SEED DISCRIMINATION BY TASTE IN THE BOBWHITE QUAIL

A Thesis

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by

Gerald J. Wiens

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Dwight L. Spencer
Approved for Major Department

Harold E. Durst
Approved for Graduate Council

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INTRODUCTION

Taste discrimination has been critically studied in but few species of birds. Most ornithological texts indicate that the senses of taste and smell generally seem to be poorly developed in birds (Wallace, 1955; Van Tyne and Berger, 1959; Welty, 1962; Pettingill, 1970; Wallace and Mahan, 1975). Pettingill (1970) generalized that all birds are able to detect certain substances by taste, but in selecting their food they depend more on its visual properties. Moncrieff (1946) concluded that birds gain more information about their environment through their eyes than from all other sense organs combined. The apparent general acceptance of high visual acuity in birds has resulted in few studies of taste and smell.

Taste is often correlated with and sometimes inseparable from smell (Wallace and Mahan, 1975). Both taste and smell are types of chemoreception. The organs of taste and smell are sensitive to molecules of chemical substances that may warrant a response. There are three main types of chemoreception, each distinguished by the location of receptors on the body surface and by their relative sensitivity (Marler and Hamilton, 1966). The least sensitive is the rather poorly defined common chemical sense; distinct from smell, taste, touch, and pain and with its own set of receptors (Moncrieff, 1946). These receptors are the free nerve endings of spinal and cranial nerves, with sensitivity confined to those areas where the mucous membrane is exposed. There is no complicated end-organ of the common chemical sense corresponding to the taste buds (taste organs) or even to the olfactory cells (olfactory organs). Marler and Hamilton (1966) stated that taste was intermediate in sensitivity and usually required direct contact between the receptor surface and the stimulus source, while the sense of smell was most sensitive, responding to low concentrations of chemicals in the medium. Moncrieff (1946) has argued that apparent olfactory and gustatory sensitivity in birds may actually be due to common chemical sensitivity. However, anatomical evidence indicates that the senses of taste and smell do exist in birds, but that the common chemical sense may also contribute (Farner and King, 1973).

Although bird taste receptors apparently have the same construction as those of mammals, they never occur in "taste bud" aggregations visible to the naked eye (Welty, 1962; Gentle, 1971). Compared to mammals, a bird's taste buds are few in number and occur at the sides and base of the tongue and in the soft palate, but never at the tip of the tongue (Welty, 1962). Moore and Elliot (1946) found that pigeons averaged 37 taste buds per bird and the maximum number found in any bird was approximately 400 in parrots (Marshall, 1960). By contrast, 10,000 have been reported in man and 35,000 in cattle (Moncrieff, 1946).

Virtually all studies involving taste discrimination in birds have employed some form of preference testing. Using flavored solutions which evoke the four basic taste sensations in man, researchers have conducted experiments with a number of bird species; for example, with domestic fowl (earlier work summarized by Wood-Gush, 1955; Kare, Black, and Allison, 1957; Deyce et. al., 1962; Gentle, 1971), with feral pigeons (Duncan, 1960, 1964), with great tits (Warren and Vince, 1963), and with bobwhite quail (Hamrum, 1953; Brindley, 1965; Brindley and Prior, 1968; Cane and Vince, 1968). The majority of taste experiments with birds involved various concentrations of substances placed in the drinking water. Beginning with low concentrations and gradually increasing the concentrations of test substances, researchers observed the point of rejection of a specific substance. When a specific concentration of a substance was rejected, it was assumed that the bird had a sense of taste. The general conclusions from bobwhite quail studies are that bobwhite accept sweet and slightly acid tastes and reject bitter and salty tastes (Brindley, 1965). Furthermore, Brindley and Prior (1968) and Cane and Vince (1968) found that taste discrimination in bobwhite quail varied with age. Other researchers concluded that bobwhite quail possess an olfactory sense and that olfactory stimuli probably influence their choice of food (Frings and Boyd, 1952; Hamrum, 1953).

Davison (1962), experimenting with a wide variety of dyed and natural colored foods at feeding stations, discovered that selection of seeds and berries was based on "taste" (involving taste buds and olfactory organs) rather than color. The word taste, as used in this paper, refers only to the gustatory sense, not a combination of olfaction and taste, unless specifically noted.

This study was undertaken to determine whether or not bobwhite quail (<u>Colinus virginianus</u>) are capable of discriminating among several selected seed types on the basis of taste. No attempt was made to determine if they make important use of such perception under natural conditions.

MATERIALS AND METHODS

Bobwhite quail used in this study were obtained from the Quail Farm at Pittsburg, Kansas, owned and operated by the Kansas Forestry, Fish, and Game Commission. Ten cocks and 10 hens were initially obtained in March, 1975. These were young-of-the-year birds and were approximately eight months old when acquired. Due to numerous deaths, it was necessary to obtain 16 additional birds (eight cocks and eight hens) in August, 1975, to complete the study. Birds obtained in August were approximately four months of age.

The birds were housed indoors in 14 x 14 x 30 inch cages (Figure 1). The cage framework was constructed of fir and covered with 0.25 inch mesh hail screen. The floor of 0.5 inch mesh screen allowed droppings to fall through onto absorbent paper which was changed once a week. Feeders (Figure 2) were constructed of sheet metal and attached to the outside of the cage. This type of feeder was utilized to eliminate or reduce grain loss resulting from natural picking and scratching habits of the bobwhite. Feeders were divided into four compartments to accommodate four types of seeds. Four holes, two inches in diameter, were cut to give the birds access to grain, and four holes 0.75 inches in diameter were cut in the bottom of the feeder to facilitate removal of uneaten grain. The unused grain was collected prior to

Figure 1. Quail cages with feeders.

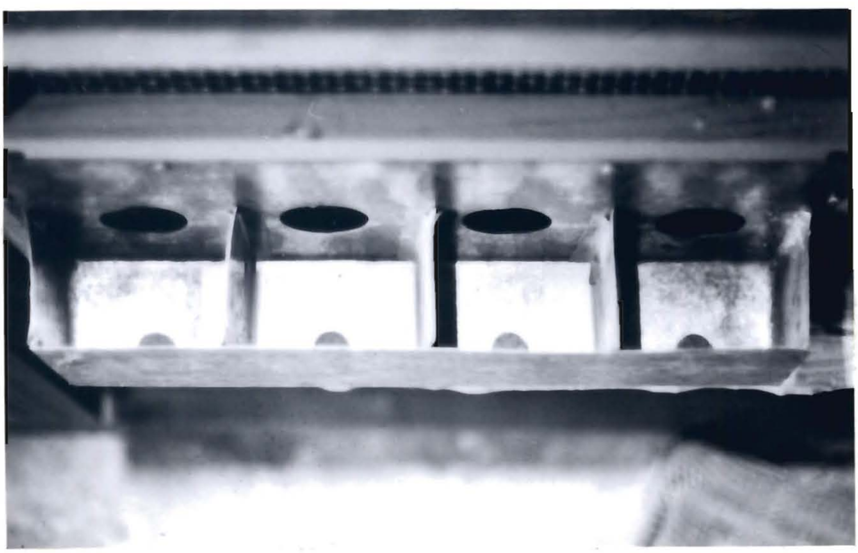

Figure 2. The feeder, showing the four compartments, the holes for feeding and the holes for grain removal.

weighing by sweeping it with a small paint brush through the holes into a cup. Rubber stoppers were used to plug the bottom holes when they were not being used for grain removal.

Initially, three birds were placed in each cage, with half (three) of the cages containing two cocks and one hen and the other half containing two hens and one cock. However, this combination was not satisfactory due to excessive fighting, so the birds were paired, one cock and one hen, for the remainder of the study. Each pair of birds was provided an adequate supply of sand for grit and water.

Davison (1958) listed corn, milo, and wheat as "choice" food for bobwhites and Stoddard (1936) reported that wheat, corn, milo, and soybeans were all suitable for cultivation on quail preserves. The term "choice", as used by Davison, describes a good quality food - one that is digestible, nutritious and readily eaten when available. Therefore, because of previous studies and opinions and of their availability, wheat, corn, milo, and soybeans were also selected for this study. The grain ration was weighed on a Harvard trip balance before being placed in the feeder and again at approximately four day intervals. The amount of grain consumed was recorded to the nearest 0.10 gram.

This research was separated into five phases. The first phase was a test of seed color preference. Milo was ground with a soil grinder and a portion was dyed either red, yellow, blue, or green with liquid food coloring. It was assumed that the food coloring imparted neither odor nor taste to the grain, since it was both odorless and tasteless to humans. The four colors of milo (Figure 3) were made available to the birds for 20 days. This test was designed to determine the specific color the four grain types would be dyed in following tests. The color of grain consumed in greatest quantities, yellow, was the one selected for use in other phases.

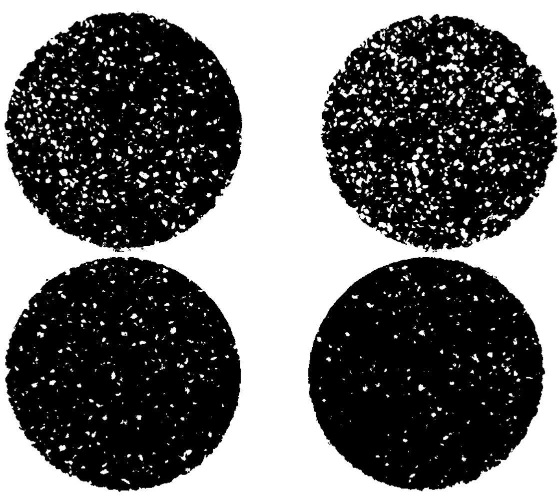

Figure 3. Ground milo utilized in phase one (dyed red, blue, yellow, and green).

Phase two, and the remaining phases, utilized the four seed types. For the second phase all seeds were ground to a uniform consistency and all were dyed yellow in order to eliminate size, shape, and color as variables (Figure 4). This phase was conducted with the bird's nostrils unplugged. In phase three, the nostrils were unplugged and the birds were fed the four different

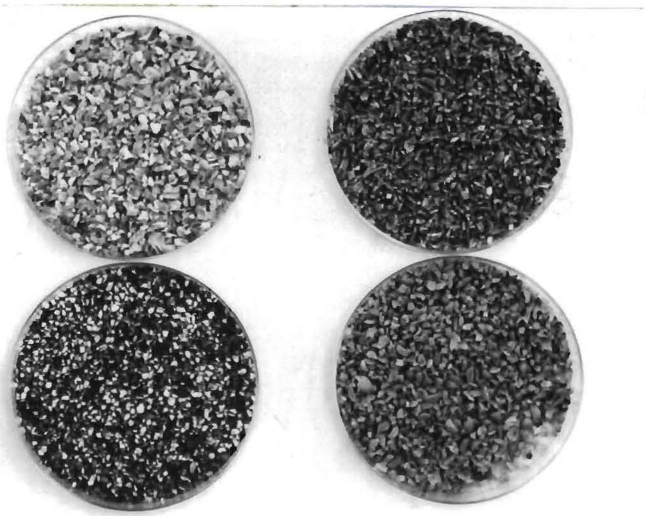

Figure 4. Ground milo, wheat, corn, and soybeans used in phases two, three, and four.

types of seeds which had been ground but left in their natural color. In phase four all conditions were the same as for phase two, except the birds' nostrils were plugged with caulking compound to eliminate the sense of olfaction through the nostrils (Figure 5). During the final phase the birds, with nostrils unplugged, were fed whole, undyed kernels of grain (Figure 6).

Figure 5. Bobwhite showing the nostril openings covered with caulking compound.

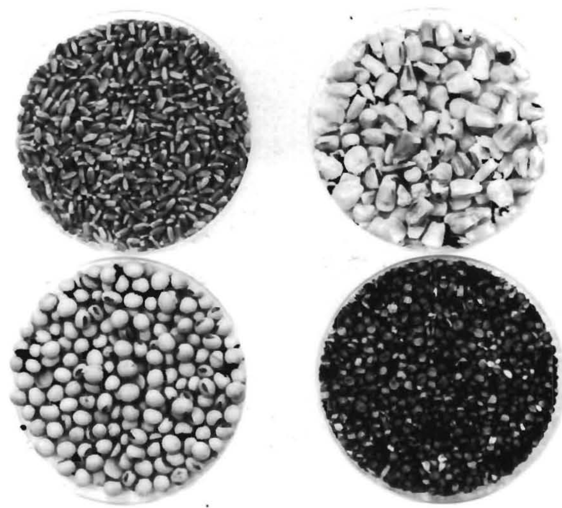

Figure 6. Whole kernel wheat, corn, milo, and soybeans used in phase five.

Phases two, three, and four were conducted for a period of approximately 40 days each, while phase five was carried out for only 12 days. Position of the four seed types in feeders was changed after each weighing to eliminate the possibility that the birds would associate a certain food type with a specific area of the feeder.

Statistical analyses (t-tests and simple linear regression) were performed on a Monroe 1785 programable calculator. The student t-test, P=.05, was used to test for significant differences between different colors of grain and different types of grain.

RESULTS AND DISCUSSION

Phase One

Results from the four colors of ground milo consumed in the first phase are presented in Table I. The purpose of phase one was to establish a color which stimulated optimum feeding behavior. In order to determine whether or not quail had a preference for a certain color of seed, a series of t-tests was performed by comparing the amount of each color of seed consumed. There was a significant difference between yellow and each of the other colors and no significant difference between all other combinations of colors (Table II). When presented the choice of four colors of ground milo, the bobwhite consumed more yellow milo than milo of other colors.

Table I. Amount of ground milo, dyed four different colors, consumed when nostrils were unplugged. Each quantity represents the total amount consumed by all individuals since the previous weighing period.

Date	Days*	Grams of milo			
		Red	Yellow	Green	Blue
24 March 1975	4	178.2	228.4	125.3	91.5
	8	132.1	201.8	125.0	101.9
	12	125.9	178.6	153.2	130.3
	16	74.3	172.3	174.1	157.5
09 April 1975	20	149.7	164.1	172.5	126.1

*The number of days elapsed since the beginning of phase one.

Table II. Results of t-tests among all combinations of the four colors of ground milo; "+" indicates significant difference and "0" indicates no significant difference at P=.05. Where there was a significant difference, the word following the + indicates which color of grain was consumed in greatest quantities.

Color Combinations	Phase I ground milo; nostrils unplugged
Red-Green	0
Red-Yellow	+ Yellow
Red-Blue	0
Yellow-Green	+ Yellow
Yellow-Blue	+ Yellow
Green-Blue	0

Figures 7 and 8 graphically show the actual amount of each color of grain consumed and simple linear regressions, respectively. During the initial four day period, larger quantities of red and yellow milo were consumed (Figure 7). This could possibly be attributed to the experience the birds had with red and yellow grains. While at the Quail Farm, the birds were fed a mixture of chopped corn and milo. In addition, for a period of approximately a week prior to beginning phase one, the birds were fed whole grain milo. The birds had had no recent association with either green or blue food. The graph representing simple linear regression shows an overall picture of the trends of phase one. The amounts of red and yellow milo consumed parallel each other in a gradual decline over the 20 day period (Figure 8).

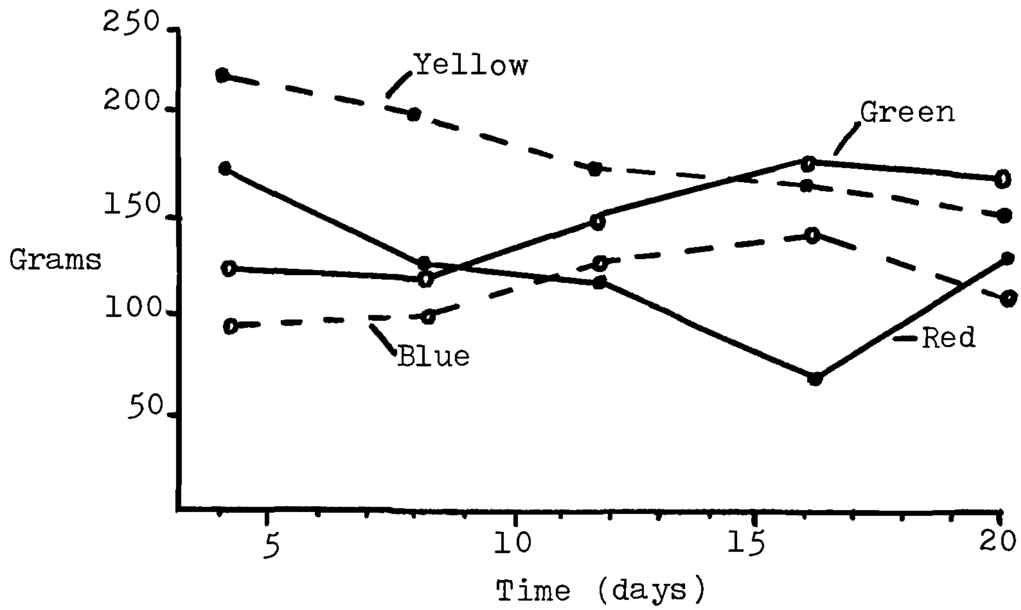

Figure 7. Amounts of four colors of ground milo consumed by bobwhites with nostrils unplugged (phase one) (20 March to 9 April 1975).

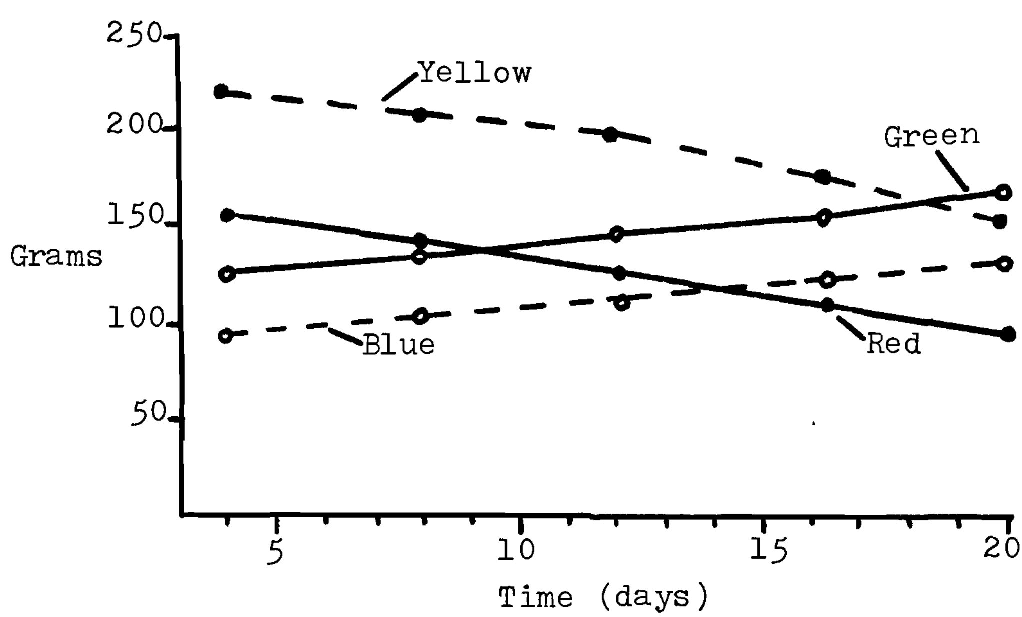

Figure 8. Conditions identical to Figure 7 above only showing simple linear regression.

Red and yellow are advancing colors as perceived by man; that is, they tend to stand out against the background (Rhode and McCall, 1971). The yellow was a bright hue and the red was a light hue, which made the yellow stand out better than red against a background. Perhaps bobwhite, with superior visual capabilities to man (Wallace and Mahan, 1975), have the same attraction as man to yellow and red. The reason for the lower amount of red milo consumed was probably due to the "pinkish" color of the red, which made it less advancing.

Although the initial amounts of green and blue milo consumed were relatively low, there was a steady increase in the amount consumed of both over the 20 day period (Figure 8). Blue and green are closely associated on the color spectrum and their consumption could possibly have paralleled each other for that reason. Stoddard (1936) reported that poultrymen had learned that tender growing vegetation contained vitamins and nutritive substances vital in keeping poultry healthy. Bobwhite held in captivity must have some form of tender vegetation if the birds are to be kept free of nutritional deficiencies and other serious ailments (Stoddard, 1936). Stoddard found green vegetation in 50 % of bobwhite crops that he examined. An innate physiological mechanism may be present to aid a bird in making the association of green vegetation with nutritional requirements present. Perhaps the bobwhite in this study gradually consumed more green milo in an attempt to obtain the nutrients normally obtained from green plants.

In addition, the results presented in Figure 7 indicate that perhaps the birds learned that all colors of grain tasted the same. On the final weighing day, the amounts of all four colors of grain were separated by less than 50 grams. There appeared to be a gradual convergence of the amounts of the four colors of grain consumed throughout phase one (Figure 7).

Phase Two

In the second phase, bobwhites with unplugged nostrils were fed the four different seed types - wheat, corn, milo, and soybeans - all ground to the same consistency and dyed yellow. Amounts of grain consumed in phase two are presented in Table III. With shape, size, and color variation of the food hopefully eliminated, taste and smell were the primary senses involved in food selection. In order to determine whether or not bobwhite quail had a preference for a certain type of seed, in phases two, three, four, and five, a series of t-tests was performed by comparing amounts of each type of seed consumed. There was a significant difference in amounts consumed between all combinations of grain except corn and milo, which showed no significant difference (Table IV).

When comparing the amounts of different seeds consumed, the nutritional value of the individual food item

Table III. Amounts of ground, yellow grain consumed with the nostrils unplugged. Each quantity represents the total amount consumed by all individuals since the previous weighing period.

Date	Days*	Grams			
		Wheat	Corn	Milo	Soybeans
18 Apr. 1975	4	67.6	119.3	204.8	37.8
	8	106.6	211.2	225.4	162.8
	12	135.9	131.1	113.6	252.5
	16	82.4	127.5	112.7	331.6
	19	33.2	98.5	100.3	368.3
	23	37.2	101.2	87.7	416.8
	27	18.9	85.0	47.0	455.4
	31	16.7	108.5	66.2	409.2
1 June 1975	35	24.0	120.0	75.6	384.3

* The number of days elapsed since the beginning of phase two.

is important. Some common chemical components of the seeds used in this study are listed in Table V. The cereal grains, wheat, corn, and milo, showing only slight variations in the overall percentages, are rich in carbohydrates and starch, and low in crude protein, fats, and minerals. Soybeans (a legume) tend to be the opposite of the cereal grains; rich in crude protein, fats, and minerals and low in carbohydrates and starch. In comparison, corn contains more diversity and greater quantities of the essential vitamins. In fact, corn is so well balanced nutritionally that Nestler (1949) maintained penned bobwhites through the winter on corn alone.

Table IV. Results of t-tests between all combinations of the four types of grain in each test phase; "+" indicates a significant difference and "0" indicates no significant difference at P=.05. In those instances when there was a significant difference, the word following the + indicates which grain was consumed in greatest quantities.

Grain Combinations	Phase 2 ground yellow grain, nostrils unplugged	Phase 3 ground natural-colored grain; nostrils unplugged	Phase 4 ground yellow grain; nostrils plugged	Phase 5 whole kernel, uncolored grain; nostrils unplugged
Wheat-Corn	+ Corn	+ Corn	0	0
Wheat-Milo	+ Milo	+ Milo	0	+ Milo
Wheat-Soybeans	+ Soybeans	+ Soybeans	+ Wheat	0
Corn-Milo	0	0	0	+ Milo
Corn-Soybeans	+ Soybeans	0	+ Corn	0
Milo-Soybeans	+ Soybeans	0	+ Milo	+ Milo

Table V. Some common chemical components of wheat, corn, milo, and soybeans. All values are approximations condensed from Henry and Morrison, 1922; Morrison, 1950; and Blanck, 1955.

Component	Wheat	Corn	Milo	Soybeans
Carbohydrates	82%	79%	75%	25%
Fats	2.3%	5%	3.8%	20%
Crude protein	12%	10%	11%	37%
Starch	85%	70%	72%	2%
The following expressed in units per lbs. All units are mg unless otherwise noted.				
Vitamin A	67 IU	3667 IU	150 IU	633 IU
Vitamin E	---	390	---	180
Vitamin K	---	.07	---	---
Niacin	25	9	18	10
Thiamine	2.3	9	1.8	5
Riboflavin	0.5	0.5	0.4	1.2
Carotene	.04	2.2	.09	.38
Calcium	45	20	30	240
Phosphorous	420	450	450	700
Iron	5	3	4	8
Potassium	480	400	440	1800
Sodium	70	50	---	240

The large amounts of milo consumed during the first eight days of phase two (Figure 9) were possibly related to the fact that the birds were fed only milo in the previous test, and were therefore, more accustomed to eating milo. Michael and Beckwith (1955) concluded that bobwhite quail did not require an introductory period to become accustomed to new foods. Contrary to Michael and Beckwith, the data of phase two seem to indicate that a short introductory period was necessary for the bobwhite to become accustomed to a new food item (wheat and soybeans).

Figures 9 and 10 indicate the high preference for soybeans by quail under the particular conditions of phase two. The large amount of soybeans consumed was possibly associated with the month of the year. In late April, at which time this study was being conducted, bobwhite quail coveys begin to break up and pairing and mating begins (Stoddard, 1936). Seasonal variations in light, temperature, food supply, availability of nesting material and the presence of other birds can induce hormonal changes associated with the breeding season (Lehrman, 1959). Nestler (1949) found that more protein was required for quail in the breeding season compared to non-reproductive mature birds in winter. To maintain a certain level of nutrient intake, a bird will consume larger quantities of low nutritive value foods (Lack, 1954). In addition, Wood-Gush (1955) discovered that birds are capable of selecting a nutritive diet with some

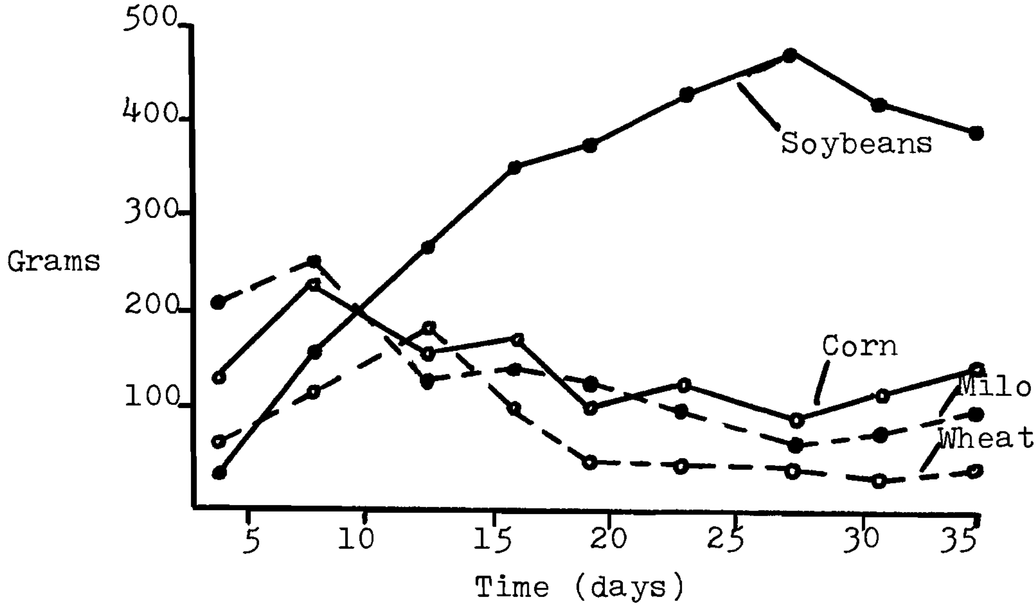

Figure 9. Amounts of ground, yellow grain consumed by bobwhites with unplugged nostrils (Phase Two) (14 April to 1 June, 1975, with a break from 22 April until 05 May).

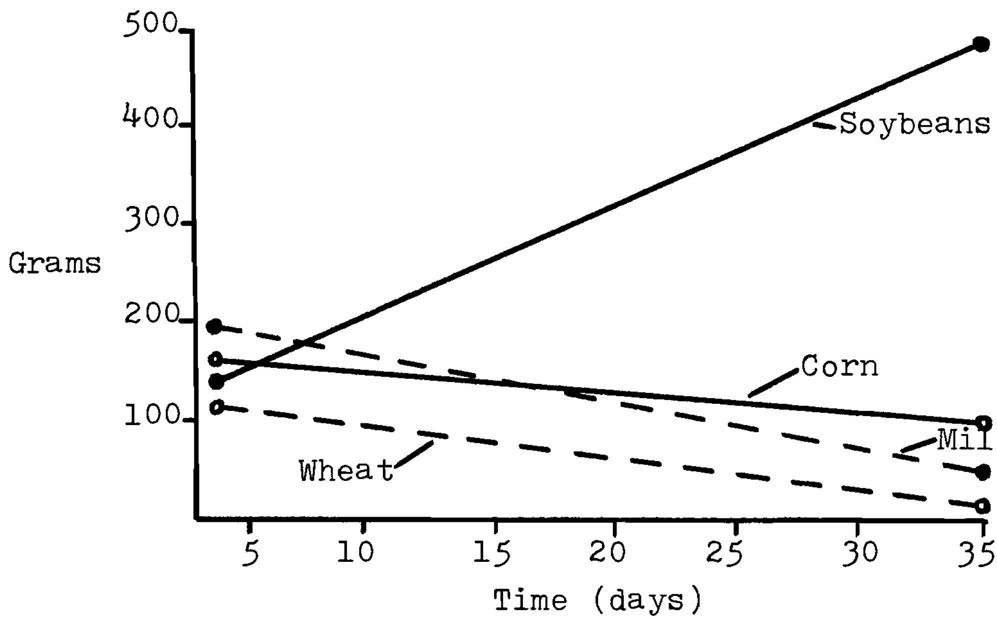

Figure 10. Conditions identical to Figure 9 above only showing simple linear regression.

accuracy. Whether or not it is some type of physiological mechanism which enables birds to select nutritional food is not known. The results of above-mentioned studies may explain, in part, the large quantities of soybeans consumed. Further indications that bobwhite quail are capable of selecting a diet to fill their nutritional requirements were suggested by Nestler (1949). He observed less pecking by bobwhites on food items of diets relished by bobwhites than on diets that were unpalatable. In addition, he found more pecking among bobwhite chicks on a 22 % protein diet than on a higher protein diet (28 % protein provided optimum growth). Apparently, bobwhite quail can detect the nutritional content of food items either by taste or smell or a combination of both. Other vital components that soybeans contain in large quantities that bobwhites require for egg production, are calcium and phosphorous. Nestler (1949) and Cole and Ronning (1974) stated that exceptionally large quantities of calcium and phosphorous were necessary for avian egg production. Other factors affected by the calcium-phosphorous intake included greater food consumption, better maintenance of weight, and stronger egg shells (Nestler, 1949). Perhaps the bobwhites, at the onset of breeding season, could detect the larger quantities of protein and minerals present in soybeans, and, therefore, consumed large quantities of soybeans.

Phase Three

The amounts of each seed type consumed in the third phase are presented in Table VI. When offered natural-colored, ground grain and with nostrils unplugged, the birds followed a definite pattern of consumption for all seeds except soybeans. For example, amounts of corn, wheat, and milo consumed increased and decreased in the same weighing period with less wheat being consumed than corn and milo during phase two (Figure 11). There was a significant difference between all combinations with wheat and no significant difference between all other combinations (Table IV).

Table VI. Amounts of ground, natural-colored grain consumed with the nostrils unplugged. Each quantity represents the total amount consumed by all individuals since the previous weighing period.

Date	Days*	Grams			
		Wheat	Corn	Milo	Soybeans
05 June 1975	4	22.2	101.8	112.0	173.0
	8	44.8	118.1	113.3	136.3
	14	81.3	184.3	156.8	104.5
	17	40.5	93.0	89.5	48.9
	21	79.1	167.3	134.2	69.1
	25	68.3	127.4	153.0	61.7
	29	69.6	128.0	137.1	77.2
	32	34.5	108.1	79.5	88.8
07 July 1975	36	60.0	142.4	132.5	113.2

* The number of days elapsed since the beginning of phase three.

The only difference between phase three and the previous phase was that the seeds were not dyed. The large amount of soybeans consumed during the first week of phase three could possibly be a continuation of the preference that the birds exhibited for soybeans in phase two. Since the reasons for "in unison" fluctuations are unknown, perhaps it is better to interpret the fluctuations as abnormalities and review instead the simple linear regression (Figure 12). Although the amount of soybeans consumed steadily declined throughout the 36 day period (Figure 12), the amounts of corn, milo, and wheat eaten were quite constant, with a significantly less amount of wheat consumed.

The lack of uniform yellow color apparently had minimal effect upon the amounts of each type of seed eaten. Figure 12 appears to be a continuation of Figure 9 (phase two). The initial amounts of corn, milo, and wheat consumed in phase three are similar to the final amounts consumed in phase two. It is important to note that there was no break between the phases, and that phase three commenced immediately at the conclusion of the second phase. The amount of soybeans eaten began to drop the last eight days of phase two (Figure 9) and continued to decline throughout phase three (Figure 12). The high consumption of soybeans in phase two was related to the bobwhite breeding season and additional requirements for protein and minerals

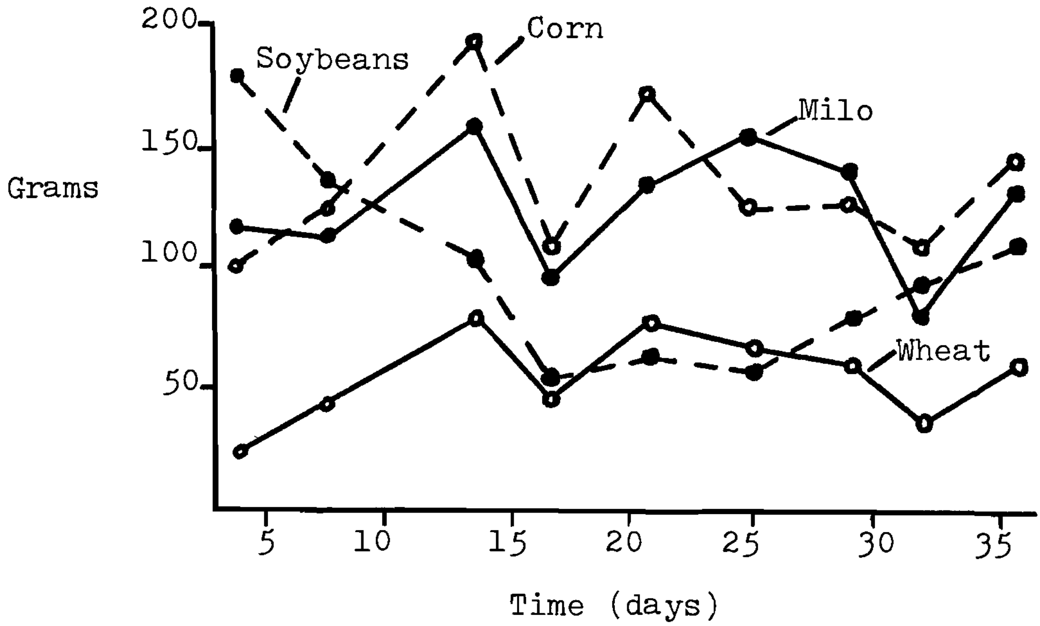

Figure 11. Amounts of ground, natural-colored grain consumed by bobwhites with unplugged nostrils (Phase Three) (1 June to 7 July 1975).

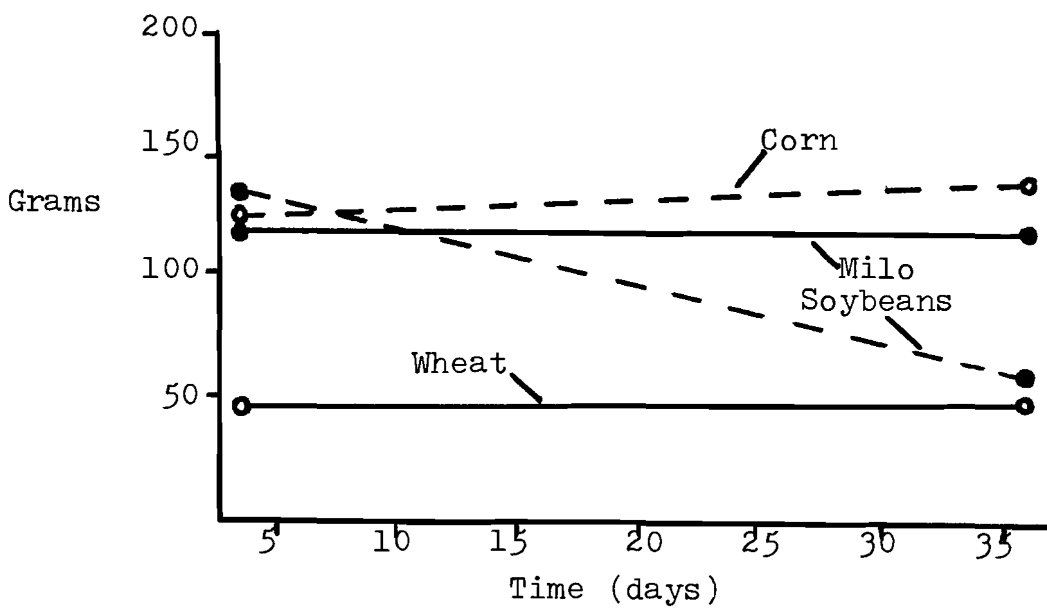

Figure 12. Conditions identical to Figure 11 above only showing simple linear regression.

necessary for egg production. Without adequate nesting materials, the birds may have lacked necessary stimuli to initiate egg production (Lehrman, 1959). Only four eggs were laid by all females during the entire study. With several of the necessary reproductive stimuli lacking (nesting material and nutritional requirements) egg production ceased (Johnson and Fisher, 1959). Once egg production ceased, the additional requirements for proteins and minerals also decreased; consequently, the lower consumption of soybeans in phase three. Because of the indications that bobwhite quail, with gustatory and olfactory senses unimpaired are capable of selecting a food which best fulfills their particular nutritional requirements, corn, a good maintenance food (Nestler, 1949), replaced the previous high intake of soybeans.

Phase Four

Data obtained in phase four, with ground yellow grain and nostrils plugged, are listed in Table VII. Because of the high mortality during the previous phases, a different group of bobwhites was used for phases four and five. There should have been minimal differences between the two groups of birds because of the number of individuals involved. However, Goatcher and Church (1970) found that the physical condition of a bird will affect the amount of food consumed and the second group of bobwhite were in much better physical condition than

Table VII. Amounts of ground, yellow grain consumed with the nostrils plugged. Each quantity represents the total amount consumed by all individuals since the previous weighing period.

Date	Days*	Grams			
		Wheat	Corn	Milo	Soybeans
09 August 1975	4	68.8	220.5	385.4	88.8
	8	218.0	233.9	162.8	76.0
	12	296.7	222.5	92.3	98.6
	16	258.0	154.5	162.1	120.5
	20	152.2	171.6	206.2	121.4
	24	172.6	159.7	228.8	91.5
	28	217.2	144.2	201.2	146.3
	32	121.3	122.2	207.3	167.2
	36	105.0	166.0	198.6	130.3
18 Sept. 1975	40	145.5	102.4	160.8	111.0

* The number of days elapsed since the beginning of phase four.

the original group was at the end of phase three. All combinations with soybeans showed a significant difference in amounts of grain consumed (Table IV).

The fourth phase produced highly variable fluctuations in the amounts of grain consumed from one weighing period to the next, without one particular seed type dominating (Figure 13). As with the first group of birds, the second group had an initial preference for milo and corn over wheat and soybeans probably because they were accustomed to eating milo and corn at the Quail Farm (Figure 13). Each of the cereal grains was either the largest amount consumed or the smallest amount consumed at one point during the fourth phase. Soybeans, however, was the least consumed of all grain types. Simple linear regression (Figure 14) illustrates the uniformity of the amounts of milo, wheat, and corn consumed, with the amount of soybeans eaten being significantly less.

Bobwhites showed no consistent preference for any one type of seed when the nostrils were plugged. This indicates that the sense of "external" olfaction plays an important role in food selection. The term "external" is used to differentiate it from the possibility of internal olfaction. Welty (1962) stated that it was probable that birds carry odors from the mouth directly to the olfactory receptors, enabling them to smell a food item while it is held in its mouth. However, the data of phase four indicate that when the passage of air through the nasal ducts is eliminated, the sense of internal and external olfaction is at least reduced. That quail may have an acutely developed sense of smell and that this sense may play an important role in food selection was indicated by the data of phase four.

Further evidence of olfactory discrimination in quail was demonstrated by Michael and Beckwith (1955). They buried five grams of a highly preferred food under 10 grams of a low preference food and the quail were able to detect the buried high preference food. Also, Frings and Boyd (1952) concluded that quail acquired a preference for certain feeders which could only be

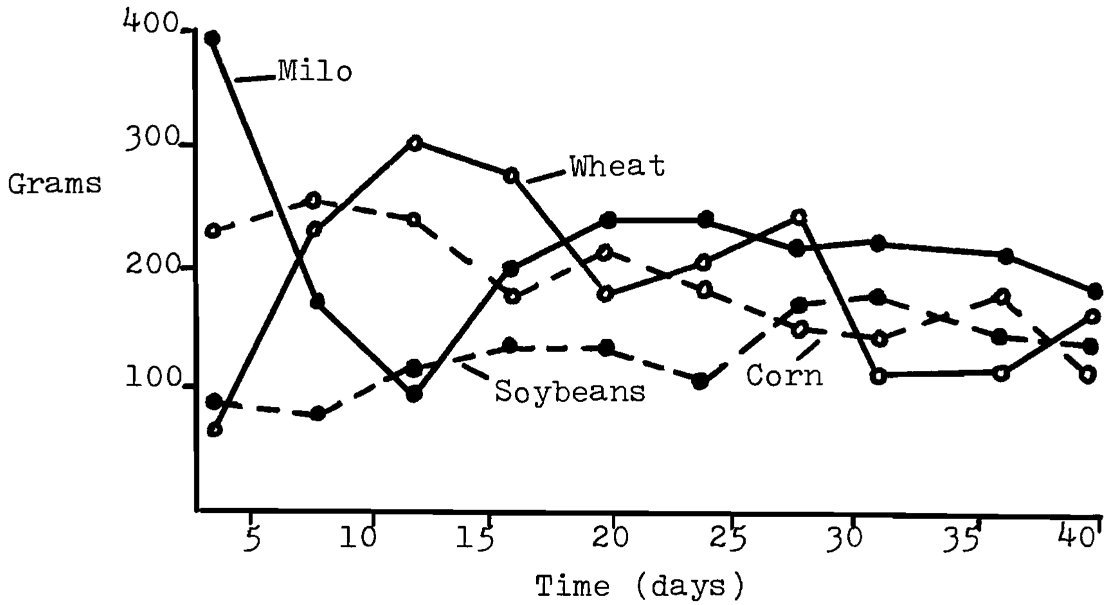

Figure 13. Amounts of ground, yellow grains consumed by bobwhites with plugged nostrils (Phase Four) (9 August to 18 September 1975).

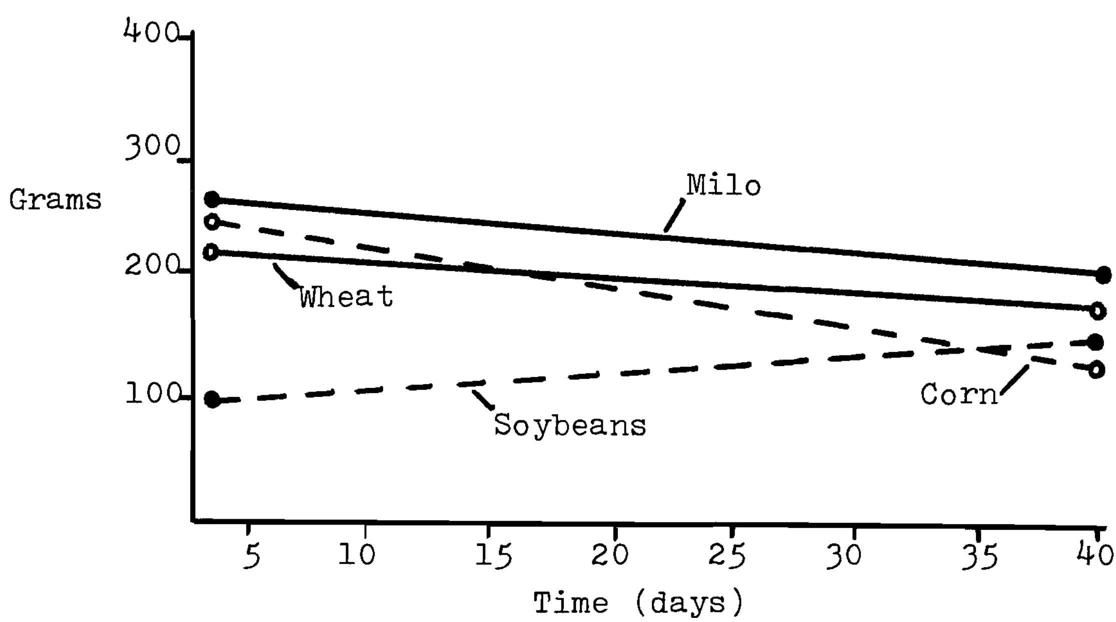

Figure 14. Conditions identical to Figure 13 above only showing simple linear regression.

attributed to the ability of the birds to differentiate odors associated with the feeders. In addition, it has been suggested that birds with an insectivorous diet may have a greater need for a sense of taste than seed-eating birds, since many insects are distasteful (Wallace, 1955; Yang and Kare, 1968). Rosene (1969) found that the animal portion (chiefly insects) of the bobwhite's diet varied from about 30 % in summer to 5 % in winter, with availability of insects being the limiting factor. The fact that insects comprise at least a portion of the bobwhite's diet further supports the conclusion that bobwhite quail have a well developed sense of smell.

Phase Five

A problem developed when birds, with unplugged nostrils, were fed whole kernel, natural-colored grain in phase five. Seeds of corn and soybeans were taken from the feeder, held in the mandibles, and then dropped into the feces, without being eaten. To remedy the situation, seeds were removed from the feces, washed, dried in a plant drier for several days, and then weighed. The results of phase five are listed in Table VIII.

Phase five was discontinued after 12 days for two reasons. First, the task of picking seeds out of the feces, washing, drying and then weighing was laborious. Secondly, data indicated that the amount of each seed type consumed was quite constant. There was a significant

Table VIII. Amounts of whole kernel, natural-colored grain consumed when nostrils were unplugged. Each quantity represents the total amount consumed by all individuals since the previous weighing period.

Date	Days*	Grams			
		Wheat	Corn	Milo	Soybeans
18 Sept. 1975	4	71.1	58.2	236.6	51.0
	8	102.9	39.4	275.4	51.1
26 Sept. 1975	12	93.4	44.5	286.2	40.6

* The number of days elapsed since the beginning of phase five.

difference between all combinations with milo and no significant difference between all other combinations (Table IV).

Even though corn and soybeans were taken from the feeders, little of either type was consumed. Failure to eat these types was apparently due to their large size. Errington (1939) stated ".....one may justifiably expect bobwhites sooner or later to sample or to eat incidentally almost all objects of swallowable size occurring in their habitats". Whole grains of corn and soybeans are of swallowable size for bobwhites, but preference was shown for the smaller size seeds of milo and wheat. Furthermore, the bobwhites exhibited a preference for milo over wheat, with significantly more milo consumed in phase five.

Mortality

There were numerous bobwhite deaths during this study. During the first four months nearly one-half of the bobwhites died. Ruffled feathering with wing primaries standing out from the body and drooping, diarrhea, and swollen and watering eyes were symptoms evident in each case of bird mortality. Stoddard (1936) and Nestler and Bailey (1943) listed the same symptoms in describing vitamin A deficiency.

In animal nutrition, vitamin A ranks first in importance among the vitamins (Morrison, 1950). True vitamin A does not occur as such in feeds of plant origin. However, green-leaved plants and certain other feeds of plant origin contain substances grouped under the term "carotene" which can be converted to vitamin A within the bodies of animals. Even though carotene is not stored as efficiently as true vitamin A in the liver, Nestler (1949) found that bobwhite quail weight, food consumption, and egg fertility were unaffected, regardless of whether true vitamin A or carotene was fed. Nestler also revealed that pen-reared bobwhites cannot survive long without access to true vitamin A or carotene, even though they were fed an abundance of wholesome and nutritious foods. Of the four seeds utilized in this study, corn was the only one which contained appreciable amounts of carotene or vitamin A (Table V). Yet, yellow corn will not meet the vitamin A requirements of laying hens (Nestler, 1949).

Vitamin A deficiency can be corrected by providing the birds with green plant material (Stoddard, 1936). In addition to providing vitamin A, green vegetation will also provide riboflavin which is not abundant in seeds. Vitamin D, which is also important in bird nutrition, was also missing in this study, since the natural stimulus of vitamin D synthesis is the sun. Stoddard (1936), Michael and Beckwith (1955), and Ellis (1961) all indicated that continuously restricted bobwhite diets consisting of from one to several seed varieties almost invariably caused symptoms that are characteristic of a shortage of vitamin A. Michael and Beckwith (1955) also found that quail generally maintained their body weight for only 7-15 days on a diet consisting solely of one seed variety, even though it was a highly preferred seed; and that changing the diet to another kind of seed or adding another one or two kinds of seed to the diet failed to alleviate those conditions.

This study was discontinued from 22 April until 5 May in order to provide a period during which the birds were fed green plant material. This appeared to stabilize the health of the birds and mortality was decreased during that time.

Total Consumption

The total amounts of the four seed types consumed in phases two through five are listed in Table IX. It is important to not compare the amounts of grain consumed between phases too critically because the number of days that each phase was conducted differed and the number of birds differed because of deaths. However, bobwhite quail showed the least preference for wheat

Table IX. Total quantities of the four types of seed consumed in phases two through five.

Phase	Grams			
	Wheat	Corn	Milo	Soybeans
Two	522.5	1104.3	1033.3	2818.7
Three	500.3	1170.4	1107.9	872.7
Four	1755.3	1697.5	2005.5	1151.9
Five	267.4	142.1	798.2	142.7
TOTALS	3045.5	4114.3	4944.9	4986.0

in most phases except when the nostrils were plugged in phase four. Also, the total amount of wheat consumed (3045.5 grams) was considerably less than the other three types, with over half of the wheat consumed (1755.3 grams) in phase four when the nostrils were plugged. These data seem to indicate that wheat has an odor which makes it less desirable for bobwhite quail when presented as one choice among wheat, corn, milo, and soybeans. Total consumption of milo and soybeans differed by only 41.1 grams with more soybeans eaten than any other grain. If the amounts of seeds consumed in phase five were omitted, the total consumption of corn and milo would be similar (corn - 3972.2 grams, and milo - 4142.7 grams). This could be indicative of the fact that the birds were fed only corn and milo at the Quail Farm and were, therefore, more accustomed to eating them.

Suggestions For Similar Studies

There are several possible changes which could be made if one were to attempt a similar study. First, house the birds outside in pens where they could have exposure to sunlight and especially to green tender vegetation. This would probably reduce mortality considerably. Secondly, an attempt should be made to put the seeds in pellet form, which would further reduce the size and shape variations. Finally, each phase could possibly be continued for a longer period of time with all phases being conducted concurrently. It is hoped that these suggestions may aid future investigators attempting to do a similar study with birds.

SUMMARY

This study was conducted from March 1975 to October 1975 to determine whether or not bobwhite quail are capable of discriminating among several selected seed types on the basis of taste. The study was divided into five phases with the amount of each type or color of seed consumed compared in each phase.

Bobwhite quail showed a preference for yellow colored grain over green, red, and blue grain in the first phase, possibly because the yellow grain was most visible against the background. In addition, bobwhite may have an innate physiological mechanism which may aid a bird in associating green color with essential nutritional requirements normally obtained from green vegetation.

Phases two, three, and four indicated that bobwhite quail can detect the nutritional content of food items either by taste, smell, or a combination of both. With the increased requirements for protein and calcium during egg production, the birds can select the grain which best fulfills their nutritional requirements. The sense of olfaction may play an important role in food selection. However, when the passage of air through the nasal ducts was eliminated, the sense of olfaction was reduced. Finally, some type of odor associated

with wheat made it less preferred than corn, milo, and soybeans.

Bobwhites consumed little whole grain corn and soybeans in phase five apparently because of the large seed size.

A short introductory period may be necessary for the bobwhite to become accustomed to new food items.

It is doubtful that seeds alone are sufficient to satisfy the nutritional requirements of experimental quail. The seeds lack sufficient vitamin A and riboflavin which are important vitamins in quail nutrition.

This study did not establish that taste and smell are critical cues or even necessary under natural conditions, but that bobwhite quail have the physiological ability to discriminate among seed types with a combination of the olfactory and gustatory senses, with the sense of smell more refined and developed than the sense of taste.

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