeny of birds selected by El-Ibiary and Shaffner (1950) suffered mortality of 10.42 percent for the high line and 4.54 percent for the low line as shown in Table 83. The next year after approximately two generations of selection the high line had a mortality of 0,66 percent compared to 0.34 percent for the low line shown in Table 84. After approximately three generations of selection the situation was reversed, as shown in Table 85, being 6.80 percent for the high line and 9.45 percent for the low line. The results are shown graphically

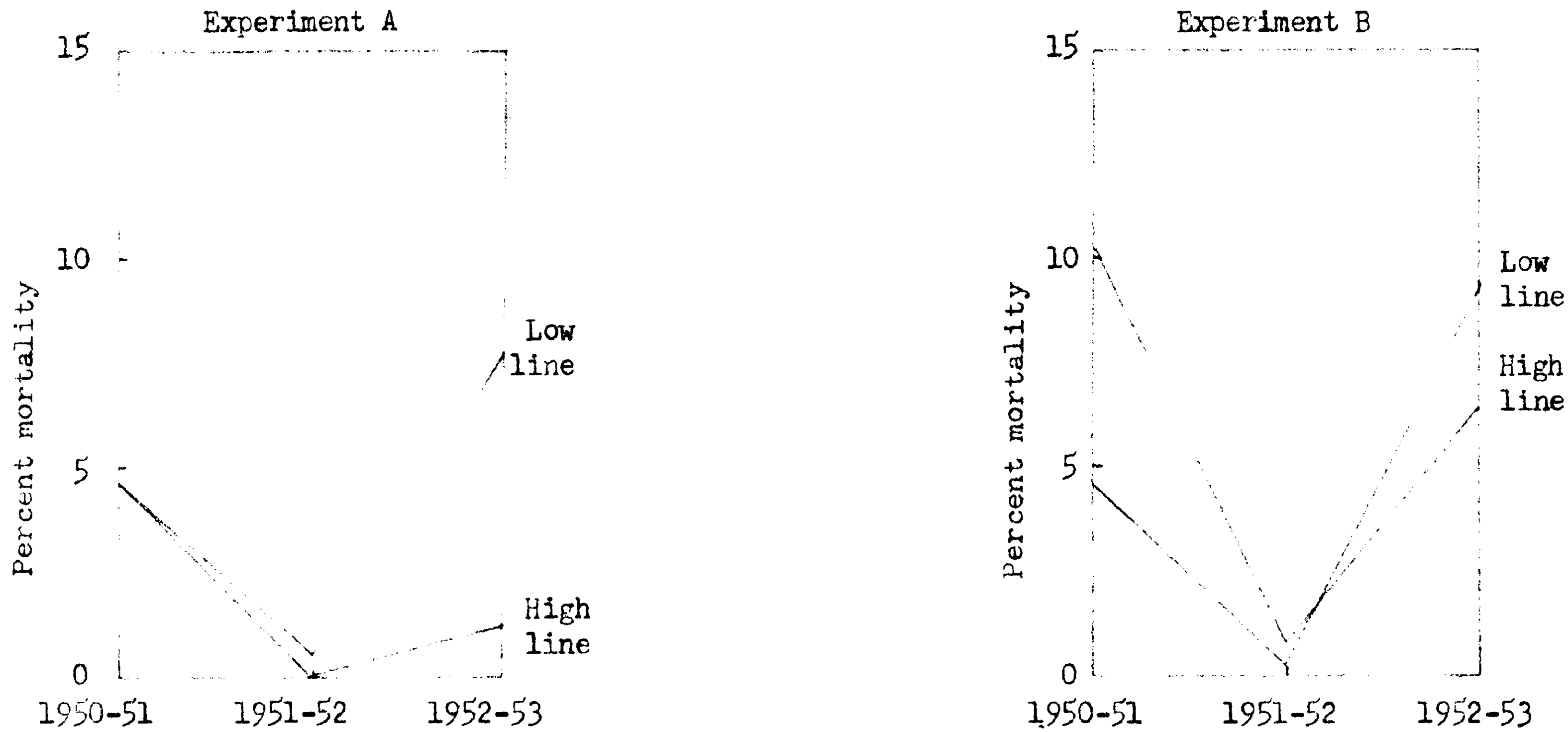

Figure 11. Mortality to four weeks of age in chicks selected for high and low thyroid weight response to thiouracil.

TABLE 83. Mortality of thiouracil treated chicks in Experiment B to four weeks of age after approximately one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
10	120	10.83	8	105	0.00
11	60	10.00	9	77	9.09
	180	10.42		182	4.54

TABLE 84. Mortality of thiouracil treated chicks in Experiment B to four weeks of age after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
22	76	1.32	20	57	0.00
23	72	0.00	21	148	0.68
	148	0.66		205	0.34

in Figure 11.

No consistent differences between the two lines was found regarding mortality to four weeks of age on a ration containing thiouracil as 0.2 percent by weight.

TABLE 85. Mortality of thiouracil treated chicks in Experiment B to four weeks of age after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of chicks	Mortality (%)	Sire	No. of chicks	Mortality (%)
22	26	11.53	20	66	15.15
23	48	2.08	21	80	3.75
	74	6.80		146	9.45

Accumulative mortality to 10 weeks of age was obtained during the broiler experiment during the spring of 1951 referred to previously in the body weight investigations. These data are presented in Table 86. The high line had

TABLE 86. Mortality of untreated chicks in Experiment A to 10 weeks of age after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of birds	Mortality (%)	Sire	No. of birds	Mortality (%)
12	85	4.7	13	63	6.4
19	61	3.3	25	62	4.8
24	13	23.1	26	110	7.3
	159	10.4		235	6.2

higher mortality with 10.4 percent than the low line with 6.2 percent but the difference was not significant. A short time later two additional hatches were checked at 10 weeks of age with the results noted in Table 87. The mortality of the

TABLE 87. Mortality of untreated chicks in Experiment A, to 10 weeks of age following a Newcastle disease outbreak after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of birds	Mortality (%)	Sire	No. of birds	Mortality (%)
12	162	18.52	13	97	3.09
19	90	37.78	25	60	16.67
24	105	11.32	26	180	8.33
	357	22.54		337	9.36

high line was greater with 22.54 percent than that of the low line with 9.36 percent. Although not statistically significant the difference between lines is large, and may be explained by the Newcastle disease outbreak which occurred when the birds were two to four weeks of age. A large percentage of the mortality of both lines occurred at that time.

The data for Experiment B in Table 88 were also affected by the Newcastle disease outbreak. Mortality of the high line was 16.76 percent compared to 11.76 percent for the

TABLE 88. Mortality of untreated chicks in Experiment B to 10 weeks of age following a Newcastle disease outbreak after approximately two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Sire	No. of birds	Mortality (%)	Sire	No. of birds	Mortality (%)
22	124	18.40	20	99	12.12
23	135	19.12	21	237	11.39
	259	18.76		336	11.76

low line, and the difference between lines was not significant.

In view of the results noted here, it can only be said that no evidence exists for a difference between mortality of the two lines up to 10 weeks of age on a normal ration.

From the time the pullets were placed in the breeding pens until after several months of egg production, a record was kept of those which died, or were culled because of poor physical condition. In Table 89 the records for each of the pens of unselected pullets are expressed as percentages, with an average of 6.55 percent laying house mortality from December 1950 to June 1951. After one generation of selection in Experiment A the high line had slightly less mortality

TABLE 89. Laying house mortality of untreated pullets in the unselected population from December 1950 to June 1951.

Pen	No. of pullets	Mortality (%)
8	8	0.00
9	7	14.28
10	8	0.00
11	8	12.50
12	8	0.00
13	8	12.50
	47	6.55

with 29.0 percent than the low line with 35.7 percent as shown in Table 90. Table 91 shows the results after two

TABLE 90. Laying house mortality of untreated pullets in Experiment A after one generation of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Mortality (%)	Pen	No. of pullets	Mortality (%)
12	15	37.5	13	13	35.7
19	10	27.3	25	12	64.3
24	10	22.2	26	13	7.1
	35	29.0		38	35.7

generations of selection and this time the high line had greater mortality with 36.7 percent compared to 21.9 percent for the low line.

TABLE 91. Laying house mortality of untreated pullets in Experiment A after two generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Mortality (%)	Pen	No. of pullets	Mortality (%)
12	10	50.0	13	19	26.3
19	15	26.7	25	14	14.3
24	15	33.3	26	16	25.0
	35	36.7		49	21.9

In Experiment B, no information regarding laying house mortality was obtained after approximately two generations of selection. After approximately three generations of selection, the high line also had greater mortality than the low line as shown in Table 92 with

TABLE 92. Laying house mortality of unselected pullets in Experiment B after approximately three generations of selection for high and low thyroid weight response to thiouracil.

High line			Low line		
Pen	No. of pullets	Mortality (%)	Pen	No. of pullets	Mortality (%)
22	17	23.5	20	15	20.0
23	16	37.5	21	12	8.3
	33	30.5		27	14.2

30.5 percent and 14.2 percent, respectively. However, the laying house mortality results are inconsistent, and no clear evidence for a difference between the high and low lines was found. Reports in the literature indicate that mild hyperthyroidism or hypothyroidism has little or no effect on mortality. The results reported herein provide no consistent evidence that selection for high and low thyroid response to thiouracil affects mortality.

SUMMARY AND CONCLUSIONS

New Hampshire chicks were fed thiouracil as 0.2 percent of the ration from the time of hatching until they were four weeks of age, at which time they were sacrificed and their thyroid glands weighed. Full sibs of the families which exhibited the largest and the smallest thyroid glands, respectively, were raised for breeding purposes and were used to establish lines differing in their response to thiouracil.

The mean thyroid weight of the low line in Experiment B was decreased to about 80 percent of the mean of the unselected population, but the thyroid weight of the high line was increased to about 365 percent of the mean of the unselected population. These results were obtained after approximately three generations of selection. Reciprocal crosses between the two lines indicated that the genetic mechanisms controlling thyroid response to thiouracil were largely additive, although some evidence for dominance or epistasis was found.

When full sibs of the high and low response chicks were fed a thiouracil-free diet, the thyroid gland weights of high line chicks were less than those of low line chicks. The difference was not significant, however, and the evidence was not sufficient to justify conclusions for a negative relationship between thyroid weights of thiouracil treated and non-treated birds.

Accompanying data on sexual maturity, egg production, fertility, hatchability, incubation period, body weight, rate of feathering, disease resistance, and mortality were accumulated. Although the evidence suggested that the low line chicks were later feathering and were more resistant to Newcastle disease than the high line chicks, no significant differences between the two lines were found regarding any of the economic characteristics. Therefore, it is concluded that any hyperthyroidism or hypothyroidism produced by this selection program was not sufficient to be of economic importance.

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Publications

Shaklee, William E., Charles W. Knox, and Stanley J. Marsden. 1952. Inheritance of the sex difference of body weight in turkeys. Poultry Science. 31:822-825.

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