Genetic Studies with Japanese Quail*

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Summary. An inbreeding study and two selection experiments with Japanese quail are reported which have been conducted on a comparative basis with similar work in chickens.

Japanese quail exhibit pronounced inbreeding depression of reproductive traits such as egg production, fertility, hatchability and viability. Compared to the domestic fowl, the quail populations were found to show three times more damage from inbreeding for their entire reproductive cycle. These findings raise some questions concerning the history of the quail's domestication, and the breeding techniques required for developing highly inbred laboratory populations of that species.

Selection experiments for high body weight at 6 weeks of age have shown response patterns comparable to those found in chicken populations. Inbreeding effects have tended to obscure some of the genetic gains in egg number which could be demonstrated only in appropriate comparisons with control populations.

Introduction

For the last decade experiments have been carried out at our laboratory with the general objective of exploring the Japanese quail (*Coturnix coturnix japonica*) as pilot animal for other gallinaceous species. The stimulus for this effort arose when research in controlled environments was contemplated. For this type of work a small bird was needed which resembled chickens and turkeys in its physiological responses to light and temperature changes. Japanese quail appeared promising and were acquired in 1957.

It soon became apparent that Japanese quail were suitable, not only for management and nutrition studies (WILSON et al. 1961), but were even more promising as pilot animal for genetic research. Preliminary studies demonstrated that *Coturnix* females matured as early as 5 weeks of age, with an average age at first egg of 8 weeks under our laboratory conditions. Thus, as many as four generations can be obtained per year under optimal conditions; in selection experiments requiring egg records two to three generations per year are feasible. Body size increases rapidly to 6 weeks of age and most birds reach their full size by 12 weeks.

Populations of quail hens, when held under adequate lighting of 14 or more hours of light per day are capable of initial egg production rates exceeding 80 percent (80 eggs per 100 hens per day), and thus are at par with the best laying flocks of chickens. Under controlled laboratory conditions high production rates are maintained over several months with a gradual decline so that production rates of one year old quail populations have declined to about 40 percent. However, neither molting nor other seasonal cycles in production rates are observed under laboratory conditions. When egg production is considered in conjunction with egg size and body size it appears that quail females secrete egg substance at roughly twice the rate of chickens. Thus each quail egg weighs about 10 grams, or approximately one fifteenth of the hen's body size, while a chicken egg is only about one thirtieth the weight of a hen. Viewed in this light the Japanese quail shows every sign of being far advanced in domestication. This finding agrees with the fact the Japanese have kept the quail as domestic animals for over 300 years or probably as many as 600 generations. For purposes of selection research the Japanese quail can thus be considered further advanced in its genetic improvement than laying chickens or turkeys. If this were true they should be useful in the study and demonstration of problems which might be anticipatory of similar developments in the other domestic species.

Genetic studies conducted at our laboratory have followed several lines of investigation, namely: The establishment of control populations; studies of inbreeding effects; selection experiments for increased growth, and selection experiments for egg production.

Control Populations

At the outset of this project an attempt was made to establish a control population based on a broad genetic background and maintained under random selection and mating. For this purpose hatching eggs were obtained from three populations of Japanese quail maintained by two local game breeders. Over a period of 6 generations these initial populations were crossed to establish the first control population (Line 903). The populations contributing to this line were allegedly imported from Japan during the three preceding years. It was suspected, however, that the initial samples of stock were derived from closely related sources in Japan. Therefore, a new source of genetic material was sought and eventually found in the form of 200 hatching eggs supplied by one of our former students in Formosa. Of these eggs, only 3 males reached maturity and were crossed with the existing control line. The resulting outcross was then multiplied in order to establish a new genetically more broadly based control, Line 908. This population has been in use for all our environmental and some genetic studies since 1962. It is reproduced, each generation, with approximately 200 females and 100 males. No artificial selection has been applied to this control population since its inception, but between generations 5 and 10 it was used in an extensive study of inbreeding effects (SITTMANN et al. 1966).

The Effects of Inbreeding

Beginning with generation 5 of line 908 a series of brother-sister matings was initiated from families with a history of random mating. Sib-matings of this kind were also made in the following 4 generations and inbred offspring from such sib-matings were further used to produce inbred lines with two or

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* Dedicated to Professor HANS STUBBE on the occasion of his 65th birthday.

Table 1. *Hatchability of offspring from different mating types used in a study of inbreeding effects in generations 5 through 10 of the control population.*

Mating type		Expected Inbreeding (F, in %)		Total Number of Matings	Percent of Hatchability
		Parents	Offspring		
R_0:	Random mating, excluding close inbreeding	0	0	526	73
S_1:	Progeny from mating of brother × sister (full-sib mating)	0	25	338	53
S_2:	Progeny from second consecutive full-sib mating	25	37.5	66	40
S_3:	Progeny from third consecutive full-sib mating	37.5	50	15	26
R_1:	Progeny from crosses of unrelated, inbred, S_1 parents ($S_1 \times S_1$)	25	0	61	63
R_2:	Progeny from crosses of unrelated, inbred, S_2 parents ($S_2 \times S_2$)	37.5	0	21	61
R_0^2:	Offspring from matings of unrelated R_1 parents	0	0	17	71
S_1^2:	Inbred individual offspring from full-sib matings among R_1 parents	0	31.2	65	55

three consecutive generations of sib mating as well as in line crosses, as described in Table 1.

The results of this study establish a basis for many of the difficulties encountered at our laboratory in the maintenance and breeding of quail. Hatchability of the Japanese quail as defined by the percentage of chicks hatched from fertilized eggs shows the most drastic reduction from inbreeding of all the traits considered. A comparison of non inbred embryos (R_0, R_1, R_2, R_0^2) obtained in crosses from dams of various inbreeding levels reveals that hatchability declines about 3 percent for every 10% increase of the dams inbreeding. Inbreeding of the embryo itself, however, plays a more important role. Parents with identical inbreeding were either sib-mated to give inbred embryos (S_1, S_2, and S_3) or crossed to unrelated lines (R_1, R_0, R_2) so that embryos of various inbreeding levels could be compared with non inbred controls. On this basis it appears that hatchability declines by approximately 7% for every 10% inbreeding of the embryo. It can thus be concluded that in a closed population of quail where inbreeding levels of parents and offspring increase simultaneously a loss of one percent hatchability would be sustained for every percent increase in the degree of inbreeding. This inbreeding depression is about twice as severe as that observed for chickens.

Similarly drastic inbreeding effects were also observed for mortality and fertility of surviving birds, as shown in Table 2. With 37.5% inbreeding (S_2) the mortality of quail to 16 weeks of age is more than doubled and the percent fertile eggs reduced from 90 to 52 percent. In addition, the percentage of non layers to 16 weeks of age among inbred S_1 females is 14.6%, almost threefold the control level of 5%.

All the traits mentioned above directly affect the chance of successful reproduction of a planned mating. SITTMANN et al. (1966) have summarized the probability of successful reproduction of planned matings and found, based on the above results, that the chance of successful reproduction of a mated quail female with 25% inbreeding is only one third of that for a non inbred hen.

Less drastic but significant inbreeding effects are observed in the form of reduced egg production, delayed age at first egg, reduced body weight at 6 weeks of age and smaller egg size. For these characteristics inbreeding depression may be considered comparable in magnitude to that found in chickens.

In conclusion it may be said that inbreeding depression in reproductive fitness of Japanese quail is so severe that the development of highly inbred lines by sib matings or even half-sib matings is virtually impossible. Direct evidence for this point of view is a fact that we have been unable to obtain live offspring beyond the third generation of continued sib-matings (S_3) although 139 sib-lines were initiated in the course of this study.

Selection for increased body size

An experiment on selection for rapid growth as measured by six week body weight was initiated in 1960. The original plan called for selection in small populations under three different feeding regimes. Treatments consisted of a control diet, fed ad libitum; the control diet fed at approximately 70% of normal intake between 3 and 6 weeks of age; and a diluted diet with 40% sugar added to the normal feed. Details of the feeding procedures and selection results under experimental conditions will be omitted

Table 2. *Effects of inbreeding on the percentage mortality of quail to 16 weeks, the percentage of non-layers among hens, the percent fertility of eggs incubated and other traits of adult birds.*

	Inbreeding (F, in percent) and Mating type				
	0(R_0)	0(R_1)	25(S_1)	37.5(S_2)	50(S_3)
Number of chicks banded	2659	499	1391	326	26
Mortality: 0 to 5 weeks %	17.2	23.1	25.8	40.9	71.4
5 to 16 weeks % males	5.9	6.4	7.5	11.5	....
females	11.5	5.2	16.1	18.9	....
Number of surviving females	793	128	350	61	0
Non-laying females among survivors %	5.0	5.0	8.7	14.6	....
Total eggs incubated	10.863	1241	2775	741	....
Percent fertile eggs	88.2	89.1	72.4	52.2	....
Age at first egg (days)	56.7	57.3	59.6	65.1	....
Number of eggs to 16 weeks of age	47.7	49.1	42.4	35.1	....
Egg weight (gm) at 12 weeks	10.26	10.27	9.83	9.56	....
Body weight (gm) at 6 weeks — males	107.9	104.3	102.7	98.9	....
females	121.1	112.7	110.0	108.2	....

here, since the effects of the experimental diets on selection response were not found to be consistent or significant. Suffice to say that after generation 7 of this experiment all populations were selected under a standard feeding procedure. Also, during the first 7 generations, while selecting under different diets, samples of birds from all populations were tested under standard conditions in most generations.

At the inception of this experiment 6 small subpopulations were established on each diet, namely: Four populations of size 4 (2 males mated to 2 females in a colony cage) and two populations of size 8 (4 males mass mated to 4 females). Under the standard diet 8 full-sib lines were used in addition to the above mentioned populations. These plans soon proved to be impractical as inbreeding depression of reproduction took its toll among the small populations. By generation 4 each feeding regime was represented by only two populations, the others having been lost or discarded for lack of satisfactory reproduction. The following initial populations were thus continued beyond generation 4:

Standard diet: One population based on an initial full-sib mating.

A second population had to be newly established from the control in generation 5.

Restricted diet: One population of initial size 4 and one of initial size 8.

Diluted diet: One population of initial size 4 and one of initial size 8.

From generation 4 through generation 6 each of the above populations was propagated by 10 pair matings. In generation 7 selected parents of the two populations receiving the same diet were crossed to establish 3 composite populations, one representing each treatment and each propagated by 20 matings. These populations were further selected till generation 12 when 2-way and the 3-way crosses among them were made. From these crosses two composite populations were established in generation 13 each based on selected individuals from all possible crosses. Selection was hence continued with the two populations each propagated by 9 mass matings of 2 males and 4 females each.

The general breeding plan followed in this study was thus one of selection within several initial populations, which were combined into composite populations at generations 7 and 13. At the same time the size of individual populations was approximately doubled following each cross, as well as in generation 4.

Throughout the first 12 generations of the experiment a selection intensity of 1 out of 4 was attempted in both sexes. Thereafter males were selected more intensively than females at a rate of approximately 1 in 8.

The observed response to selection as measured by increase in 6 week body weight of males and females is given in Figure 1. Some of the difficulties encountered in the course of this work are reflected in the selection response curve. One of them, as mentioned earlier, was the loss of some lines in the first three generations due to their poor reproduction under inbreeding. These were lines reproduced by males mated to their full-sisters or half-sisters. Inbreeding levels typical of half-sib and full sib-matings were therefore established for them and can be held accountable for the early loss of these inbred lines. Inbreeding effects were largely eliminated by line crosses in generations 7 and 13, respectively and are unlikely to have modified average response appreciably beyond generation 7. Thus, in generation 13, where the average of 3 contributing selected populations are compared with their line crosses it would appear that inbreeding depression accounted for only about a 2-gram depression of weight in males and a 7-gram depression in female body weights. The relatively pronounced inbreeding effect in females can be attributed partly to delayed sexual maturity.

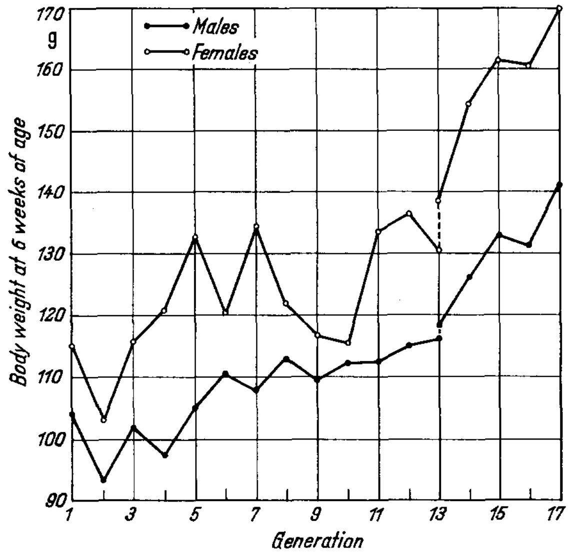

Fig. 1. A response in 6 week body weight of male and female quail during 17 generations of mass selection. Each point of the graphs represents an average of several independent populations as described in the text. In generation 13 averages for closed populations are shown separately from those of crosses among them.

A second irregularity in selection response is evident also for female body weights of generations 8, 9 and 10. The decline observed for this period is almost entirely due to the fact that brooding conditions at that stage were changed from the use of continuous artificial light to natural daylight conditions prevailing in the brooder house. This reduction in daily light delayed the onset of sexual maturity in females. As a consequence they had relatively undeveloped ovaries, while hens before and after the period were either in lay or on the verge of production. Presence or absence of mature follicles or eggs in hens may fully account for the observed decline in 6 week body weight. The original level of performance was restored in generation 9 by providing 16 hours of light per day.

Perhaps the most striking feature of selection response in this experiment is the fact that its magnitude increased following generation 13 when composite lines were established from line crosses. Up to that point a realized heritability of 0.15 was estimated from the regression of generation averages on cumulated selection differentials, ranging from .06 to .25 for the three lines considered (COLLINS and ABPLANALP, 1965). It would thus appear that selection response for rapid growth was considerably less in the first phase of this experiment than one would have anticipated from selection studies with chickens of turkeys (Abplanalp et al., 1963; Johnson and Gowe, 1962; Nordskog and Festing, 1962; Siegel, 1962). However, after generation 13 selection response almost doubled compared to previously observed rates, with a realized heritability of 0.43 for combined lines. An estimate of heritability of 0.6 for body weight at 6 weeks as derived from analyses of variance in the base population by Sittmann et al. (1966) and an estimate of 0.36 reported by Marks and Kinney (1964) agree fairly well with the response observed after generation 13. An explanation for the lack of selection response in the early stages of this selection experiment must await more detailed analyses of the data; tentatively it may be suggested here that the use of suboptimal diets as well as small initial population sizes may account for lack of response in the first seven generations. Between generations 7 and 13 these restrictions no longer held. The lack of selection response in that phase of the study may be due to the fact that 6-week weight of females depended heavily on the state of their sexual maturity, as mentioned above and hence on a trait which may have a low genetic correlation with mature body size.

From generation 13 on selection was stronger for males than for females and hence tended to place stronger emphasis on growth as such rather than on early sexual maturation of hens.

Finally, it is likely that natural selection has operated against the intended selection goal. Thus, the larger birds among selected parents may have left smaller numbers of offspring than selected individuals of less extreme size. Such negative forces would tend to be less pronounced in their effect upon selection differentials of males than of females, since the latter are involved mainly in egg production, fertility and hatchability of eggs, while males contribute to the fertility, but not the other steps in reproduction.

Table 3. *Comparison of the average performance of 2 lines selected for high 6-week body weight with the control population in the 10th generation of selection.*

Trait	Control Line (908)		Average of Two Selected Lines	
	Males	Females	Males	Females
Number of birds at 6 weeks	86	90	103	91
Body weight (gm) at:				
6 weeks	109.4	130.9	132.3	167.1
18 weeks	123.8	155.2	149.0	182.6
Egg weight (gm) at:				
16 weeks		10.7		11.0
30 weeks		10.7		11.1
Percent fertile eggs at:				
9 weeks		75.7		60.5
17 weeks		72.5		75.6
25 weeks		73.4		57.5
33 weeks		75.2		58.1
41 weeks		62.8		42.9
Percent hatchability of fertile eggs at:				
9 weeks		74.7		57.8
17 weeks		72.5		69.8
25 weeks		79.6		62.5
33 weeks		69.2		60.0
41 weeks		75.3		50.5
Egg production to 16 weeks:		43.0		44.3

Correlated responses in fertility and hatchability of eggs (Table 3) show indeed that these traits deteriorated in lines selected for large six week weight, and hence are negatively correlated with body size as suggested above. The data also show that fertility and hatchability deteriorated with age more rapidly in selected lines than in the control populations.

Table 3 also gives comparisons of egg size, body size and egg production of selected and control lines. Egg production apparently did not suffer under selection for body size, in contrast to findings with chickens (Nordskog and Festing, 1962).

Selection for Increased Egg Production

The use of Japanese quail as pilot animal was considered particularly appropriate for studies of egg production rate. One of today's questions foremost in the minds of poultry geneticists and breeders concerns the possibility of increasing the rate of lay beyond the limit of one egg per day. Clearly this involves problems basic to physiology as well as population genetics and information derived from long-term selection experiments on egg production in quail might have relevance to future prospects of improving performance in chickens.

An experiment on mass selection for high egg number of *Coturnix* hens was started in 1959. Hens were placed into single cages at 5 weeks of age and egg number recorded to 16 weeks of age on five days each week. This test of egg production was thus planned to last until the populations had reached twice the average age at first egg. Since chickens reach maturity at about 25 weeks of age, one might assume that the 16 week record of quail corresponds approximately to production records of 40 to 50 week old chickens. The initial population (905) used for this study was propagated by 10 pairs of selected parents. Females with highest egg production were chosen each generation by mass selection from a group of 40 to 50 tested individuals. Selection on the male side was held deliberately weak and consisted primarily of a physical examination of available individuals at mating time. Each male was examined for its state of sexual activity. Sexually active and mature males are characterized by visibly enlarged cloacal glands which extrude a white foam. Immature or sexually inactive males lack outward signs of this organ. Selection differentials in female hens averaged 12 eggs per generation and were practically zero for males.

As in other selection studies of quail based on relatively small populations it became apparent by the fourth generation of this study that inbreeding effects had a strong influence on average egg production and especially on the hatchability of eggs. A second population (951), also consisting of 10 pairs of selected parents was therefore initiated from the control line (908) when the first population had reached its fifth generation. The two populations were crossed and combined into a single population when they had reached their 9th and 4th generation of selection, respectively. From generation 10 to 14 the combined population was propagated by 20 pairs

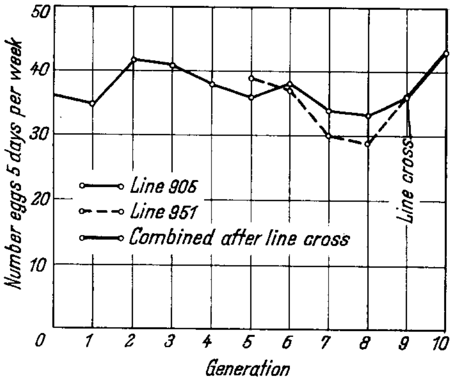

Fig. 2. Response to mass selection of the number of eggs laid by quail hens to 16 weeks of age. Data are based on egg records taken on 5 days of the week.

per generation so as to hold the rate of inbreeding below 2% per generation.

Preliminary results of this experiment are given in Figure 2 for the first 10 generations of selection. Positive selection response was apparent only in the second selected generation of line 905 and again after this line had been crossed to line 951. The intervening generations of both populations all showed consistent downward trends in the number of eggs laid. These results can be explained, in retrospect, as due to the fact that actual selection response was obscured in this case by adverse inbreeding effects until the selected lines were crossed. Only when relatively non inbred offspring were produced from non inbred parents was selection response fully expressed. This conclusion is confirmed by comparison of the selected lines, with the control population (908) in generation 14 of this experiment (Table 4). Twenty-five hens from each of these two lines were tested under control conditions of 14 hours light and 10 hours darkness. The results of this comparison, shown in Table 4 indicate that selection response did indeed take place. It can be seen, however, that the selected line exceeds the control population primarily in the number of eggs produced before the 12th week of age, and not thereafter. Selection response thus was effected primarily by an advancement in age of sexual maturity and not by a greatly increased rate of lay thereafter. Very similar results have in fact been obtained with chicken populations selected for early egg production to 40 weeks of age (Abplanalp, 1966).

Selection for egg number in the present study also resulted in a correlated response in egg size; thus average egg weight of hens belonging to the selected population (generation 14) showed a decline of almost 10% (0.85 grams) relative to the control (Table 4). This result again agrees with those of similar studies in chickens, where negative genetic correlations between egg number and egg size constitute one of the major practical obstacles to rapid improvements in egg number (Abplanalp et al., 1964).

Table 4. *Egg production and average egg weight of a quail population selected for high egg production over 14 generations.*

	Control Population	Selected Population
Average Egg Production		
6—12 weeks of age	16.8	28.1
12—16 weeks of age	25.1	24.5
Average Egg Weight at:		
12 weeks of age (gm)	9.89	9.15

Conclusions

The experiments reported here were conducted with the general aim of exploring and demonstrating the suitability of Japanese quail for the study of problems in quantitative genetics, relevant to genetic improvement of chickens and other bird species.

The most distinctive genetic property of quail populations appears to be their pronounced inbreeding depression in reproductive performance. The effects of inbreeding on hatchability, variability and egg production were found to be approximately twice as severe as those found in the fowl. Breeding experiments with quail therefore would have to be conducted with larger populations than comparable studies in chickens if significant inbreeding effects were to be avoided. The development of inbred laboratory strains of quail should prove difficult. Systems other than rapid inbreeding by brother-sister mating must be devised, so as to allow adequate selection against deleterious recessive genes.

One may also conclude from these findings that the domestication of Japanese quail must have been practiced on a broad genetic basis, at the exclusion of inbreeding. Otherwise the present populations should be relatively free of deleterious genes and show less inbreeding depression than was found in the present study. An alternative explanation for the apparent abundance of deleterious recessive genes is that domesticated Japanese quail populations were outcrossed in recent times to wild populations; the latter in turn are likely to be very large and hence capable of carrying substantial genetic loads.

The existence of pronounced inbreeding effects presumably due to many genes suggests that quail populations carry much genetic variability. The discovery and description in this species of large numbers of distinct major genes can therefore be only a matter of time. Several have in fact been described in the course of the work reported here. Among them have been recessive autosomal lethals causing micromelia (Hill et al., 1963), congenital loco (Sittmann et al., 1965), and white plumage (Sittmann and Abplanalp, 1965). A non-lethal gene causing differential migration of serum albumin under starch gel electrophoresis has been found be Haley (1965) and a gene for white egg color was reported by Poole (1964). A sex linked gene causing albinism (al) has been reported by Lauber (1964) and autosomal gene causing buff plumage color and pink eyes (pk) has been described by Sittmann et al. (1966). These authors also demonstrated that both of the albino genes cause a marked reduction in reproductive fitness when homozygous. Unpublished data from this laboratory further suggest the existence of abundant single gene variation in egg proteins, blood serum proteins, as well as additional embryonic lethals. The Japanese quail should therefore be considered favorable genetic material for problems relating to developmental and biochemical genetics.

Selection experiments for increased body size at maturity and egg production have demonstrated that quail populations respond to selection in much the same way as chickens do. Comparative studies might take advantage of the fact that quail tend to age more rapidly than chickens as demonstrated by a relatively early and pronounced decline of hatchability and fertility of eggs from females belonging to lines selected for large body size. Quail also exhibit some of the correlated responses found with selection for high egg number in chickens. Thus populations selected for egg number to 16 weeks of age tend to respond by advancing the onset of lay and reducing the size of eggs. At the same time there appears to be very little change in the rate of production after hens have begun to lay, as evidenced by lack of selection response in eggs laid after 12 weeks of age. These findings suggest that quail might be useful in projecting correlated response patterns under selection in chickens. In particular one might wish to use this early maturing bird for studies of age-related phenomena such as the persistency of lay or the decline in fitness under selection for increased rates of growth or egg production. Due to the rapid potential generation turnover one might thus employ the Japanese quail to forecast solutions to problems now facing population geneticists and poultry breeders.

Zusammenfassung

Es wird über einen Inzuchtversuch und zwei Selektionsexperimente mit Japanischen Wachteln berichtet, die zum Vergleich mit ähnlichen Arbeiten mit Hühnern durchgeführt wurden.

Die Japanische Wachtel zeigt bei reproduktiven Eigenschaften, wie Eiproduktion, Fertilität, Schlüpfen und Vitalität ausgesprochene Inzuchtdepression. Im Vergleich mit dem Haushuhn ergab sich, daß Wachtelpopulationen in ihrem gesamten Reproduktionszyklus dreifach höhere Inzuchtschäden aufwiesen. Diese Feststellungen werfen einige Fragen bezüglich der Geschichte der Domestikation und bezüglich der Zuchtmethoden auf, die angewendet werden müssen, um stark ingezüchtete Laborpopulationen dieser Art zu entwickeln.

Selektionen auf hohes Körpergewicht im Alter von 6 Wochen brachten vergleichbare Werte mit bei Hühnerpopulationen gefundenen Ergebnissen. Durch Inzuchtwirkungen wurden z. T. genetisch bedingte Steigerungen der Eizahl verschleiert, die nur durch geeignete Vergleiche mit Kontrollpopulationen aufgezeigt werden konnten.

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Buchbesprechungen / Book Reviews

Alexopoulos, Constantine John: Einführung in die Mykologie. Stuttgart: Gustav Fischer Verlag 1966. 496 S., 194 Abb. Geb. DM 62,—. Lizenzauflage beim VEB Gustav Fischer Verlag, Jena, MDN 69,—.

Dem Gustav-Fischer-Verlag, Stuttgart, ist für die Herausgabe der deutschen Übersetzung dieses bewährten amerikanischen Mykologie-Lehrbuchs sehr zu danken. Es unterscheidet sich in mehrfacher Hinsicht von dem hervorragenden, bisher einzigen deutschsprachigen Buch über die Pilze, dem „Gäumann": Dieses neue Lehrbuch wendet sich bewußt an die Anfänger auf dem Gebiet der Mykologie, und es vermeidet darum absichtlich spekulative phylogenetische Erörterungen. Dem Charakter des Buches entsprechend werden neueingeführte Fachausdrücke etymologisch erklärt; da das nicht nur mit Hilfe eines Glossars, sondern auch im Text geschieht, ergeben sich häufig der Gedankenführung nicht gerade dienliche Unterbrechungen, die man durch die Verwendung von Fußnoten hätte vermeiden können. Ein besonderer Vorzug sind die zahlreichen sehr instruktiven Schemata der Entwicklungsgänge bei den verschiedenen Pilzgruppen. Der Inhalt des Buches ist wie folgt gegliedert: Einer 33 Seiten langen Einführung, in der dem Leser die wichtigsten Eigenschaften und Besonderheiten der Pilze auf recht elementare Weise erläutert werden, folgen Kapitel über die einzelnen Pilzgruppen. Diese Darstellung beginnt mit protozoenartigen Organismen, wie den Acrasiales und Labyrinthulales, die nicht eindeutig einer der großen Pilzklassen zugeordnet werden können. Daran schließen sich die Myxomyzeten und die einzelnen Klassen der Phycomyzeten an. Bei der Behandlung der Ascomyzeten folgt der Autor weitgehend der auf den Ergebnissen Luttrells basierenden Einteilung von Martin in 3 Unterklassen (Hemiascomycetidae, Euascomycetidae und Loculoascomycetidae). Hervorgehoben zu werden verdient, daß in diesem Buch die Fungi imperfecti eingehender besprochen werden als in Mykologie-Lehrbüchern sonst üblich ist; dabei wird u. a. auf die Problematik der Parasexualität und auf neuere taxonomische Erkenntnisse näher eingegangen. Hinreichend Berücksichtigung finden auch die (phyto- und human-) pathogenen Eigenschaften vieler Pilze. Jedem Kapitel ist eine Literaturliste angefügt. Autoren- und Sachregister sind vorhanden. Das hervorragend ausgestattete Buch ist im allgemeinen sehr gut übersetzt, Druckfehler sind selten. Die Terminologie weicht zuweilen etwas von der im