PLANTS FOR IMPROVING LAND-USE AND BOBWHITE HABITAT IN NORTHWESTERN OKLAHOMA

By

WILLIAM R. HANSON II

Bachelor of Arts

Montana State University

Missoula, Montana

1943

Submitted to the Faculty of the Graduate School of
the Oklahoma Agricultural and Mechanical College
in Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY
July, 1953

PLANTS FOR IMPROVING LAND-USE AND BOBWHITE HABITAT IN NORTHWESTERN OKLAHOMA

Thesis Approved:

Thesis Adviser

H. J. Featherly

F. M. Baumgartner

W. H. Irwin

Roy W. Jones

Geo. A. Moore

D. G. McFetridge

Dean of the Graduate School

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ILLUSTRATIONS

Figure Page

INTRODUCTION

Today there is a widespread movement to improve wildlife environment by manipulating food and cover plants. It is generally agreed that most of this environmental improvement of necessity will be done by the farmer and rancher. Nevertheless, few of them will establish plants for wildlife unless the plants also benefit their use of land (Davison, 1942; Graham, 1944 and 1947; Van Dersal, 1940).

Since there has been no previous investigation of which plants are most likely to improve bobwhite habitat and man's use of land in northwestern Oklahoma, the present study was undertaken. Its objectives were to ascertain (1) the winter food habits of quail (Colinus virginianus L.) in northwestern Oklahoma, (2) the ecology of plants valuable to both quail and agriculture, and (3) the uses to which these plants could be put.

This investigation was part of a broader study of bobwhite quail ecology carried on for some years by workers at the Oklahoma Cooperative Wildlife Research Unit. Aspects of the study elaborated by other workers have included the statewide winter food habits of quail, the gross patterns of vegetation most favorable at different seasons, the effects of certain habitat factors, and population characteristics of quail.

Field work was followed on a full-time basis from September

20, 1950, to September 1, 1951. Several trips of short duration also were taken to the study area during the winter of 1951-52, and during that of 1952-53.

Field work was conducted in northwestern Oklahoma, principally in the county of Woodward. Investigations, however, were also carried out in Harper and Ellis Counties, and to a lesser extent in several other western areas. In addition, some of the plant species were studied by me in other Great Plains states prior to the beginning of the project. Headquarters for the field work were at the Southern Great Plains Field Station, Woodward, Oklahoma.

The area considered in this report, unless stated otherwise, will be taken more or less arbitrarily as all of Oklahoma west of the eastern limit of the mixedgrass-eroded plains game type of Duck and Fletcher (ca., 1944) and north of the southern edge of Roger Mills and Custer Counties. The eastern edge of the mixedgrass-eroded plains type follows in a general way the parallel of ninety-eight and one-half degrees of west longitude.

ACKNOWLEDGEMENTS

I am greatly indebted to Walter P. Taylor, retired Unit Leader, Oklahoma Cooperative Wildlife Research Unit, for direction of the field work; and to A. M. Stebler, present Unit Leader, Oklahoma Cooperative Wildlife Research Unit, for direction in the preparation of this report. The Wildlife Management Institute contributed generous financial assistance to the project. Office space and other facilities were provided at the U. S. Southern Great Plains Field Station, Woodward, Oklahoma, by D. A. Savage, formerly Superintendent.

For a wealth of information regarding the ecology and use of numerous plants I am very grateful to J. E. Engleman, U. S. Soil Conservation Service, Woodward, Oklahoma, and to E. W. Johnson, U. S. Field Station, Woodward. Others providing valuable information on the ecology and use of certain plants were E. H. McIlvain, U. S. Field Station, Woodward; Jack R. Harlan, and H. I. Featherly, both of Oklahoma A. and M. College; and F. W. Albertson, Fort Hays Kansas State College. V. L. Cory, Southern Methodist University, identified numerous plants. A. C. Martin, U. S. Fish and Wildlife Service, Laurel, Maryland, identified the seeds of certain species.

In connection with the study of the food habits of bobwhite, I became indebted to many persons. F. M. Baumgartner, Oklahoma A. and M. College, was consulted freely regarding the ecology of Oklahoma quail, particularly concerning their

food habits. Franklin Graybill, Oklahoma A. and M. College, assisted in determining the number of quail crops which must be analyzed to provide an adequate sample. The Oklahoma Game and Fish Department provided a special permit for collecting quail after the legal hunting season closed. Rangers of the Oklahoma Game and Fish Department, students of Oklahoma A. and M. College, and numerous sportsmen furnished quail crops for analysis. Many of these crops were analyzed by John L. Steele, Meredith J. Morris, George C. Merrifield, Earl W. Patterson, and Earnest E. Sisney.

Finally, I wish to acknowledge the extensive stenographic and other assistance of my wife, Helen L. Hanson.

THE REGIONAL ENVIRONMENT

Physical Influences

Climate.

The following account of the climate of western Oklahoma is based on material from Wahlgren (1941), Kincer (1936), and the Weather Bureau (1950). The climate is a continental one characterized by hot summers and comparatively mild winters. There are pronounced seasonal differences in precipitation and temperature, and droughts and dust storms occur rather frequently. Some of the highest average wind velocities in the United States are found here. Physiographic influences are insufficient to affect greatly the climate of different parts of the region, but from east to west a pronounced temperature and precipitation gradient occurs. Growing conditions for plants are relatively severe even in the east and rapidly become more so as one travels westward. Although the growing season is 220 days long in the southern areas, it is only 180 days in the western end of the Panhandle. In the winter, temperatures may occasionally drop to 10, or even 20, degrees below zero.

The average annual precipitation for Oklahoma west of the ninety-ninth meridian decreases in a progressive manner westward from 28 inches to 17 inches. The average monthly and annual rainfall for Woodward, Oklahoma is given in Table 1. From the table it will be seen that most of the precipitation

falls during the growing season months of April to October inclusive. January and December are the driest months and May and June the wettest. A prominent feature of the climate is that droughts may strike at any time. Therefore, great variations in precipitation are to be expected. During the period that the field work was conducted, there was some monthly variation from the average precipitation, but the over-all moisture situation remained fairly typical for the region.

Table 1. The Average Precipitation in Inches at Woodward, Oklahoma, Through the Year 1941.

Month	Precipitation
January	.59
February	1.05
March	1.40
April	2.42
May	3.64
June	3.43
July	2.64
August	2.60
September	2.80
October	2.17
November	1.61
December	.79
Annual Precipitation	25.14
Length of Record	40 years

Physiography.

Approximately the western two-thirds of the Panhandle is in the High Plains Region (Fenneman, 1931). It is characterized by vast, very level expanses dissected here and there by stream courses. The aspect is frequently one of monotonous distances unbroken except by man-made structures.

Here and there, shallow sinks, or playas, are to be found. At the extreme western end of the Panhandle the High Plains suddenly merge into a semimountainous area, the foothills of the Rockies. Although the region appears nearly level, it slopes gradually downward to the east. Elevations vary from an average of about 4,000 feet in the west to about 1,500 feet in the eastern part of the Low Plains.

There is a transitional belt between the High Plains on the west and the Low Plains on the east. Its eastern boundary runs diagonally from the southeastern corner of the Panhandle toward the northeast to Kansas. This transition area is a moderately dissected plain. Large, level plateaus alternate with rolling or hilly terrain.

The remainder of the western part of the state is eroded, generally rolling country called, appropriately, the Low Plains (Fenneman, 1931). Here the surface strata belong to the Permian Redbeds. Into the surface plain, streams have cut broad, sand-choked channels, often bordered by extensive dunes. Geologic erosion has had a greater effect than westward, and the region is not only more dissected but lies at a lower level. There are areas with precipitous bluffs and deep ravines and extensive tracts of rounded hills separated by swales. The more hilly areas along the northwestern side of the Low Plains are often referred to as the Gypsum Hills Region (Snider, 1917). In general, widespread physiographic influences are not enough to affect greatly the vegetation within one part of northwestern Oklahoma as compared

to another. Some of the variations in physiography in western Oklahoma are shown in Figures 1 and 2.

Soils.

Northwestern Oklahoma, except for the very western end of the Panhandle, is in the great soil group of the reddish chestnut soils. In this group the "...surface soils are typically dark reddish brown and friable, and the subsoils heavier and tougher, reddish brown to red in the upper part and lighter or grayer in color and highly calcareous in the lower part" (Bureau of Chemistry and Soils, 1938). The redness is due to the parent material, the organic matter in the surface horizon having failed to darken it (Marbut, 1936). Greater amounts of organic matter have failed to accumulate in part because of erosion. Nevertheless, the reddish chestnut soils are fertile, being the equivalent of the chernozem soils found nearby to the north.

Because of low rainfall, little leaching has occurred in western Oklahoma. "Consequently, most of the soils in this area are well supplied with minerals containing available plant nutrients" (Chaffin, no date). Even though these soils are adequate in minerals now, they will be generally deficient in phosphorous in the foreseeable future if they are continuously farmed to cash crops (Daniel, Elwell, and Murphy, 1942). The principal soil deficiency, then, at the present time is organic matter.

Figure 1. Rough, broken country in the Gypsum Hills near Waynoka, Oklahoma. Stockpond in foreground and valley of Cimarron River in the distance.

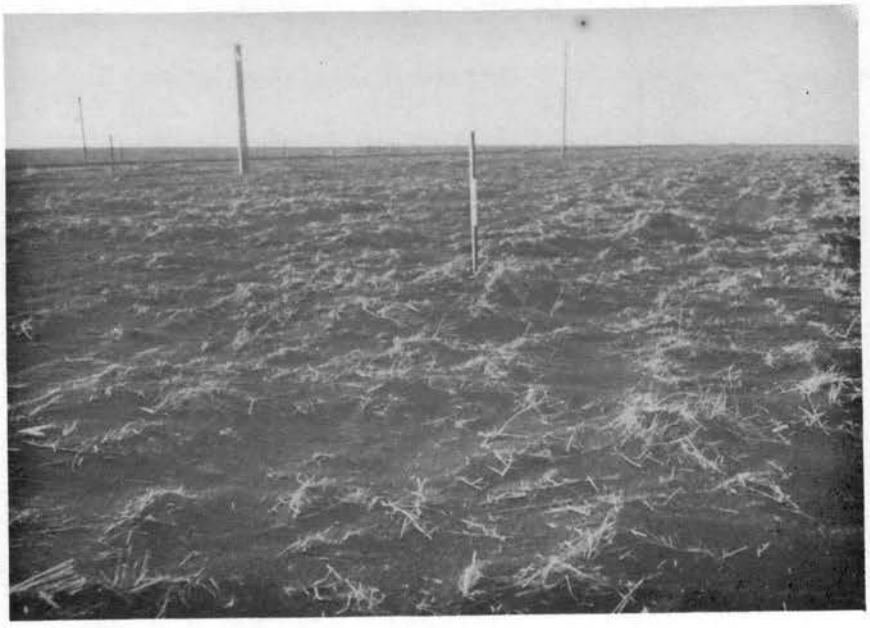

Figure 2. Very flat terrain and large grain fields typical of much of the High Plains. Near Guymon, Oklahoma.

The texture of the soils of western Oklahoma is predominantly sandy. Some areas, for example the extensive dunes along the major river courses, or the rolling sandhills in Ellis and Roger Mills Counties, have exceedingly light soils. The effects of wind erosion, therefore, are often severe (Figure 3). The soils of the level or gently rolling country in the Panhandle are usually deep sandy loams. Because of the relatively level topography and permeable soils, water erosion is not usually serious there although the effects of wind can be. This area was in the heart of the "Dust Bowl" of the '30's. The soils, in the Low Plains Region, in general, are considerably heavier than to the westward. The texture is often a silty loam or clay loam. The heavier soils and more broken relief intensify water erosion but lessen that of wind (Finnell, 1939) (Figure 1).

Land-Use

The northwestern part of the state falls in the general wheat and small grains farming region (Bureau of Agricultural Economics, 1950). Hard winter wheat is the chief farm enterprise, but it is grown in combination with large acreages of sorgums. Field crop acreage, as of 1945, averaged between 30 percent and 40 percent of the available amount in most of the counties of this region (Oklahoma State Board for Vocational Education, 1950). Cultivation is generally less intensive than in many areas of southwestern Oklahoma. Nevertheless, there are places in the Panhandle where virtually unbroken fields of grain stretch for miles (Figure 2). Crop

rotations are based on a very few crops. One reason is that there are few or no generally satisfactory legumes for the region, especially for the Panhandle (Bureau of Agricultural Economics, 1950). Another difficulty is that one can summer fallow cropland only on the finer-textured soils because of the ever-present exposure to wind erosion (Chaffin, no date). Wind erosion as a result of very light soils and scanty plant cover is shown in Figure 3.

The southern Great Plains, of which Oklahoma is a part, is an important livestock producing region. In western Oklahoma the percentage of land in pasture varies from 50 percent to 60 percent (Oklahoma State Board for Vocational Education, 1950). Woodward County produces considerably more cattle than any county bordering it. Much of this part of the state is very heavily grazed, and there seems no doubt that this has an important bearing on wildlife populations.

A pronounced trend toward larger farms or ranches exists (McMillan, 1949). Also, there is a trend toward regrassing of marginal land formerly cultivated (Figure 4). A number of shelterbelts are used, especially to the southward. Unfortunately, shelterbelts are being eradicated, to make way for new cropland, faster than they are being planted according to H. R. Wells, State Forester, U. S. Soil Conservation Service (personal communication). Numerous farm ponds have been established, but few of them have been fenced and so are of reduced value to wildlife.

Figure 3. Wind erosion on a very sandy soil planted to a row crop (sorgum). The shrubs catching soil are aromatic sumac. Near Woodward, Oklahoma, in the sandsage game type.

Figure 4. Abandoned field which has been revegetated with sand lovegrass, switchgrass, and blue gramagrass three years previously. (Compare with Figures 19 and 20.) Ten miles northeast of Woodward, Oklahoma.

Vegetation

Historical Accounts.

In 1820 Edwin James traveled eastward down or near the South Canadian River with the S. H. Long expedition (James, 1905). He says, "...The luxuriance and fineness of the grasses, as well as the astonishing number and good condition of the herbivorous animals of this region, clearly indicate its value for the purposes of pasturage." James tells of soft sand under foot in many places and immense drifts piled along the river banks. He speaks of plum bushes as being almost the only woody plants found on the sand hills. Nothing is said of the extensive tracts of shinnery oak which now occupy the area through which the expedition must have come. (The scientific names of all plants mentioned in this report are given in Table 22.) Near what was perhaps the center of the Texas Panhandle this party first encountered, as they traveled east, the bobwhite at approximately its present westward limit.

Washington Irving traveled across what is now eastern and central Oklahoma in the fall of 1832. Some of the observations in his account (Irving, 1926) should apply also to the western part of the state. Only short grasses, which he calls "buffalo grass", are mentioned here and there. Much comment was made about the density of trees, shrubs, and vines along stream courses and the difficulty of passing through

them. This contrasts with the open growth usually present in such situations now. Repeated references were made to the frequence and extent of fires on the prairie resulting from the activities of Indians.

Gregg (1845) also found extensive sand dunes along the rivers. Gregg, in contrast to James, found the sand plum and species of shinnery oak abundant on the dunes. He says, "We also met with the same in many other places on the Prairies."

Bigelow (1856) made extensive collections of plants along the South Canadian River as he traveled westward across Oklahoma. Sandsage was only collected on "rocky hills on the Canadian" although it is very abundant on sandy soils in northwestern Oklahoma today. As found by James, there were no noteworthy tracts of brush such as exist now in western Oklahoma. Some forbs common now were also common in the 1850's; in this category he places "Helianthus, Euphorbiaceae, and shrubby and herbaceous Mimosae."

At about the time Bigelow was in the state, T. T. Woodhouse (1858) traveled west along the North Canadian River to the Gypsum Hills. His account seems to substantiate several points of earlier writers: fires set by Indians were very prevalent; pasture for horses was hard to find; no mention is made of tall grasses, except along one river bottom; and, the rivers "ran red with mud" after rains.

Present-Day Vegetation.

In discussing the communities of a region it is often useful to begin by reviewing the classification adopted by

some other workers. Authors treating the biotic communities of western Oklahoma have used different names for their communities and have discussed ones of different rank. The whole of western Oklahoma is in the mixed prairie association of the prairie biome of Clements and Shelford (1939); the high plains community, or one transitional to it from the eastern forest community, of Webb (1950); the great plains biome of Allee, et al. (1949); and the Kansan biotic province of Dice (1943). These larger areas were subdivided by Blair and Hubbell (1938) as the short-grass plains biotic district of the Panhandle and northwest, the mesquite plains district of the extreme southwest, the Wichita district of the Wichita Mountains in the southwest, and the mixedgrass plains district occupying the remainder of western Oklahoma.

Speaking now of vegetation only, one finds that approximately the western one-half of Oklahoma was called the mixed prairie association of the prairie formation by Weaver and Clements (1938). On the basis of the Clementsian terminology, Bruner (1931) classified the vegetation of the state but differed by assigning the short grass vegetation the status of a climax. Weaver and Clements, however, subsequently showed the latter to be dominated by both short and mid-grasses and, hence, that the mixed grass association is the climax.

The otherwise valuable study of Bruner seems weakened by his designation of the Oklahoma mixed prairie as the Stipa-Koeleria association since Stipa extends into the state for only a short distance in the region where he states this association to occur and then is sparsely distributed (Featherly,

1946). Blair and Hubbell (1938) followed Bruner in calling this the Stipa-Koeleria association. Furthermore, the inclusion of the chaparral, that is, the shinnery oak area, in the eastern deciduous forest formation by Bruner appears of questionable merit. The majority of the species of shinnery oak reach their northeastern limits along the western edge of Oklahoma and extend from there into southwestern Texas, New Mexico, or even farther west (Wooten and Standley, 1915). The shinnery oak region is separated by about ninety miles from the main body of the nearest deciduous forest, and so its affinities are apparently more particularly with the southwestern scrub vegetation.

A game type map developed by Duck and Fletcher (ca. 1944) compares well, for northwestern Oklahoma, with a map of communities published earlier by Blair and Hubbell (1938). Both of them in turn compare well, for the northwestern part of the state, with the map of vegetational units published still earlier by Bruner (1931).

The study, important for present purposes, of Duck and Fletcher (ca. 1944) will be discussed here in more detail since their ecologic regions will be referred to from time to time. These regions they called "game types", and they are stated to represent a correlation of vegetation, physiography, soils, climate, and land-use in relation to game populations.

The mixedgrass-eroded plains game type of Duck and Fletcher extends north-south across the state, its eastern edge coinciding fairly well with the parallel of ninety-eight and

one-half degrees of longitude. The region extends westward to the vicinity of the origin of the Panhandle, but here is somewhat interspersed with other game types. Most of the mixedgrass-eroded plains type has a definite ravine relief, and it lies in the Low Plains Physiographic Province (Figure 5). Important dominants are buffalo grass, blue gramagrass, sideoats gramagrass, and little bluestem. In the southwestern part of the state there are extensive areas characterized by open stands of mesquite although small areas of mesquite exist also in the northwest. Weaver and Clements (1938) have discussed the climatic reasons for the gradation of the tallgrass community into the mixedgrass community. Soils characterized by heavier textures and steeper slopes are typical of this game type (Finnell, 1939). The principal game species today are bobwhite and mourning doves, with a few pheasants to the north and west.

In northwestern Oklahoma and extending across the Panhandle is found the shortgrass-high plains game type (Figures 2 and 18). The dominant vegetation is buffalo grass, blue gramagrass, sideoats gramagrass, and several species of threeawn grass. Near the center of the Panhandle, the bobwhite population finds its principal western limit in the state, the scaled quail its eastern limit (Duck and Fletcher, ca. 1944). Mourning doves are important game species and the principal pheasant range of the state is found here. A small herd of antelope is present in the western part of the Panhandle. Rapidly decreasing rainfall, strong winds, comparatively smooth topography, tighter soils, and increasing elevation

all combine as one proceeds westward to account for the abundance of short grasses, few shrubs, and fewer trees.

A high agreement among ecologists concerning this type is apparent. Furthermore, the community coincides quite closely with the High Plains Region of physiographers. Perhaps, one reason for the agreement of ecologists, in regard to the boundaries of the shortgrass community, is because of its relative uniformity. Some of the other communities, as the mixedgrass-eroded plains, are so variable that it has been difficult to determine what areas should be included in them and what areas should not be. Not only is the shortgrass community relatively uniform, but it is set off rather sharply from adjacent communities, at least in Oklahoma. This is due probably to the relatively level topography and the medium-textured soils since generally the topography is more rolling and the soils either lighter or heavier in adjoining game types.

The sandsage game type occupies the deep sands and/or dunelands along the major streams and is characterized by an extensive mixture of sandsage, aromatic sumac, sand plum, bumelia, netleaf hackberry, big and little bluestem, sand bluestem, switchgrass, and Indiangrass (Figure 6). Small areas on the north sides of the Cimarron and the North Canadian Rivers were classified as belonging to the stabilized dune type. The principal difference, according to Duck and Fletcher, between the latter and sandsage type is the presence of higher dunes and the more frequent trees of the stabilized dune type. These two dissimilarities seem to be of insufficient

Figure 5. An area representative of the mixedgrass game type. Five miles north of Quinlan, Oklahoma. Ravines dominated by American elm; oat field nearer, and prairie sunflower along roadside.

Figure 6. An area representative of the sandsage game type. Eight miles northwest of Woodward, Oklahoma. Aromatic sumac in lower left corner of picture; larger shrubs toward right center, netleaf hackberry; and other shrubs, sandsage. Background cleared of brush.

magnitude to justify recognition of the two types. In this report, henceforth, both will be considered together as the sandsage type. The bobwhite populations of these areas are among the densest in Oklahoma, and in winter there is even a considerable influx of quail from adjacent regions.

In the extreme west-central part of the state, there is a fairly large area named the shinnery oak-grassland type. Bruner (1931) called it the chaparral association. The dominants are the shinnery oak and several species of tall- and mid-grasses (Figure 7). Where grazing is not too severe, by far the most abundant grass is little bluestem. Although the soils are also extremely sandy, the sands do not lie in dunes along major rivers. Sandsage is not nearly so abundant here in spite of the sandy soils. The local topography consists of small hills and broad drainage ways; few ravines are found as water erosion has not made any appreciable headway. The principal game species are bobwhite, lesser prairie chicken, and mourning doves, and a few flocks of turkeys range near the Washita and South Canadian Rivers in the region close to the Texas boundary.

The bottomland timber type is found principally along major streams, but greater or lesser tracts may be located along creeks and even in the larger ravines (Figure 8). This type is a western extension of the deciduous forest (Weaver and Clements, 1938). The dominant trees are American elm, green ash, cottonwood, bumelia, and netleaf hackberry. Because of a higher water table and/or the flow of run-off water to the lower places which the community occupies, there is

Figure 7. View of clumps of shinnery oak in the shinnery oak game type, three miles west of Sharon, Oklahoma. Lower plants in foreground, Texas croton. Yardstick shows height of nearest clump.

Figure 8. View of bottomland game type along Wolf Creek just above junction with North Canadian River, Fort Supply, Oklahoma. Taller trees in foreground mostly cottonwood.

considerable soil moisture.

All of the game types just discussed occur abundantly in the counties where most of my field work was carried out, that is, in Woodward, Harper, and Ellis Counties. A number of quail crops for food habits analyses were taken in each of the game types described above. Most of the field investigations of plants, on the other hand, were made in the sandsage, and the mixedgrass types.

METHODS

Quail Food Habits

The methods followed in the analyses of crop contents were similar to the ones employed by Baumgartner, Morris, Steele, and Williams (1952). Any crop that contained even a trace of material was saved for analysis. The percentage by volume of a food was computed according to the aggregate volume method of Martin, Gensch, and Brown (1946). That is, the total volume of a particular food from all of the crops analyzed in a series was divided by the total volume of all food in all crops of that series. Since Martin (1949) has pointed out the fallacy of making an unjustified specific determination of materials in the crop, identification to the species was not attempted unless there were good grounds for so doing. Animal foods were listed only as such; green vegetation was ordinarily not further identified.

The size of sample required in food habits investigations is always perplexing. The following method, however, was used in determining this for the sandsage community, which was selected as an example. First, a pilot study was made to secure needed information. From it the fifteen foods eaten in greatest volume were determined. Then from these fifteen foods the one was selected, the quantity per crop of which varied greatest in the pilot series of crops.

The size of sample which would give a reliable estimate

of the mean volume of the food item found to be most variable, as to volume in the crop series, was next computed. It was assumed, then, that a sample large enough to give a reliable estimate of the food occurring in most varying volumes would also be large enough for the other foods occurring in less varying volumes, provided the food was among those fifteen foods eaten in greatest volume. According to Snedecor (1946), the required size of a sample is found from the formula:

$$n = t^2 s^2 / (\bar{x} - m)^2$$

In this formula n is sample size, t is the ratio of $\bar{x}-m$ to the standard error, s is the variance, $\bar{x}$ is the mean of the sample, and m is the true mean of the whole population.

Investigation of Plants

The relative abundance of plants within the western part of the state and adjoining regions was estimated from available reports supplemented where possible by some personal observations.

The morphology of plants is of obvious importance to quail, as well as to other animals. The gross structure of the plants of a species is relatively fixed, of course, and the inspection of even a few plants ordinarily showed the characteristic form. Where grazing, browsing, wind, or other influences altered the growth form to a considerable extent, this was noted.

The general site requirements of various plants were continually observed. Attention was paid to surface relief,

exposure, soils, and soil moisture conditions. Soil textures were approximated by inspection. In some cases use was made of the detailed Woodward County soil survey (Fitzpatrick and Boatright, 1938) to establish the soil types where certain species were found. Indicator plants were of considerable value in assessing some of the site factors. Where the requirements of certain species were quite well-known, these species were then used to indicate the habitat factors affecting the distribution of associated species. The cautions of various writers in regard to use of indicator species were kept in mind (Davidson, 1952; Pelton, 1951; Sampson, 1939; Shantz, 1911).

Earlier reconnaisance, and later more intensive observation, often showed the communities where certain species were typically found. To find the stage, or stages, of succession occupied by various species, areas affected by different degrees of disturbance were inspected. Indicator plants, extent of erosion, and other signs of man's activities frequently showed the amount and duration of disturbance. On the other hand, communities relatively well-protected from agricultural disturbance for some time provided an estimation of the relations of different plants to the climax. A protected area thus studied was Boiling Springs State Park, about five miles east of Woodward, Oklahoma. Such reservations are, as a result, of great value in providing areas of reference for ecological investigations.

The time, manner, and rates of growth, and of reproduction were followed as far as could be. Events frequently noted

were the time of first annual growth of herbaceous plants and first maturation of fruit. Also occasionally recorded were the dates at which various amounts of the seeds or fruits of some plants had become dispersed. Where it was not already well-known or where there was some question concerning competitive ability, the principal means of reproduction was noted. Particular heed was paid to qualities which might make a non-native species a pest. The rarity or uncommoness of native or naturalized species was considered in the light of possibly poor competitive capacity.

The status of winter-growing plants was investigated in a preliminary way from the standpoint of identity of species, distribution, abundance, and time and rate of growth. Because there seemed to be no previous inventory of species which make some growth in winter, considerable effort was made to identify as many of these plants as possible. Where the plants could not be identified in the vegetative state, they were potted and removed to the greenhouse at the Southern Great Plains Field Station and grown until they flowered. A few still remain unidentified, and doubtless others were unnoticed. Many aquatic or semi-aquatic plants remain green in winter in western Oklahoma; none of these was considered in the investigation. Trees were ignored as well as all species grown for ornamental purposes. Plants which had green leaves as early as February were considered true winter-growers for the purposes of this study. Although most of the plants developing green herbage were found to be herbs, a few were partly shrubby. The relations of these plants to site and land-use

was estimated from a few transect studies and other observations. In February 1951, twelve transects were examined for winter-growers in representative situations in the western part of the state exclusive of the Panhandle. Each transect was two hundred yards long and two feet wide; the dimensions usually were estimated by pacing. A list was kept of each species and the number of its individuals occurring along the transects. A determination was made of the general type of soil and kind of land-use where each transect was located. In February 1953, twelve more transects were examined in the vicinity of Woodward, Oklahoma. The procedure followed with respect to these was the same as that followed in 1951.

When studying the plants, the principal question kept in mind was whether or not the species would in some way be useful in land management. Observations were continually being made of the nature and extent of land-use practices affecting quail food and cover plants. Also, note was made of the areas where farmers or ranchers used shelterbelts, living fences, field borders, or other possibly beneficial practices, or of areas where they might do so.

The investigation of some non-native species had to be largely limited to observation of their performances in nurseries since they were grown little or not at all elsewhere in the region. For this purpose, the nurseries of the U. S. Southern Great Plains Field Station were especially valuable.

QUAIL FOOD HABITS

While examining the results of the quail food habits study, several cautions should be kept in mind. It must be remembered that the environment is a constantly fluctuating one and that conditions in it change from day to day and place to place (Dice, 1952; Hesse, Allee, and Schmidt, 1937). To get any adequate idea at all of the food relations of quail of even a single community, one would have to continue such an investigation through each month of a period of years. Since land-use practices and climate particularly are known to vary with time, it seems mandatory to investigate quail food habits for a number of years in any one region. Even then, it would still be difficult to interpret preference on the part of quail and availability and abundance of food. Yet, if we are going to manage quail in any true sense of the word, such information must be known along with much else.

The crop contents of 701 quail are reported here. The quail have been collected in different years beginning with 1939, but the great bulk of them are from the year 1950. All except some fifty of these birds were killed during the hunting season period, mid-November to the end of December. As a consequence, the crop analyses apply principally to about 12 percent of a one year period. Land-use changes, climatic variations, and seasonal physiological requirements of quail would probably give an entirely different picture if a number

of crops were considered for other years and/or seasons. The analyses of crops from western Oklahoma discussed by Baumgartner et al. (1952) and Lee (1948) were compiled with 350 previously unreported ones to give the total of 701 mentioned above.

Throughout this report, plants are listed by the common names. The scientific names of plants which correspond to the common names are given in Table 22. The scientific nomenclature of most plants is that given by Waterfall (1952); that of many cultivated plants follow Bailey (1949). In most cases the common names are those given by Kelsey and Dayton (1942). Where their common name seemed inappropriate, or where they did not list one, I have used others from various sources.

Since it was very difficult to distinguish between the seeds of certain species or genera, some of the food items have been lumped into one group. For example, pigweed and lamb's-quarter are treated together because of this. Also, in spite of considerable effort, certain kinds of food or food residues remained unidentified.

In the following food habits tables, percentage frequency refers to the percentage of birds which ate a particular food. Percentage volume refers to the percentage which the total volume of a certain food was of the total of all foods eaten.

Classes of Food

It is possible to group broad classes or kinds of food into various categories which may enhance an understanding of such data. Some of the classes of food eaten by the bobwhite considered in this inquiry are shown in Table 2. One notes

Table 2. Classes of Food Eaten by Bobwhite in Western Oklahoma

(Based on 701 crops, and recorded as percentages.)

Game Type	Vegetable Food		Animal Food		Green Herbage		Cultivated Grains		Legume Seeds	
	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.	Vol.	Freq.
Sandsage (236 crops)	98.6	100	1.4	21.4	1.4	25.6	36.2	46.6	2.2	23.5
Mixedgrass (222 crops)	98.9	100	1.1	27.6	1.4	27.6	66.0	72.9	T*	10.8
Shortgrass (139 crops)	98.0	100	2.0	31.7	1.2	30.9	28.5	43.1	1.1	27.7
Shinnery Oak (68 crops)	98.6	100	1.4	19.1	0.9	13.2	29.3	44.1	1.5	20.6
Bottomland (48 crops)	94.7	100	5.3	56.3	2.8	27.1	4.4	8.3	26.4	41.7

*T signifies less than 0.1 percent

that the volume of vegetable food and the volume of animal food were quite consistent throughout the different game types except for the bottomland. Because of the smaller number of crops analyzed from the bottomland for the hunting season period, it is difficult to say if this inconsistency is of any significance.

It is not known why a greater percentage of animal matter was eaten in the bottomland community. We might assume it reflected either a greater availability of animal matter or a shortage of vegetable food. On the other hand, it might indicate some physiological need for such food in this community. The bottomland community is extremely dissected by adjacent game cover types in northwestern Oklahoma. Consequently, there is a considerable diversity of plants and possibly also of insects. If the latter is true, the increased consumption of insects in the bottomland may reflect their greater availability.

Each bird regardless of game cover type ate some vegetable food, and this made up the great bulk of the total food. The frequency of animal food, in contrast to the volume, fluctuated considerably from area to area. The same was true of other food frequencies.

Stoddard (1931) found animal matter to make up a much higher percentage of the diet by both volume and frequency in Georgia and Florida than that shown in Table 2. He learned that crops collected from November to March inclusive contained about 4.5 percent of animal food by volume and about 74 percent by frequency. In the crops examined by Korschgen

for Missouri (1948) vegetable items comprised 97.6 percent and animal items 2.4 percent, which was similar to the results given here. Gray (1940) gave vegetable food as 96.9 percent and animal food as 3.1 percent by volume in Alabama, a result intermediate between that found by Stoddard and by Korschgen. Crops from the summer period showed animal food as being much more prominent in the diet than in winter, according to Stoddard. The same result probably would have taken place had any appreciable number of summer killed birds, particularly young, been secured in connection with this inquiry.

The volume of greens ran low in each game type; approximately one-fourth, however, of all the birds in each type did eat greater or lesser quantities of green material on the day when they were killed. In the shinnery oak area the percentage frequency of greens was considerably lower than in the other types although the reason for this is not known.

In this investigation, green herbage, in all but one type, varied between 1 percent and 2 percent by volume. Stoddard (1931) states that during the winter it increased, reaching its highest point, 23.9 percent by volume, in March. In the study of Davison (1942) of birds from a number of southeastern states, greens made up 1.3 percent by volume. Gray (1940) found they made up 6.23 percent by volume and 63.36 percent by frequency. Chenault (1940) lists some plants for south Texas which he says are "valuable to bobwhite as green food" but he does not give the amount eaten of this kind of food. Green herbage generally seems to be a larger

item of food in the south and southeast than it does here. This might be expected because of the greater availability of greens there as a result of much milder and wetter winters which would favor their growth.

For three of the game types, cultivated grain was noticeably uniform in volume, but in the mixedgrass type the volume used was very high because of the large amount of sorgum eaten. Most of the cultivated grain taken by quail in western Oklahoma was sorgum, and other cultivated foods were usually minor by comparison with it. Little farming is done in the western Oklahoma bottomland type, hence little grain would be available in that community. It must be remembered that this high percentage volume and percentage frequency shown by the grains for the hunting season of 1950 might not hold for other seasons, or possibly even the same season of other years.

In Missouri, corn and sorgum made up about 28 percent of the quail diet (Korschgen, 1948), in Virginia cultivated grains made up about 25 percent (Baldwin and Handley, 1946), in Kentucky corn amounted to about 9 percent (Barbour, 1951), and in south Texas sorgum comprised about 11 percent (Lehmann and Ward, 1941). Grains, therefore, appeared to be an important fraction of the diet during the winter months in all of the states referred to. Nevertheless, in the states mentioned, except Missouri, cultivated grains were lower in percentage volume than in western Oklahoma. Other eastern studies show cultivated food material to be used even less by quail. In Florida and Georgia, for example, all cultivated plants,

whether cereal grains or not, varied in volume each month between 6.3 percent and 1.6 percent from November to February inclusive (Stoddard, 1931). Another study of the southeastern states showed cereals amounting to about 3 percent by volume during the winter (Davison, 1942).

The above indicates that in western Oklahoma the bobwhite probably eats greater quantities of cultivated grain in winter than it does over much of its range. The reason probably is due to the differing land-use as between the West and East. Cultivated grains appeared to be more eaten here because of the greater availability of them and the lesser availability of alternate foods as compared with the East. The difference in time of harvest of grains, and in time when bobwhite were killed for study, may also be responsible for the differing uses of grains.

The last class of food considered in Table 2 is that of legume seeds. As has been noted with other foods, the mixed-grass and the bottomland game types differed considerably as to the amount of legume seed taken by quail. In the bottomland legumes made up an appreciable volume of the total food because of the amounts of small wildbean which were used. The latter appears to be more abundant in the bottomland. The greater consumption of legumes in that community is due probably to greater availability which in turn is due to greater abundance.

The lower volume of cultivated grain taken by the bobwhite in other regions of the nation seems to be offset there by a rise in volume of legumes, whether wild or cultivated. In

the southeastern United States the amount of legumes eaten seems especially high as compared to western Oklahoma. In Florida and Georgia it varied from about 23 percent to 52 percent during the winter months (Stoddard, 1931), whereas in the southeast in general it was about 62 percent (Davison, 1942). In Missouri, legumes accounted for 28.4 percent of the late fall and early winter quail food (Korschgen, 1948). These volumes contrast sharply with the small amounts of legume material found in all but the bottomland type in western Oklahoma.

Changes in Food Use Over a Short Period

It was impossible to learn definitely if the proportions of different foods varied with the seasons through the year because most of the crops upon which this inquiry is based were taken during the open hunting season, a relatively short period of the year. But, since it was desired to weigh this contingency tentatively, a comparison was made between the crops from early in the hunting season and those from a later period. The mixedgrass game type was selected as an example. The nine foods eaten in greatest quantity were selected for comparison. These nine species accounted for 82.2 percent of the total volume of all crops from the mixedgrass area.

Table 3 presents the percentage volumes and frequencies of the food materials used by November-killed birds as compared to ones from December and January. The percentages are given as the ratio of food eaten in the early, or later, season to that eaten during the whole study. Since more

specimens were at hand for November than for the later period, the percentages cannot be immediately compared. This is because the ratios of each period are taken from a common base -- the total food eaten during the whole study. The number of December-January crops equalled only .56 of the number of November crops. Therefore, to make the figures comparable, the percentages for November were multiplied by .56.

Except in the case of sorgum, the percentage volumes given in Table 3 are so low that to draw definite conclusions from them is unwarranted. Contrary to expectations, the volume of sorgum increased with the passage of time. Sumac did not increase later in the winter, as might have been expected, since some writers say that it is eaten in greater amounts when other foods become scarce (Stoddard, 1931; Leopold, 1933). Greens were used more at the later period; perhaps winter-growing vegetation is more abundant later in the winter. The customary explanation for a decline in volume, or frequency, with advance of the season is a decline in availability. However, sorgum, ragweeds, and sunflowers should have declined as much in availability as the other foods; nevertheless, their volumes and frequencies increased or remained about static with the passage of time. Therefore, other factors than availability may be responsible for decline in amount eaten of one food and lack of decline in another. Apparently, either the availability of sorgum, ragweed, and sunflowers declined more slowly than some of the other foods, or the former were especially sought after by quail. Inasmuch as we know little of quail physiology or the change in availability

of different foods, it seems impossible to explain now the true reason for these apparent trends.

Table 3. Status of Nine Quail Foods Eaten During Different Periods in the Mixedgrass Game Type.

(Given as percentages of the total food eaten during the study.)

Species	Nov. 21 - 28 (66 Birds)		Dec. 28 - Jan. 29 (37 Birds)	
	Volume	Frequency	Volume	Frequency
Sorgum	2.8	6.7	15.1	14.8
Spurges	1.0	5.3	T	1.9
Ragweeds	0.9	4.8	1.3	4.8
Johnsongrass	0.6	6.4	0	T
Wheat	0.6	0.5	0.2	1.0
Panicgrasses	0.5	8.0	T	5.2
Smooth Sumac	0.2	0.5	0	0
Green Herbage	T	3.2	1.0	5.7
Sunflowers	T	2.7	T	1.9

The environment of quail, therefore, changes not only from place to place, but from time to time. Other writers have commented on the change in bobwhite food habits with change in season (Stoddard, 1931; Davison, 1949; Errington and Hamerstrom, 1936). The data presented (Table 3) seem to bear out the idea of change in environmental conditions, but insufficient results are present to show how the quail diet varies here from year to year, or over longer periods. We can conjecture that it undoubtedly does, and a comparison of the results of Davison (1935) for the shinnery oak with those given in this report seems to point in the direction of marked change.

of different foods, it seems impossible to explain now the true reason for these apparent trends.

Table 3. Status of Nine Quail Foods Eaten During Different Periods in the Mixedgrass Game Type.

(Given as percentages of the total food eaten during the study.)

Species	Nov. 21 - 28 (66 Birds)		Dec. 28 - Jan. 29 (37 Birds)	
	Volume	Frequency	Volume	Frequency
Sorgum	2.8	6.7	15.1	14.8
Spurges	1.0	5.3	T	1.9
Ragweeds	0.9	4.8	1.3	4.8
Johnsongrass	0.6	6.4	0	T
Wheat	0.6	0.5	0.2	1.0
Paniegrasses	0.5	8.0	T	5.2
Smooth Sumac	0.2	0.5	0	0
Green Herbage	T	3.2	1.0	5.7
Sunflowers	T	2.7	T	1.9

The environment of quail, therefore, changes not only from place to place, but from time to time. Other writers have commented on the change in bobwhite food habits with change in season (Stoddard, 1931; Davison, 1949; Errington and Hamerstrom, 1936). The data presented (Table 3) seem to bear out the idea of change in environmental conditions, but insufficient results are present to show how the quail diet varies here from year to year, or over longer periods. We can conjecture that it undoubtedly does, and a comparison of the results of Davison (1935) for the shinnery oak with those given in this report seems to point in the direction of marked change.

Number of Kinds of Food.

Another clue to the variability of the environment is gained from a different analysis of the data. A study was made of the average number of kinds of food eaten by bobwhite in the different game types (Table 4). Although these differences in the average number of kinds of food eaten may not seem great, they still may be quite important. For example, the birds ate 50 percent more kinds of food in the shortgrass region than they did in the mixedgrass region. Apparently, either a greater variety of satisfactory foods was present and available in certain types, or the quantity of satisfactory food was sufficiently scarce that the birds ate many different food materials in order to secure enough for subsistence.

According to Davison (1942), a large variety of foods in the quail crops indicates poor quail range. That is, he assumes the birds have to eat a large variety of materials to keep from starving. However, Duck and Fletcher (ca. 1944) found the sandsage type, where there is much diversity in kinds of food, to have a much higher density of quail than the mixedgrass type, and my observations suggested the same thing. Therefore, such a diversity of foods taken may suggest poor stands of any one species, but not necessarily range that is poor as a whole.

There are other reasons for assuming the environment usually to be stronger if a variety of plants are present. For example, in the event of drought, snows, heavy grazing, or other conditions making food unavailable, there would be a greater chance that some plants would still be able to

meet the particular conditions and produce food. Since it is well-known that the bobwhite uses a great number of different foods throughout its continental range, it seems that the taking of numerous kinds of food in one locality could be regarded, more properly, as an expression of the adaptability of the birds rather than necessarily an indication of inferior range. For these reasons given above, the mixedgrass region of Oklahoma is considered less desirable from the standpoint of quail foods than several of the other game types.

Table 4. The Average Number of Kinds of Food Eaten by Bobwhite in Northwestern Oklahoma According to Game Cover Type.

(Based on 701 crops.)

Game Type	Number of Foods
Bottomland	6.8
Shortgrass	6.0
Sandsage	5.2
Shinnery Oak	4.3
Mixedgrass	4.0

The information contained in Table 4 suggests that the number of kinds of food eaten, in contrast to the volumes, in western Oklahoma varies noticeably from one vegetal type to another. That it also varies within one and the same community with passage of time appears likely from Table 5. Here, within a brief period, the average number of kinds of food eaten by bobwhite in two different communities declined perceptibly. Perhaps other areas would have shown the same result. Percentagewise, the decline was greater in the mixedgrass. This evidence, although based on a limited number of crops, seems to substantiate the decline in variety of quail foods with the

advance of the winter season noted by other writers (Davison, 1949; Errington and Hamerstrom, 1936). This appears to be an example of the seasonal fluctuation in the status of the food of most animals discussed by Dice (1952).

The larger number of foods eaten at the earlier dates, when availability is greater, again does not seem to indicate that quail eat a greater variety of materials because of necessity. The greater percentage decline in types of food in the mixedgrass area probably shows that the food supply was contracting more rapidly there.

The sandy regions, as the sandsage type, are prone to soil disturbance. Also, the sandy soils have a greater supply of water available for the growth of plants (Weaver and Clements, 1938). These two factors seem to permit a larger variety of plants in the sandsage type because more successional stages, and more niches in all stages, are present. Land-use practices and soil moisture, therefore, apparently are responsible for the greater number of kinds of food eaten by bobwhite in the sandsage, shortgrass, and bottomland types.

Table 5. The Average Number of Kinds of Food Eaten by Bobwhite During Different Periods in Western Oklahoma.

Mixedgrass Type	Nov. 21-28 (66 crops)	Dec. 28-Jan. 29 (37 crops)
	4.44	3.49
Sandsage Type	Nov. 20-28 (42 crops)	Dec. 27-Jan. 16 (64 crops)
	5.24	4.42

Average Amount of Food Eaten

Other information on food status in the different game cover types is given according to average volume of food contained in the crops of quail at the time they were killed (Table 6). Four of the five game cover types show a rather consistent average amount of food. In the fifth, the mixedgrass type, about one-third less was eaten per bird than in the other types. Several explanations of this appear possible. In the mixedgrass region, perhaps either the birds could not secure more to eat, or they did not need to because their nutritional requirements were satisfied. Chemical analyses and feeding experiments involving the foods eaten in each type appear necessary to understand the nutritiousness of the different diets. Other lines of evidence given earlier indicate that there is perhaps less variety of available food in the mixedgrass community. There is a temptation to say that a smaller quantity, also, of food is available, but I have insufficient evidence to know if that is true. For the present, this departure in average amount of food eaten in the mixedgrass type is pointed out to show the considerable gaps in our knowledge of bobwhite ecology. At any rate, it is clear that the mixedgrass game type differs noticeably from the other vegetal types considered so far as quail food is concerned.

Table 6. The Average Amount of Food in the Crops of Bobwhite in Northwestern Oklahoma, According to Game Cover Type.

(Amount given as cubic centimeters).

Game Type	Amount
Sandsage	3.15
Shinnery Oak	3.11
Shortgrass	2.95
Bottomland	2.91
Mixedgrass	2.01

Food by Game Types

Tables 7 to 11 inclusive give the results of the food habits analyses when segregated according to the game types recognized. Six foods, sorgum, ragweed, bumelia, sumpweed, spurges, and sumac, made up about three-fourths of the total food by volume in the sandsage game type during the period studied (Table 7). Sorgum constituted a far larger proportion of the bobwhite diet at that time than any other food. Three of these kinds of plants, ragweed, sumpweed, and the spurges, are undesirable when they are weeds. The status of animal matter and green food in the various ecologic communities was discussed earlier (Table 2).

In the sandsage game type, ragweed had the highest frequency, followed in descending order by sorgum, panicgrasses, sand paspalum, green herbage, and crotons. A high frequency shows that a large proportion of the birds examined ate some of the given food. A high frequency but a low volume, such as is given for crotons, may indicate a wide distribution for a plant but one nowhere abundant.

Hence, a number of birds would have access to such a food but would not be able to eat any quantity of it. A high frequency may, of course, suggest a number of other things as well. It may be that the food is widely dispersed, and even abundant, but that only a small amount satisfies some physiological requirement. The low volume but high frequency of green herbage (Table 7) may be indicative of this last point. A number value integrating percentage volume and percentage frequency, such as was derived by Baumgartner et al. (1952), no doubt has value but was not used here because of the difficulty in assigning proper weight to each term of the equation.

A total of 63 identifiable kinds of food were eaten in the sandsage region. However, as just indicated, most of the volume was accounted for by only a few of the food materials present. The same relations held also for frequency.

Of the 15 foods eaten in greatest volume, at least 10 are from plants greatly increased, in general, by present land-use. In fact, several of them would not even be growing here had they not been introduced by man. Of the 62 kinds of food which were eaten, 33 are increased by present land-use practices, whereas 16 groups of plants are, in general, decreased. The status of the remaining 13 groups is not known by me in all cases; probably most of them are relatively little affected except by cultivation, spraying, or mowing. Thus, one sees that land-use may have an important, all-pervading influence on availability of quail foods in this game type.

The quail crops from the mixedgrass game type (Table 8) showed an unexpected result, namely, that sorgum made up about two-thirds of the diet of the birds examined. Here again, it must be borne in mind that a series of crops from the spring or summer would probably give an entirely different result because of the reduced availability of sorgum during those seasons. The six foods ranking highest in volume made up 82 percent of the total volume for this type, so far as this series of crops was concerned.

Table 7. Early Winter Foods of Bobwhite in the Sandsage Game Type.

(Based on 236 crops; total volume of food equalled 754.0 cc's.)

Kind of Food	% Volume	% Frequency
Sorgum	32.1	42.1
Ragweed	14.8	54.9
Bumelia	8.5	10.6
Sumpweed	8.4	8.9
Spurge	5.4	23.4
Sumac	5.1	15.3
Sand Paspalum	4.5	36.2
Corn	3.1	4.3
Sunflower	2.9	19.6
Knotweed	2.9	4.3
Wheat	2.1	3.8
Panicgrass (Mostly P. capillare)	1.5	37.5
Animal Matter	1.5	24.3
Green Herbage	1.4	25.5
Dayflower	.8	13.2
Pigweed and Lamb's-quarter	.5	18.3
Lovegrass	.5	10.2
Dropseedgrass	.5	6.0
Foxtail	.4	6.8
Snakeweed	.4	2.1
Deervetch	.4	.9
Rye	.3	2.1
Black Locust	.3	3.0

Table 7. --Continued

Kind of Food	% Volume	% Frequency
Croton	.2	24.3
Cowpea	.2	.9
Dock	.2	11.5
Oak	.2	1.3
Small Wildbean	.1	8.9
Johnsongrass	.1	7.2
Bee-Plant	.1	.9
Western Indigo	.1	4.3
Pricklepoppy	.1	3.0
Golden Weed	.1	6.0
Tephrosia	.1	2.1
Wild Grape	.1	1.7
Partridge Pea	.1	4.3
Stillingia	.1	.9
Netleaf Hackberry	T	.9
Buffalobur	T	1.7
Tickclover	T	.4
Crabgrass and Fall Witchgrass	T	.9
Milkpea	T	.9
Sedge	T	7.2
Eriogonum	T	.4
Puccoon	T	3.4
Mentzelia	T	3.8
Cristatella	T	2.6
Sweet Clover	T	.4
Prairieclover	T	1.3
Roundhead Lespedeza and Slender Lespedeza	T	1.7
Buttonweed	T	.4
Redtop	T	.9
Carpetweed	T	.4
Illinois Bundleflower	T	.4
Alfalfa	T	.4
Giant Sandgrass	T	1.3
Indiangrass	T	1.3
Buffalogourd	T	.4
Neptunia	T	.4
Unidentified	0.1	5.1

Foods showing a high volume also showed a high frequency. On the other hand, some items were high in frequency but low in volume, as for example, sand paspalum and animal matter.

There is no greater proportion of sorgum farming in the

mixedgrass type than in shortgrass type. Therefore, it is not possible to attribute the high percentage volume of sorgum in the mixedgrass type quail crops entirely to the acreage of it being grown. It may be that cultivated foods are more available in the mixedgrass region than in the shortgrass region because of a better dispersion of cover. Field observations indicate more and better distributed cover in the northern half of the mixedgrass type (from whence most of the quail crops were taken) as compared to the relatively coverless High Plains occupied by the shortgrass type.

Table 8. Early Winter Foods of Bobwhite in the Mixedgrass Game Type

(Based on 210 crops; total volume of food equalled 424.6 cc's.)

Species	% Volume	% Frequency
Sorgum	62.6	65.7
Ragweed	6.0	40.9
Spurge	4.0	19.0
Panicgrass (Mostly P. capillare)	3.6	35.3
Green Herbage	3.5	27.6
Wheat	2.3	4.8
Smooth Sumac	2.0	5.2
Sunflower	2.0	12.8
Johnsongrass	1.6	25.7
Gourd	1.3	1.0
Pigweed and Lamb's-Quarter	1.1	21.4
Animal Matter	1.1	16.8
Oak	1.1	1.0
Bumelia	1.1	7.6
Corn	1.1	1.4
Snakeweed	0.9	7.1
Croton	0.8	7.2
Sand Paspalum	0.1	11.9
Foxtail	0.5	13.6
Wild Grape	0.5	4.3
Knotweed	0.3	2.4

Table 8. --Continued

Species	% Volume	% Frequency
Lovegrass	0.2	3.2
Pricklepoppy	0.2	1.0
Dropseedgrass	0.2	5.2
Black Locust	0.2	3.2
Beggarticks	0.2	0.5
Small Wildbean	0.1	2.9
Nightshade	0.1	1.4
Sedge	0.1	2.4
Coralberry	0.1	2.4
Snow-on-the-Mountain	T	1.9
Partridge Pea	T	1.4
Oats	T	0.5
Tickclover	T	0.5
Goldenweed	T	3.8
Buffalograss	T	3.2
Giant Ragweed	T	1.4
Tephrosia	T	1.0
Netleaf Hackberry	T	0.5
Yucca	T	0.5
Switchgrass	T	2.4
Dayflower	T	1.4
Dock	T	1.4
Triodia	T	1.4
Cristatella	T	1.0
Scribner's Panicgrass	T	1.0
Sumpweed	T	1.0
Puccoon	T	1.0
Cultivated Lespedeza	T	0.5
Rye	T	0.5
Alfalfa	T	0.5
Sweet Clover	T	0.5
Gaura	T	0.5
Buffalogourd	T	0.5
Verbena	T	0.5
Carpetweed	T	0.5
Cocklebur	T	0.5
Unidentified	0.9	4.8

Whatever the cause of the high proportion of sorgum in the quail crops from the mixedgrass type, it is probably correlated with the low average number of kinds of foods and the low average volume of food eaten in that community noted earlier (Tables 4 and 5).

A total of 58 identifiable kinds of material was eaten in the mixedgrass game type, or a total number similar to that eaten in the sandsage area. Of these 58 materials, 35 are increased and nine are decreased in abundance by current land-use. Fourteen are either not affected by man's activities or their relation to them is not known by me. This suggests that a greater proportion of the quail foods in the mixedgrass region than in the sandsage area was from plants increased by present land-use. Since only a few of the species furnishing food were relatively unaffected, one begins to appreciate the impact of man on the quail environment in another region.

In Table 9, dealing with the shortgrass type, it can be seen that the six foods ranking highest in volume made up 77.5 percent of the total, or a figure similar to the sandsage and mixedgrass areas. Two of the first six items, sand paspalum and mentzelia, occupied a much higher position than in the two game types previously discussed. Although sorgum is grown as extensively in the shortgrass type as in the mixedgrass area (Oklahoma State Board for Vocational Education, 1950), it was considerably scarcer in the quail crops from the shortgrass for the season here reported. Many birds consumed pigweed and lamb's-quarter, green herbage, and animal matter, but only small amounts.

Of the total of 63 identifiable foods eaten in the shortgrass area, 30 are increased by present land-use, 19 are decreased, and the other 14 are not affected or their status is unknown. Although fewer crops were analyzed from this vegetation type, the total number of foods eaten is as high

as from the sandsage area, and higher than from the mixedgrass area (Table 8). The number of foods affected by land-use in the shortgrass type was about the same as from the sandsage type. However, the number of species which are increasers was considerably greater among the mixedgrass foods; correspondingly, the number of decreasers was considerably lower in the mixedgrass type as compared to the shortgrass community. This suggests that land management practices have a much more pronounced effect on quail food plants in the mixedgrass game type than they do in the shortgrass game type.

The remaining game types, the shinnery oak and the bottomland, were represented by fewer crops. The results of the quail food habits analyses for the shinnery oak type (Table 10) show that sorgum and ragweed were again the items highest

Table 9. Early Winter Foods of Bobwhite in the Shortgrass Type.

(Based on 139 crops; total volume eaten, 411.1 cc's.)

Species	% Volume	% Frequency
Sorgum	28.3	41.7
Ragweed	20.4	53.4
Mentzelia	11.0	14.4
Sand Paspalum	6.8	49.0
Spurge	6.4	28.1
Snow-on-the-Mountain	4.6	8.6
Sunflower	3.9	22.3
Croton	2.8	36.7
Dayflower	2.6	18.7
Animal Matter	1.9	31.7
Johnsongrass	1.6	15.6
Green Herbage	1.2	30.9
Giant Ragweed	0.9	5.8
Foxtail	0.6	10.6
Bumelia	0.6	1.4

Table 9. --Continued

Species	% Volume	% Frequency
Stillingia	0.6	0.7
Lovegrass	0.6	12.9
Groundcherry	0.6	2.9
Small Wildbean	0.6	10.0
Aromatic Sumac	0.5	3.6
Dock	0.4	12.4
Switchgrass	0.4	12.9
Russian Thistle	0.3	2.2
Black Locust	0.3	3.6
Snakeweed	T	1.4
Puccoon	0.2	1.4
Pigweed and Lamb's-quarter	0.2	25.9
Panicgrass	0.2	21.6
Wheat	0.1	5.0
Sedge	0.1	13.7
Illinois Bundleflower	0.1	4.3
Western Indigo	0.1	5.0
Eriogonum	0.1	2.2
Cristatella	0.1	1.4
Scurfpea	T	3.6
Sumpweed	T	3.6
Dropseedgrass	T	3.6
Dogwood	T	1.4
Netleaf Hackberry	T	0.7
Indiangrass	T	2.2
Buffalogourd	T	2.2
Stickseed	T	2.2
Tephrosia	T	1.4
Violet	T	0.7
Partridge Pea	T	7.2
Clammyweed	T	6.5
Knotweed	T	4.3
Pricklepoppy	T	2.2
Bee-Plant	T	2.2
Goldenweed	T	2.2
Fall Witchgrass	T	2.2
Wild Grape	T	2.2
Prairieclover	T	2.2
Giant Sandgrass	T	1.4
Scribner's Panicgrass	T	1.4
Waterhemp	T	0.7
Beggarticks	T	0.7
Buttonweed	T	0.7
Nightshade	T	0.7
Croton (*C. glandulosus*)	T	0.7
Triodia	T	0.7
Wild Lespedeza	T	0.7
Unidentified	T	5.8

in volume for the period studied. As would be expected, acorns were a large factor in the diet during this period of the year but probably would not be at some other seasons. Davison (1935), on the contrary, did not even find that acorns were among the twenty-five major quail foods in this game type, during any season, when he made his investigation. The six foods highest in volume (Table 10) made up 77.3 percent of the volume of all foods, an amount remarkably consistent with the total represented by the six highest items in the other game types here considered.

It can be seen also that the frequencies of the different foods in the shinnery region were much more nearly similar and uniform than was the case for the other regions already noted. Since the size of the food item influences the volume of the item, the percentage volume of acorns is high even though the percentage frequency is moderate. Some of the small-seeded plants of wide distribution, for example, bristlegrass and pigweed and lamb's-quarter, are represented by high frequencies although the volumes are low.

A total of 42 identifiable kinds of food were eaten in the shinnery game type. This was a large number, but again only a few kinds accounted for the bulk of the food. Because many fewer crops were analyzed, a comparison with the game types just discussed is unwarranted. Twenty-three of these foods are from plants recognized as increasers; the percentage of increasers is greater than in all types except the mixed-grass.

Quail crops from the bottomland type exhibited a

considerable divergence as to food content from those of the other regions. In this type two legumes were among the six foods highest in volumes (Table 11). Other differences were that neither ragweed nor sorgum was in the list of these six foods. Although based on a small number of crops, the dietary of quail from this area seems to differ markedly from that of quail in the other communities. Possible reasons for this were given previously when discussing the classes of food eaten in each type (Table 2). Only two woody species contributed appreciably to the food volume during the period when the crops were collected. These species were aromatic sumac and bumelia. Foods from woody plants might have been expected to make up a higher volume, or even frequency, than they did. In the southeastern United States, Stoddard (1931)

Table 10. Early Winter Foods of Bobwhite in the Shinnery Oak Type.

(Based on 68 crops; total food eaten 211.9 cc's.)

Species	% Volume	% Frequency
Sorgum	26.2	45.6
Ragweed	21.8	44.1
Oak	10.9	11.8
Sand Paspalum	8.5	36.8
Nightshade	5.4	5.9
Bumelia	4.5	2.9
Dropseedgrass	3.5	7.4
Croton	2.2	13.3
Johnsongrass	2.1	17.6
Wheat	2.1	1.5
Sunflower	1.6	8.8
Sumac	1.5	4.4
Black Locust	1.5	11.8
Animal Matter	1.4	19.1
Panicgrass	1.1	19.1

Table 10. --Continued

Species	% Volume	% Frequency
Sumpweed	1.1	5.9
Corn	1.0	2.9
Snakeweed	0.9	4.4
Green Herbage	0.8	13.3
Wild Grape	0.7	22.0
Foxtail	0.7	14.7
Pigweed and Lamb's-Quarter	0.6	16.2
Gourd	0.3	1.5
Dayflower	0.2	7.4
Stillingia	0.2	2.9
Spurge	0.2	8.8
Netleaf Hackberry	0.1	2.9
Prairie Acacia	0.1	1.5
Bluestem	0.1	1.5
Puccoon	T	8.8
Partridge Pea	T	4.4
Goldenweed	T	2.9
Knotweed	T	2.9
Crabgrass	T	2.9
Tephrosia	T	1.5
Roundhead Lespedeza	T	1.5
Waterhemp	T	1.5
Gaura	T	1.5
Tickclover	T	1.5
Deervetch	T	1.5
Mentzelia	T	1.5
Unidentified	1.1	13.3

found that the seeds of pine trees alone occurred with about 50 percent frequency.

Although fewer crops were studied from the bottomland than from the shinnery area, more kinds of foods were eaten in the former. Forty-nine identifiable kinds of food were taken in the bottomland game type, and about 50 percent of these are increased by present land-use. Thus, a smaller percentage of the foods was from increasers in the bottomland and shortgrass communities than in the other communities.

Numerous analyses of bobwhite quail crops have been made

elsewhere in the United States. A comparison of the results of some other authors with those found here, as regards specific kinds of food, shows that the bobwhite diet is extremely variable on a continental basis. Even when the same plant occurs in some abundance in several different parts of the nation, there is no assurance that it is an important food for quail in one area just because it was in another. For instance, Stoddard (1931) found that partridge pea occurred in the crops or gizzards of about 70 percent of the birds he examined. Although several species of partridge pea were used in the southeast, the frequency of partridge pea in quail crops was much greater there than in western Oklahoma. As other examples of variability of diet, tephrosia showed a

Table 11. Early Winter Food of Bobwhite in the Bottomland Type.

(Based on 48 crops; total food eaten 139.7 cc's.)

Species	% Volume	% Frequency
Partridge Pea	13.5	18.7
Aromatic Sumac	11.9	18.7
Johnsongrass	10.7	16.7
Panicgrass	9.6	50.0
Small Wildbean	9.3	41.6
Sumpweed	9.1	25.0
Animal Matter	5.3	51.2
Ragweed	4.8	52.1
Sorgum	4.4	8.3
Bumelia	3.6	6.3
Black Locust	3.6	4.2
Sunflower	3.2	20.8
Spurge	3.0	20.8
Green Herbage	2.8	27.0
Sand Paspalum	2.6	43.7
Foxtail	1.2	8.3
Giant Ragweed	1.1	16.7
Snow-on-the-Mountain	0.9	8.3

Table 11. --Continued

Species	% Volume	% Frequency
Dropseedgrass	0.9	10.4
Giant Sandgrass	0.5	8.3
Dayflower	0.4	14.6
Mentzelia	0.2	14.6
Dock	0.1	6.3
Goldenweed	0.1	6.3
Western Indigo	0.1	20.8
Croton	0.1	14.6
Woody Plant Buds	0.1	2.1
Pokeberry	0.1	2.1
Puccoon	T	8.3
Prairie Acacia	T	8.3
Pigweed and Lamb's-Quarter	T	6.3
Alfalfa	T	4.2
Nutrush	T	4.2
Wild Grape	T	4.2
Smooth Sumac	T	2.1
Prairieclover	T	2.1
Knotweed	T	2.1
Deervetch	T	2.1
Illinois Bundleflower	T	2.1
Sedge	T	2.1
Pricklepoppy	T	2.1
Waterhemp	T	2.1
Snakeweed	T	2.1
Bluestem	T	2.1
Wild Geranium	T	2.1
Cristatella	T	2.1
Bermudagrass	T	2.1
Fall Witchgrass	T	2.1
Wild Lespedeza	T	2.1
Unidentified	T	12.5

high frequency in Stoddard's inquiry and an extremely low one in this inquiry. Nevertheless, both tephrosia and partridge pea are fairly common in western Oklahoma, particularly in the sandsage game type.

Other examples of specific differences in choice of food by bobwhites in different areas, as opposed to differences in classes of food, may be mentioned. Barbour (1951) in a report on the winter food of 331 quail from Kentucky showed introduced

lespedezas to have a high volume. Since introduced lespedezas are grown only on a very limited scale in western Oklahoma, they were of no consequence as food. Gray (1940) found that 440 quail collected in winter in Alabama had eaten a high volume of common lespedeza (an introduced plant) and of tickclover, whereas these plants are extremely rare in northwestern Oklahoma. Gray also found, contrary to the present results, that partridge pea had a high volume but paspalum grasses a low volume. The foods occurring in highest volume in 5,472 crops from Missouri as reported by Korschgen (1948) were Korean lespedeza, corn, common ragweed, and sorgum. Although all of these grow in western Oklahoma, only sorgum is abundant, while the other three species are uncommon or rare. Perhaps partly as a result of this, only sorgum was found in this investigation to be an important food during the interval studied.

Introduced lespedezas, cowpeas, and soybeans, all cultivated plants, were leading foods by volume in the study of Davison (1942) of 5,889 crops from the southeastern states. A small amount of cowpeas are grown in northwestern Oklahoma but they did not appear in other than very small quantities in the quail diet in this region. Lehmann and Ward (1941) analyzed 565 crops collected during the winter in southwestern Texas. They found Texas panicgrass, sorgum, and crotons to have the highest volume in their series of crops. Two of the crotons mentioned by Lehmann and Ward are often abundant here but both made a poor growth during the summer of 1950. Nevertheless, they did occur sparingly in the crops analyzed for

the present study. Texas panicgrass, on the other hand, does not grow in northwestern Oklahoma.

These studies of quail provender in other parts of the nation show that many plants important elsewhere did not rank high either in volume, or in frequency, for the region here being considered. The bobwhite, thus, is highly adaptable in its food habits, as would be expected of a widely ranging bird.

Since the crops from western Oklahoma which were discussed by Baumgartner, et al. (1952) and Lee (1948) are included in the compilations given in this report, it is not possible to compare their results with my own as far as specific foods are concerned. The quail crops from the shinnery oak community analyzed by Davison (1935) can, however, be compared. Many of the foods listed by Davison as of major importance were eaten in small quantities or not at all by the quail examined for the present work. Davison found tephrosia, tickclover, scurfpea, black locust, partridge pea, tragia, and tumbleweed of importance. None of these showed any appreciable volume or frequency in my results for the shinnery oak type. Some of the other food materials he called important showed a high volume or frequency in my study. Examples of these latter plants are ragweeds, sumpweed, dayflower, and sumacs. Therefore, the difference between the results of food habits analyses given by Davison and those given here for the shinnery type may serve to stress the variations in diet from one period of time to another.

Adequacy of Food Sample Size

The method described earlier was used for approximating the number of quail crops which should be analyzed from the sandsage game type. This type was selected as an example to test the method. From this community, 235 quail crops had already been analyzed. An inspection of the relative quantities of the fifteen principal foods eaten by these 235 birds showed that sorgum was most variable as to volume. Sorgum, therefore, was taken as establishing the number of crops which should be analyzed. Presumably a sample large enough to show the status of the most variable food would be large enough to show the status of each of the less variable foods.

The mean amount of sorgum and the variance were computed only for those crops which contained sorgum. It was found that this was necessary in order to have the amounts of sorgum form a normal curve.

Of the 235 crops analyzed from the sandsage, 91 contained sorgum in measurable amounts. The mean amount of sorgum occurring in these 91 crops was 2.636 cc's, and the variance was 4.71. Substituting the quantities in the equation already given, and solving the equation for n, one would have the following:

$$n = t^2 s^2 / (\bar{x} - m)^2$$

$$= (2)^2 (4.71)/(.527-0)^2$$

$$= 18.84/.277$$

$$= 68$$

Therefore, one would have to analyze crops until he had

completed a series in which about 70 contained sorgum. This would bring one within 20 percent, or 0.527 cc's, of the true mean amount of sorgum at the 95 percent confidence level. If it were desired to be within 10 percent of the true mean amount of sorgum with the same degree of confidence, then it would be necessary to analyze a series of which about 270 crops contained sorgum.

Since ninety-one of the crops in the series analyzed from this game type contained sorgum, in contrast to the seventy which would have had to contain it, it was concluded that more crops had been analyzed than necessary for the year, season, and ecologic community here considered. If one were concerned with birds from another season or year or community the required sample size would have to be recomputed for another representative series of specimens.

DESCRIPTION OF PLANTS

Criteria of Useful Plants

Criteria wich are given in the list below were established for judging the possible usefulness of the different plants investigated. Their order in the list does not necessarily imply the relative rank of importance attached to them. Some of the points overlap others; for example, a plant valuable to a farmer is implied to be free generally of the qualities of a noxious weed, and other examples might be given. The criteria follow:

1. Value to agriculturists.
2. Value to quail.
3. Adaptability to climate.
4. Adaptability to soils.
5. Ease of propagation.
6. Relatively long life span.
7. Competitive ability.
8. Tolerance to biotic influences other than competition.
9. Lack of pestiferous qualities.

These criteria need little elaboration; briefly, they seem to reduce to three generalizations. First, a plant species should fill an available niche in the habitats present in northwestern Oklahoma. Next, a species should be of sufficient value to agriculturists to encourage wide use. And lastly, the species should be of considerable value to quail or other wildlife for food and/or cover. It may be presumed that a native species has already proven itself acceptable on the first score and, therefore, has a great advantage over introduced species. In regard to the second

generalization, a plant useful to farmers for more than one purpose ordinarily has an advantage as to acceptance over a plant that has fewer uses. As for the third generalization, the values of many plant species to quail or other wildlife are only beginning to become known. Usually, plants valuable to quail for both food and cover were given preference over those furnishing only the one requirement or the other. Annuals were disregarded in almost all cases because of the expense of propagating them.

Other writers, including Graham (1941), Edminister (1950), Leopold (1933), and Van Dersal (1938), have discussed criteria used in evaluating plants for improving care of the land or as to usefulness to wildlife. Many of their criteria are the same, or similar to those given above.

Ecology of Suitable Species

After considering the criteria established here, 51 species were selected as having some potential value for the purposes desired. The 51 species are those listed in Table 12 and in several tables following. Future information may reveal species superior to many of those listed. Some additional plants were considered as being generally satisfactory, but further study of them seemed necessary before they could be recommended. Unfortunately, few of the 51 species rating well on the other criteria given were found to provide appreciable amounts of quail food. Further study may show that these species are valuable quail food species.

Site Relations.

Certain site relations of the 51 species judged potentially

suitable for improvement of quail environment are given in Table 12. Much of this material dealing with the soil texture tolerances is taken from the published literature. It is apparent that none of the species is adapted solely to soils with a clay texture. Because sandy and loamy soils predominate in the region studied, many of the native and naturalized plants are most tolerant of the lighter soils. As would be assumed, those plants adapted to a variety of soil types have generally the largest continental range. Most trees and shrubs are intolerant of clay in regions of low rainfall. In general, it can be said that the larger the plant the deeper the roots ordinarily penetrate and consequently the looser the soil must be to permit percolation of water. Thus, although switchgrass, a tallgrass, tolerates many soils, it makes its best growth here on lighter ones, and the same is true of most trees and shrubs. Usually, therefore, the species requiring more water tend to prefer the sandy soils since such soils are less droughty (Weaver and Clements, 1938). The only two plants in the list which prefer heavy soils in the region here considered are western wheatgrass and Missouri milkvetch.

The drought tolerances of the plants (to climatic drought) given in Table 12 are relative. They refer to the drought resistance of the plant as compared to others of its growth form. But, even the plants indicated not to be drought tolerant are nevertheless quite resistant to drought, for otherwise they would not satisfy the criteria of being adapted to the regional climate.

Table 12. Some Site Relations of Plants Potentially Suitable for Environmental Improvement

Plant	Soil Texture Tolerances	Drought Tolerant	Shade Tolerant
GRASSES			
Blue Panicgrass	Sandy	No	No
Sand Lovegrass	Sandy	Yes	Yes
Sand Paspalum	Sandy, Loamy	Yes	No
Scribner's Panicgrass	Sandy	Yes	Yes
Switchgrass	Broad	No	No
Tall Dropseed	Broad	No	No
Texas Bluegrass	Sandy, Loamy	Yes	Yes
Western Wheatgrass	Loamy, Clay	Yes	No
HERBACEOUS LEGUMES			
Austrian Winterpea	Broad	No	No
Cicer Milkvetch	Loamy-?	No	Unknown
Groundplum Milkvetch	Broad	No	Yes
Hairy Vetch	Sandy, Loamy	No	No
Illinois Bundleflower	Broad	No	No
Leadplant Amorpha	Broad	No	No
Missouri Milkvetch	Loamy, Clay	Yes	Partly
Sainfoin	Loamy-?	No	Unknown
Sensitivebrier	Broad	Yes	No
Silky Prairie-Clover	Sandy	Yes	No
Slimflower Scurfpea	Broad	Yes	No
Tephrosia	Sandy	No	No
Wand Lespedeza	Sandy, Loamy	No	No
Western Indigo	Sandy	Yes	Partly
Yellow Sweetclover	Broad	No	No
OTHER HERBS			
Berlandier Daisy	Sandy	No	No
Engelmann Daisy	Broad	No	No
Erect Dayflower	Sandy	No	Yes
Gayfeather	Broad	Yes	No
Missouri Goldenrod	Broad	No	No
Pitcher Sage	Broad	No	Unknown
Scarlet Gaura	Sandy, Loamy	Yes	No
Wild Four O'clock	Sandy, Loamy	Yes	No
SHRUBS AND TREES			
Aromatic Sumac	Broad	Yes	No
Amur Honeysuckle	Broad	Yes	No
Austrian Pine	Sandy, Loamy	No	Unknown
Black Locust	Sandy, Loamy	Yes	Yes
Bladdersenna	Sandy, Loamy	Yes	Partly

Table 12. --Continued

Plant	Soil Texture Tolerances	Drought Tolerant	Shade Tolerant
Bumelia	Sandy, Loamy	No	Partly
Chinese Elm	Broad	Yes	Yes
Common Buckthorn	Sandy, Loamy	No	No
Eastern Redcedar	Sandy, Loamy	Yes	Yes
European Privet	Broad	No	Yes
Jujube	Sandy, Loamy	Yes	Unknown
Lacebark Elm	Broad	No	Yes
Matrimony Vine	Broad	Yes	Unknown
Osage Orange	Sandy, Loamy	Yes	No
Russian Mulberry	Sandy, Loamy	Yes	Partly
Sand Plum	Sandy, Loamy	Yes	No
Smooth Sumac	Broad	No	Yes
Trifoliate Orange	Sandy, Loamy	No	Unknown
Winterberry Euonymus	Sandy, Loamy	Yes	Unknown
VINE			
Trumpetcreeper	Sandy, Loamy	No	No

Site factors, as well as all other environmental influences, interact with each other so as to modify the responses of organisms (Dice, 1952; Leopold, 1931; Hanson, 1950). This can be seen with respect to the water requirements of plants. For example, much of the brushy vegetation of western Oklahoma is on the sandier areas. But some of the species characteristic of the brushy types, as sand plum, will grow well on harder soil to the east under conditions of heavier rainfall. Because of this interaction of physical influences, therefore, it is difficult to separate the water requirements of plants from their soil texture requirements.

Knowledge of stratification as a principle of community organization helps one to determine how a plant can best be used by man. Stratification is one other principle affecting

the niche which a plant can fill in a given community (Allee et al., 1949). With some knowledge of the shade tolerances of a species, it is possible to conjecture what stratum, or layer, the species will occupy either naturally or after being planted. Consequently, information on the shade tolerances of the 51 selected species is given where known (Table 12).

Even though the typical grassland species is subjected to an abundance of intense light, some are low-growing and therefore live much of the time in the shade of other plants. The groundplum milkvetch, Missouri milkvetch, and western indigo are of this type (Table 12). Conceivably, they could be planted in mixtures with grain crops and of course with range grasses. The shrubs or shorter trees, to be successful, must be partially tolerant to shade if planted in the interior of a shelterbelt or other sites relatively deficient in light. It is noticeable that even among the trees and shrubs few are shade tolerant (Table 12), suggestive of adaptation to grassland conditions of light.

Land-Use Response.

The usual land-use response of the 51 species apparently suitable for land management and improvement of the quail environment is given in Table 13. This material, in all but a few cases, is taken from the work of Engleman and Nelson (1948). Land-use response is used in the sense discussed by Dyksterhuis (1949). That is, if existing land-use decreases the plant, it is called a decreaser; if a plant is increased by land-use, it is called an increaser. Species established by

Table 13. The Usual Land-Use Response of Certain Plants in Northwestern Oklahoma

Plant	Land-Use Response
GRASSES	
Blue Panicgrass	Cultivated
Sand Lovegrass	Decreaser
Sand Paspalum	Invader
Scribner's Panicgrass	Decreaser
Switchgrass	Decreaser
Tall Dropseed	Decreaser
Texas Bluegrass	Decreaser
Western Wheatgrass	Increaser
HERBACEOUS LEGUMES	
Austrian Winter Pea	Cultivated
Cicer Milkvetch	Cultivated
Groundplum Milkvetch	Decreaser
Hairy Vetch	Cultivated
Illinois Bundleflower	Decreaser
Leadplant Amorpha	Decreaser
Missouri Milkvetch	Decreaser
Sainfoin	Cultivated
Sensitivebrier	Decreaser
Silky Prairie-Clover	Decreaser
Slimflower Scurfpea	Increaser
Tephrosia	Decreaser
Wand Lespedeza	Decreaser
Western Indigo	Decreaser
Yellow Sweetclover	Invader
OTHER HERBS	
Berlandier Daisy	Decreaser
Engelmann Daisy	Decreaser
Erect Dayflower	Decreaser
Gayfeather	Decreaser
Missouri Goldenrod	Decreaser
Pitcher Sage	Decreaser
Scarlet Gaura	Decreaser
Wild Four O'clock	Decreaser
SHRUBS AND TREES	
Aromatic Sumac	Increaser
Amur Honeysuckle	Cultivated
Austrian Pine	Cultivated
Black Locust	Cultivated
Bladdersenna	Cultivated
Bumelia	Increaser
Chinese Elm	Cultivated
Common Buckthorn	Cultivated

Table 13. --Continued

Plant	Land-Use Response
Eastern Redcedar	Increaser
European Privet	Cultivated
Jujube	Cultivated
Lacebark Elm	Cultivated
Matrimony Vine	Cultivated
Osage Orange	Cultivated
Russian Mulberry	Cultivated
Sandplum	Increaser
Smooth Sumac	Increaser
Trifoliate Orange	Cultivated
Winterberry Euonymus	Cultivated
VINE	
Trumpetcreeper	Cultivated

man on almost every site where found are listed as cultivated.

Aromatic sumac, smooth sumac, and sand plum increase under heavy grazing or soil disturbance. Since heavy grazing is usually associated with soil erosion in northwestern Oklahoma, it is perhaps fortunate that these shrubs do then increase and thereby help prevent wind erosion. However, extensive brush control operations involving spraying, mowing, and beating are removing many of the shrubs. Figure 6 shows a brush control operation and Figure 3 portrays the sand-accumulating activities of aromatic sumac.

Most of the plants are recognized as decreasers. This is especially true of the forbs. In large part, this is because these species are palatable to livestock and are therefore reduced in numbers by them. Baumgartner (1945) has called attention to the pronounced effect of grazing on quail habitat in central Oklahoma; the same relation is undoubtedly true also for northwestern Oklahoma. Slimflower scurfpea was

regarded as an increaser by Engleman and Nelson (1948). It is probable that further study will show the plant to be a decreaser.

Life History.

Information is presented in Table 14 concerning the life history of plants which appear to satisfy the criteria of usefulness established earlier. In preparing the material on manner of reproduction (Table 14), several sources were consulted but the following were especially helpful: Bailey and Bailey (1941), Gates (1937 and 1941), Johnson (1951a), and Van Dersal (1938).

Manner of Reproduction.--The manner of reproduction influences the competitive ability of the species, the cost of maintaining a stand of the plants, and the possibility of the species becoming a pest. But, any species highly palatable to cattle is not likely to become a pest in northwestern Oklahoma no matter how aggressive its reproduction and growth because of the heavy rates of grazing which have prevailed in the region for many years.

A number of the shrubs and trees spread by underground systems in contrast to the grasses and forbs. The three main possibilities for use as a living fence in northwestern Oklahoma, matrimony vine (Figure 9), trifoliate orange, and common jujube (Figure 10), all sucker. Osage orange also spreads by underground roots and hence is not widely used anymore in the region for a living fence or hedge. Smooth sumac, a good prospect for gully control, spreads by suckers. In

Table 14. Life History Notes Concerning Certain Plants in Northwestern Oklahoma

Plant	Manner of Reproduction	Time Seed Shattering Completed	Relative Abundance
GRASSES			
Blue Panicgrass	Seed, Rhizomes?	Unknown	Scarce
Sand Lovegrass	Seed	January 1	Common
Sand Paspalum	Seed	September 1	Common
Scribner's Panicgrass	Seed	March 1	Frequent
Switchgrass	Seed, Rhizomes	April 15	Common
Tall Dropseed	Seed	Unknown	Scarce
Texas Bluegrass	Seed, Rhizomes	Unknown	Frequent
Western Wheatgrass	Seed, Rhizomes	Unknown	Common
HERBACEOUS LEGUMES			
Austrian Winterpea	Seed	Unknown	Scarce
Cicer Milkvetch	Seed	December 1	Scarce
Groundplum Milkvetch	Seed	Unknown	Scarce
Hairy Vetch	Seed	Unknown	Scarce
Illinois Bundleflower	Seed	April 1	Frequent
Leadplant Amorpha	Seed, Rhizomes?	Unknown	Scarce
Missouri Milkvetch	Seed	Unknown	Frequent
Sainfoin	Seed	Unknown	Scarce
Sensitivebrier	Seed, Rhizomes?	August 15	Frequent
Silky Prairie-Clover	Seed, Rhizomes?	Unknown	Frequent
Slimflower Scurfpea	Seed, Rhizomes	Unknown	Common
Tephrosia	Seed, Layering	December 15	Scarce
Wand Lespedeza	Seed, Suckering	April 1	Scarce
Western Indigo	Seed	February 1	Common
Yellow Sweetclover	Seed	Unknown	Frequent
OTHER HERBS			
Berlandier Daisy	Seed	September 1	Scarce
Engelmann Daisy	Seed	Unknown	Frequent
Erect Dayflower	Seed	Unknown	Scarce

Table 14. --Continued

Plant	Manner of Reproduction	Time Seed Shattering Completed	Relative Abundance
Gayfeather	Seed	March 1	Common
Missouri Goldenrod	Seed, Rhizomes	January 1	Scarce
Pitcher Sage	Seed	Unknown	Scarce
Scarlet Gaura	Seed	Unknown	Common
Wild Four O'clock	Seed	February 15	Frequent
SHRUBS AND TREES			
Aromatic Sumac	Seed, Suckering	February 1	Common
Amur Honeysuckle	Seed	January 1	Scarce
Austrian Pine	Seed	Unknown	Scarce
Black Locust	Seed, Suckering	April 1	Frequent
Bladdersenna	Seed	January 1	Scarce
Bumelia	Seed	January 15	Scarce
Chinese Elm	Seed	Unknown	Frequent
Common Buckthorn	Seed	April 15	Scarce
Eastern Redcedar	Seed	Continuous	Frequent
European Privet	Seed	May 1	Scarce
Common Jujube	Seed, Suckering	Unknown	Scarce
Lacebark Elm	Seed	Unknown	Scarce
Matrimony Vine	Seed, Suckering	Unknown	Scarce
Osage Orange	Seed, Suckering	Unknown	Scarce
Russian Mulberry	Seed	Unknown	Scarce
Sand Plum	Seed, Suckering	September 1	Common
Smooth Sumac	Seed, Suckering	May 1	Frequent
Trifoliate Orange	Seed, Suckering	Unknown	Scarce
Winterberry Euonymus	Seed	March 1	Scarce
VINE			
Trumpetcreeper	Seed, Suckering	April 15	Scarce

this case suckering probably is an advantage. Two shrubs of worth as sand dune stabilizers are aromatic sumac and sand plum (Figure 11). Here again, spreading by underground roots may be desirable.

It was found that in numerous cases semi-decumbent stems of tephrosia (Figure 12) had been covered by sand and had then taken root. Perhaps this layering of tephrosia is quite common because of the frequent exposure to wind-blown sand on the sandy areas where the species grows. In several instances, plants of wand lespedeza were found spreading by what appeared to be root sprouts, or suckers. The reproductive parts of wand lespedeza did not seem to be rhizomes although the latter would be more likely in the case of a herbaceous plant.

Time When Seed Shattering Was Completed.--Some information bearing on the time at which almost all seeds or fruit have been shed from certain species meeting the established criteria are presented in Table 14. While considering the time when seed shattering ceased in 1950-51, it must be kept in mind that because of weather conditions prevailing in other years the time of shattering may differ. According to Park (1942), however, the variation from year to year concerning the time at which seeds or fruits are shattered is slight.

The data regarding seed shattering (Table 14) indicate that several of the species, for which information was available, hold their seed or fruit until March 1, or later. Thus, their food may be more available than if it is dropped early. When foods fall to the ground they are liable to rot, to be covered by soil, to be eaten by rodents, or to otherwise

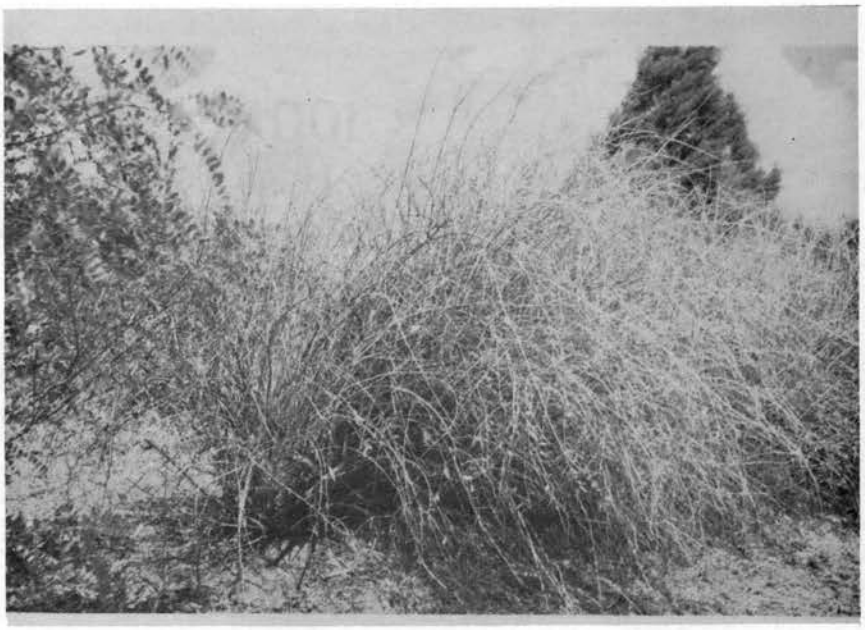

Figure 9. A colony of matrimony vine at the Field Station, Woodward, Oklahoma. Picture taken in July, 1951, but the plants had defoliated after a droughty period. Note impenetrable mass of branches.

Figure 10. Jujube spreading by suckers along a shallow ditch at Tucumcari, New Mexico. Numerous smaller plants coming up. Note rather open growth form of larger individuals.

Figure 11. A thicket of sand plum four miles north of Fort Supply, Oklahoma, showing ground relatively unobstructed below and heavier canopy overhead. Many thickets are denser than this one.

Figure 12. A colony of tephrosia in bloom. Ten miles northeast of Woodward, Oklahoma. Taller grasses, little bluestem; red sage at lower left. Notebook at right suggests the scale.

become unavailable (Davison, 1949). Even so, many of these seeds ordinarily remain available to various animals with passage of the seasons (Baumgras, 1943; Glading, Biswell, and Smith, 1940). Seeds or fruit lying on the ground, however, are likely to be covered by snow or ice, and are then unavailable to quail (Errington, 1930; Leopold, 1931 and 1933).

Nevertheless, some of the more important winter foods of bobwhite in northwestern Oklahoma are shed early by the plants. Sand paspalum is an example of this. Patterson (1952) suggested that small seeds (such as those of sand paspalum) lying on the ground may first become covered with vegetation or soil; but, in late winter, if uncovered, they may become important foods. According to him, the larger seeds or fruits may be so easily secured by various animals, in comparison to the smaller items, that the supply of the former is exhausted early. In spite of this, the small seeds of some plants were shed early but were not found in the crops analyzed for this report. Sensitivebrier was such an example (Table 14). Therefore, it is difficult to reconcile the time of seed dispersal with the quail food habits as presently known. However that may be, it is probable that a plant which gradually releases its food material through the winter and early spring is of superior value as a food producer for quail.

The percentage of seeds or fruits retained on a plant at any time must be considered in the light of the total amount produced by that plant. For example, Scribner's panicgrass finished dropping its seeds about March 1, and the same was true of winterberry euonymus. But the former yields very

few seeds to begin with whereas the euonymus is a good-sized shrub which produces a heavy crop of fruit. No data were secured regarding correlation between the amount of available quail food produced by plant species and the amount of that food consumed by quail.

Two species yielding a heavy crop of fruit which remains on the plant until late are common buckthorn and European privet (Table 14). Since these plants are being grown only experimentally, it was not possible to ascertain to what extent they would be reliable late-winter bobwhite foods.

Relative Abundance.--Information concerning the relative abundance of species fulfilling the established criteria is given in Table 14. Four categories of relative abundance are recognized: abundant, common, frequent, and scarce. The abundance of certain trees and shrubs is considered only in relation to the abundance of other species of a woody nature. Likewise, the abundance of any herbaceous species is considered only in relation to the numbers of other species of a herbaceous nature.

It is not surprising that no species tabulated, whatever the growth form, is classed as abundant and that few of them are classed as common. One reason for this can readily be found by comparing the relative abundance of a plant (Table 14) with the land-use response of that plant (Table 13). Desirable species tend to be decreased by present use of the land, or else are maintained only by cultivation. The only two woody plants which are common are both natives; however, several introduced woody species are called frequent since

they have been widely spread by man.

Growth Form.--The direction in which a plant grows (Table 15), whether vertically, horizontally, or obliquely, affects the usefulness of the species for controlling wind and water erosion. In general, the taller a plant the more it will retard wind, other factors being equal. Chinese elm, a tall tree, will be more effective in reducing wind action than a small, erect plant such as Berlandier daisy. However, dense stands of decumbent or trailing plants may also offer protection against wind erosion but in a more local way. Thus, sensitivebrier and western indigo are useful for lessening wind erosion when they grow in dense stands. Water erosion, on the other hand, is often more effectively prevented by plants that grow either wholly near the surface of the soil, or at least by those which have much of their foliage concentrated there.

Table 15. The Characteristic Growth Form of Certain Plants Desirable for Habitat Improvement.

Species	Direction of Growth	Density of Form	Special Features
GRASSES			
Sand Lovegrass	Erect	Medium	
Sand Paspalum	Erect	Open	Leaves near ground
Switchgrass	Erect	Dense	Height five-six feet
Texas Bluegrass	Erect	Medium	
Western Wheatgrass	Erect	Dense	
HERBACEOUS LEGUMES			
Cicer Milkvetch	Erect	Dense	Very succulent
Groundplum Milkvetch	Decumbent	Medium	Small, delicate plant
Hairy Vetch	Climbing	Open	
Illinois Bundleflower	Erect	Open	Few, small leaves
Leadplant Amorpha	Erect	Dense	Shrubby at base
Missouri Milkvetch	Decumbent	Open	Small plant

Table 15. --Continued

Species	Direction of Growth	Density of Form	Special Features
Sainfoin	Erect	Medium	Defoliates early
Sensitivebrier	Trailing	Medium	Many weak prickles
Silky Prairieclover	Erect	Dense	Shrubby at base
Slimflower Scurfpea	Ascending	Open	Stems become tough
Tephrosia	Ascending	Dense	Retains dead leaves
Wand Lespedeza	Erect	Open	
Western Indigo	Trailing	Medium	
Yellow Sweetclover	Erect	Open	Defoliates early
OTHER HERBS			
Berlandier Daisy	Erect	Open	Stem unbranched
Engelmann Daisy	Erect	Medium	
Erect Dayflower	Erect	Open	Slender, flimsy stems
Gayfeather	Erect	Medium	Stem unbranched
Missouri Goldenrod	Erect	Medium	
Wild Four O'clock	Erect	Open	About four feet tall
SHRUBS AND TREES			
Aromatic Sumac	Ascending	Dense	Interlocking stems
Amur Honeysuckle	Erect	Dense	Open near ground level
Austrian Pine	Erect	Open	Becomes large tree
Black Locust	Erect	Open	Few branches
Bladdersenna	Erect	Open	Open near ground level
Bumelia	Erect	Dense	Thorny
Chinese Elm	Erect	Medium	Branches break easily
Common Buckthorn	Erect	Dense	Interlocking branches
Eastern Redcedar	Erect	Dense	
European Privet	Erect	Dense	
Lacebark Elm	Erect	Medium	
Matrimony Vine	Recurved	Dense	Weak thorns
Osage Orange	Erect	Open	Long, sharp thorns
Russian Mulberry	Erect	Medium	
Sand Plum	Erect	Medium	Open near ground level
Smooth Sumac	Erect	Open	Open below
Trifoliate Orange	Erect	Dense	Long, short thorns
Winterberry Euonymus	Erect	Dense	
WOODY VINE			
Trumpetcreeper	Climbing; Trailing	Dense	Very large vine

A dense system of roots near the surface of the soil is especially valuable in slowing water runoff. Some of the erect plants, such as smooth sumac, are useful in this regard in

spite of their erect manner of growth (Table 15).

The density of the growth form is also important in arresting wind erosion as well as in providing wildlife cover. For most kinds of small game, the denser plant growth provides the better cover. However, bobwhite prefer plant cover that is dense overhead and relatively open near the ground level (Stoddard, 1931). Illinois bundleflower (Figure 13), slimflower scurfpea, and bladdersenna have an open growth form although a denser growth habit would be preferable.

The presence of thorns and prickles (Table 15) are a special feature of some plants. Thorns may make a plant, such as trifoliate orange, useful as a livestock barrier; on the other hand, thorns or prickles may prevent a potential forage plant from being grazed. Although sensitivebrier has prickles, these are so weak that cattle still graze the plants heavily. Another special feature bearing on the value of a plant for erosion control or wildlife cover is the nearness to the ground with which the branches and foliage grow. This is of concern only in the case of erect or ascending plants since the others grow sufficiently near the ground level. Certain erect plants, as bumelia (Figure 14), common buckthorn, and eastern redcedar (Figure 15), have a dense growth to the ground level. While this growth form is superior for resisting erosion it is of less value as quail cover. Thus, bobwhite were only once observed during this investigation to use eastern redcedar for cover. Sand plum, being dense overhead and open underneath in growth habit (Figure 11), appeared to me to be the most important quail cover plant in northwestern Oklahoma.

Figure 13. At the left, Illinois bundleflower is shown along a roadside near Fort Supply, Oklahoma. Note the bundles of pods and open growth habit.

Figure 14. Bumelia. The compact form and growth to ground level are shown. Sandsage in foreground. Eight miles northwest of Woodward, Oklahoma.

Figure 15. Eastern redcedar (second row) and Rocky Mountain juniper (first row) at Tucumcari, New Mexico. Note more open growth form of redcedar and the dense growth of both to ground level.

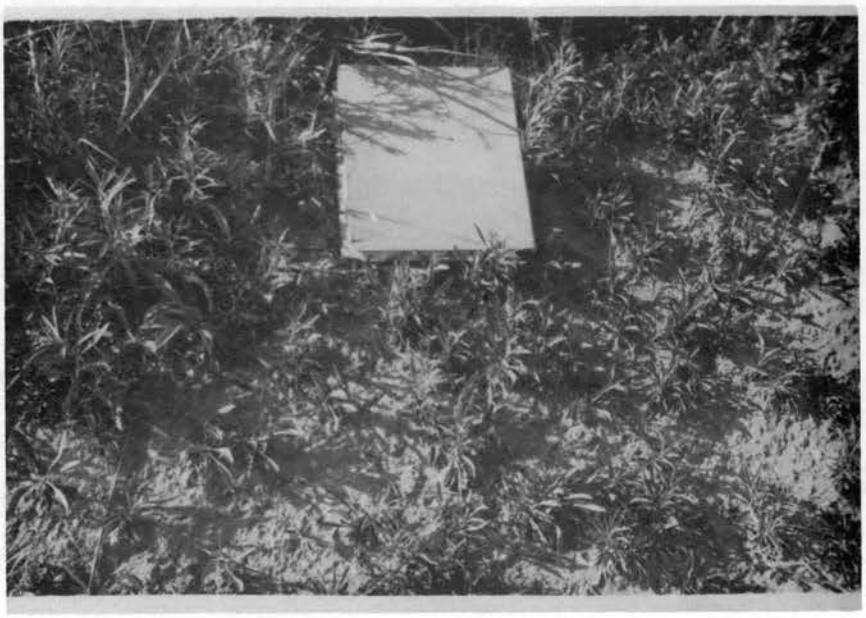

Figure 16. Colony of Missouri goldenrod growing from rhizomes, February 15, 1951. Seven miles southeast of Woodward, Oklahoma.

Ecological Notes Concerning Various Species

Growth and Reproduction During Drought Periods.

A few observations were accumulated concerning the effects of drought on quail food and cover plants. A severe spring and summer drought occurred in 1952. As a result, throughout northwestern Oklahoma plant growth was much retarded, and apparently a high proportion of the plants did not fruit. In general, herbaceous plants grew to only one-fourth or one-third of their normal height. This observation included even such drought resistant species as western ragweed, broom snakeweed, prairie sunflower, and blue gramagrass. Those showing the least growth were those whose moisture requirements were high. Thus, tall grasses, legumes, and cultivated crops, as a group, grew but little.

In most instances where observed, sorgum grew only enough to provide some ground cover. Little seed was produced. This must have been rather serious for quail in view of the large quantity of sorgum seed which they eat in winter. Other cultivated crops made equally poor growth.

In spite of the extreme drought of 1952, some plants did produce fair amounts of seed. The following species yielded fairly well: aromatic sumac, sand mentzelia, switchgrass, Indiangrass, Texas croton, goldenweed, smooth sumac, several pigweeds, wild four o'clock, and Scribner's panicgrass. A small amount of seed or fruit was produced by bumelia, netleaf hackberry, coralberry, camphor weed, Riddell's groundsel,

ironweed, sand paspalum, sunflowers, and western ragweed. Nevertheless, an overwhelming proportion of the plants failed to fruit at all. Furthermore, it was apparent that a great many plants did not even flower. All in all, the conclusion was inescapable that seed production for the plants of the region was negligible.

The direct effects of the drought on quail food production were intensified by livestock. Because of the scanty growth of forage, cattle had to graze the available plants much more closely than usual, thus permitting few plants to seed. Current forage utilization on most pastures seen was so intense that much of the herbaceous vegetation was clipped to ground level. The only herbs escaping grazing, in general, were those which were extremely unpalatable or which were protected by clumps of shrubs.

Since only one small covey of quail was found after four days of driving and tramping in some of the best quail habitat in Oklahoma, it was presumed that populations had crashed coincidentally with the extreme drought.

Growth of Plants in Winter.

Investigations conducted during two different winters indicated that 87 plant species started producing green herbage in northwestern Oklahoma prior to March 1. A list of all such species, except trees, aquatic plants, and cultivated ornamental species, is given in Table 16. The majority of the winter growers belong the the grass, composite, evening primrose, and legume families. However, as previously

Table 16. List of Winter-Growing Plants Occurring in Western Oklahoma Exclusive of Trees, Cultivated Ornamentals, and Aquatic Species.

Name of Plant
Alfalfa
Alkali Muhly
Anemone (Species ?)
Aster (A. leucelene)
Austrian Winterpea
Ball Cactus (Species ?)
Biennial Gaura
Bluets
Broom Snakeweed
Canada Wildrye
Cheat Brome
Chess Brome
Common Yellow Oxalis
Curlycup Gumweed
Cutleaf Eveningprimrose
Downy Paintbrush
Eriogonum (E. effusum ?)
Eveningprimrose (O. triloba)
Eveningprimrose (Species ?)
Fall Witchgrass
Falsegaura
Fieldcress
Foxtail Barley
Gaura (G. parviflora)
Groundplum Milkvetch
Hairy Goldaster
Hairy Vetch
Halfshrub Eveningprimrose
Heath Aster
Henbit Deadnettle
Hymenopappus (H. robustus)
Indian Ricegrass
Ironplant Goldenweed
James Nailwort
Japanese Brome
Johnnyjumpup Violet
Junegrass
Lambert Loco
Little Barley
Louisiana Sage
Low Poppymallow
Meadow Fescue
Missouri Goldenrod
Missouri Milkvetch
Narrowleaf Goldaster

Table 16. --Continued

Name of Plant
Needleandthread
Penstemon (Species ?)
Pinnate Tansymustard
Plains Bluegrass
Prairie Groundsel
Pricklypear (Several species)
Red Sage
Rescue Brome
Resinous Skullcap
Riddell Groundsel
Rosering Gaillardia
Rye
Sand Mentzelia
Sandsage
Scarlet Globemallow
Scribner Panicgrass
Sedge (Species ?)
Shepherdspurse
Sixweeks Fescue
Spiderwort (Species ?)
Stemless Townsendia
Summercypress
Sunflower (Species ?)
Texas Bluegrass
Tuber Falsedandelion
Upright Prairieconeflower
Verbena (V. pumilla)
Virginia Wildrye
Wavyleaf Thistle
Waxy Goldenweed
Western Wheatgrass
Wheat
White Polygala
White Sweetclover
Wild Onion (Species ?)
Wild Parsley
Wislizenus Spectaclepod
Woolly Loco
Woolly Plantain
Yellow Sweetclover
Yellowspine Thistle
Yucca

stated, only two native legumes were found to be winter-greening.

In Table 17 are shown the number of species of forbs

and shrubs found to be winter-growing in 1951 on transects located under different condition classes of rangeland and types of soil. The condition classes of rangeland are based on the percentage of vegetation furnished by climax species. They are defined as follows by Dyksterhuis (1949): excellent condition, 75 percent or more of the vegetation furnished by climax species; good condition, 50 percent to 75 percent; fair, 25 percent to 50 percent; and poor, less than 25 percent. These transects were widely scattered through western Oklahoma from Woodward to the Red River except that none was located in the Panhandle.

Table 17. Number of Species of Winter-Growing Forbs and Shrubs on Rangeland in Western Oklahoma, February, 1951.

(Per belt transect 200 yards long and two feet wide)

Condition of Rangeland	Sandy Soils	Loam and Clay Loam Soils
Excellent	2	6
	2	---
Good	2	---
	2	---
Fair	0	5
	0	0
	---	5 (Abandoned Field)
Poor	7	1
	---	1
	---	1
Total Species	15	19

On range in poor condition, many more species were encountered on the sandy soil transect than on any of the three

hard land transects. With this exception, the number of species was greater on harder land. Also, except for this one transect, a trend is suggested toward a greater variety of species with higher conditions of succession.

The number of individuals of winter-growing species, found on the areas studied in 1951 are given in Table 18. Here again, the one transect on sandy land where succession was in a low state differed considerably from the others. It had a much higher number of individual plants. The abandoned field on hard land also had a number of winter growers. Except for the one sandy soil transect mentioned above, there were more individual plants on hard land.

Table 18. Number of Individuals of Winter-Growing Forbs and Shrubs on Rangeland in Western Oklahoma, February, 1951.

(Per belt transect 200 yards long and two feet wide)

Condition of Rangeland	Sandy Soils	Loam and Clay Loam Soils
Excellent	10	43
	12	---
Good	56	---
	6	---
Fair	0	49
	0	0
	---	85 (Abandoned Field)
Poor	114	2
	---	1
	---	2
Total Individuals	198	182

Summing up the February 1951, transect work in particular,

and general observations through the winter of 1950-51, the following was found. Winter-growing plants were much more numerous as to species and individuals on moister areas, as in swales and ravines. Also, a greater number of species and of individuals were present on hard land than on sandy land and on higher range condition classes as opposed to poor condition rangeland (Tables 17 and 18).

The belt transects studied in 1953 were all northeast and within a radius of 20 miles of Woodward, Oklahoma. From the experience of the 1950-51 work on winter-growing plants it was concluded that the areas examined should be within a small area geographically and that the sites and types of land-use should be selected carefully. Work done in a small geographical area would eliminate significant climatic differences. With sites and types of land-use selected carefully, areas could be compared which were similar except for the factor being studied. The numbers of species thus found on the 12 transects examined in 1953 are shown in Table 19.

Many more species of winter-growing forbs and shrubs were found on the loamy and clay loam soils in the 1953 investigation than on the sandy ones. The number of grass species was either low on all sites or else no grasses were present. In grain fields abandoned only four years there were no green grasses regardless of soil texture. A possible reason for the higher number of species of forbs and shrubs on hard land follows. The sandy soils are continually in a greater state of disturbance than the hard soils. Consequently, the plant composition on sandy areas is made up of a higher proportion

Table 19. Number of Species of Winter-Growing Plants on Belt Transects in Northwestern Oklahoma, February, 1953.

(Transects 200 yards long and two feet wide)

Type of Land-Use	Sandy Soils		Loamy Soils		Clay Loam Soils	
	Grass	Other	Grass	Other	Grass	Other
Rangeland in Excellent Condition	--	--	--	--	--	21
Rangeland in Good Condition	0 1	1 2	-- 3	-- 15	-- --	-- --
Rangeland in Fair Condition	1 1	2 4	-- 2	-- 12	-- 0	-- 11
Rangeland in Poor Condition	2	2	--	--	--	--
Field Abandoned About Ten Years	2	3	--	--	--	--
Field Abandoned About Four Years	0	1	--	--	0	3
Total Species	7	15	5	27	0	36

of annuals and biennials. Since February, 1953, was during a period of extreme drought, perennials grew better than annuals and biennials. As a result, the drought apparently limited the number of species of winter-growing forbs and shrubs more severely on sandy land than on hard land. If the studies were repeated in a wet winter, or even a winter of average precipitation, different results might be expected.

Although the number of species of grasses was similar under different types of land-use, as distinct from different types of soil, the number of species of forbs and shrubs was not (Table 19). A well-graded series of land-use conditions

was not located, but there seemed to be a trend toward more species of forbs and shrubs on sites in higher successional stages.

It was unfortunate that more areas in poor and excellent condition could not be located, and only one site classified as excellent could be found. This was an area of about ten acres to which livestock could not gain access. No pastures in poor condition, other than the one studied, could be found on suitable sites. The winter-growing plant investigation, as a result, showed indirectly that most pastures in a fairly large area of northwestern Oklahoma belonged to the condition class called "fair".

The number of individuals, as opposed to the number of species, of winter-growing plants found on the transects in 1953 is shown in Table 20. These data also indicate generally greater numbers of individual forbs and shrubs on the loamy and clay loam soils than on the sandy ones. An exception to this was one of the transects on sandy land in a "fair" condition of use. This transect chanced to encounter a large colony of johnnyjumpup violet, an annual. Since few of the violets could be located elsewhere in the pasture, the vagaries of sampling have made forbs appear very important in that pasture, whereas in reality they were not. The number of individual grass plants occurring on sandy land was about the same as the number on hard land although the results hardly suggest any noticeable trend. The high number of grasses in the field abandoned ten years was because of the abundance of sixweeks fescue.

There appeared to be a greater number of individual plants of the different forbs and shrubs on the range in higher condition classes in 1953 (Table 20). The results, where number of individual grass plants is concerned, are hardly conclusive. Nevertheless, the many individual grasses on the one pasture in excellent condition may show, with more study, that the higher stages of succession on hard land will be found to have more grasses also. On sandy land, general observations indicated that "fair" and "poor" pastures probably have more winter-growing grass plants than the better ranges. This is because the principal winter-growing grass in such situations, Texas bluegrass, is, within limits, increased by heavy grazing.

In 1953 as in 1950-51, therefore, it was found that heavier soil types generally had a greater number of individual winter-growing plants than the sandier soil types. As was stated regarding the number of species, the reason was attributed to better growth of perennials than annuals and biennials during the prevailing drought and to the greater proportion of perennials on heavier soil. The observations in 1953, showed again that the moister sites had more winter-growing species and many more individuals than drier ones. No transects were run on moist sites, such as ravine bottoms, because of the difficulty of determining the soil types and degrees of grazing in such places.

The study of green plants during the two different winter seasons indicated that there is a sufficient quantity of this green material to be readily available to quail in ravines and swales or in other moist situations, even during

Table 20. Number of Individuals of Winter-Growing Plants on Belt Transects in Northwestern Oklahoma, February, 1953

(Transects 200 yards long and two feet wide)

Type of Land-Use	Sandy Soils		Loamy Soils		Clay Loam Soils	
	Grass	Other	Grass	Other	Grass	Other
Rangeland in Excellent Condition	--	--	--	--	280	94
Rangeland in Good Condition	0	2	--	--	--	--
	10	2	37	190	--	--
Rangeland in Fair Condition	53	1500*	--	--	--	--
	85	10	62	152	0	33
Rangeland in Poor Condition	71	4	--	--	--	--
Field Abandoned About Ten Years	5000*	10	--	--	--	--
Field Abandoned About Four Years	0	2	--	--	0	28
Total Individuals	5219	1530	99	342	280	156

*Number estimated.

severe droughts. The quantity is scanty however on sandy uplands, and it would probably be difficult for quail to secure other than small amounts. That green herbage might be especially important to quail following a severe drought seems apparent. However, further investigation of quail physiology would be needed to confirm this. Following such droughts, little seed or fruit is available for bobwhite. At that time, the birds might make greater use of greens. A study of quail crops collected in winter and early spring during such a dry period as the one of 1952-53, would no doubt be most worthwhile.

Unfortunately, it was impossible to secure any birds for study. Several winter-greening species have been added to the list of species meeting necessary criteria for improvement of the quail environment.

It was extremely difficult to identify green matter in the crops of quail. The only species which could be positively identified as providing green herbage were Missouri goldenrod (Figure 16), Riddell's groundsel, cutleaf eveningprimrose, and yellow sweetclover. The winter use of green herbage by quail, therefore, is poorly known as regards species.

Of the non-cultivated species green in winter, the grasses furnishing the most forage for livestock are Texas bluegrass, western wheatgrass, Canada wildrye, and Japanese brome. Forbs furnishing fair amounts of grazing are Missouri milkvetch, groundplum milkvetch, broom snakeweed, Riddell's groundsel, narrowleaf goldaster, Louisiana sage, red sage, Missouri goldenrod, and yellow sweetclover. Sandsage is a shrub providing some winter-growing leaves for forage. Winter wheat is the chief cultivated plant which is grazed in winter, although hairy vetch (Figure 17) is also used considerably for this purpose.

Nutritive Value of Certain Seeds or Fruit.

Proximate analyses of certain seeds or fruits were made to determine their possible nutritive value. For learning the value of foods to animals, chemical analyses are not sufficient (Wainio and Forbes, 1941). Also, Spinner and Bishop (1950) reported no conclusive evidence of correlation

between the chemical composition of various foods and the degree to which they were eaten by wildlife. However, in the absence of information on the use of certain food materials by bobwhite in northwestern Oklahoma, one may gain some idea of their possible nutritive value from chemical analyses. Table 21 presents the chemical composition of certain seeds or fruits. Since the analyses were made prior to the time that many species were eliminated from consideration, several species listed in the table were concluded not to fulfill the criteria mentioned previously.

It can be seen that several of the materials were high in protein; for example, seven of the species, all legumes, produced seeds containing more than 30 percent protein (Table 21). Roundhead lespedeza was especially high in protein. According to Nestler (1949) a diet containing 12 percent or more of protein is satisfactory for quail maintenance. Nitrogen-free extract is indicative of the carbohydrate content of a food. Some of the plants with a considerable amount of nitrogen-free extract were Illinois bundleflower, Tatarian honeysuckle, hybrid hackberry, silky prairieclover, anil indigo, and western indigo. Winterberry euonymus was extremely high in fat. Foods of comparatively low value for bobwhite food are lilac chastetree, rough-leaf dogwood, and American elder. These may be of low food value because they contain much fiber. It has been observed that the chastetree and dogwood retain their fruit long into the winter; apparently therefore, few animals eat their fruits to any extent. Summarizing these data, it appears that

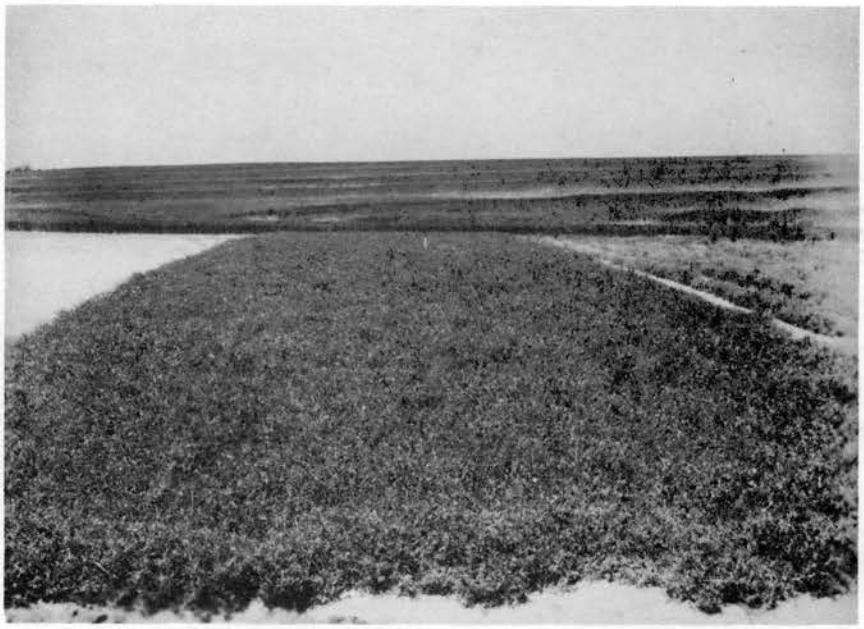

Figure 17. A pure stand of hairy vetch in a testing plot at the Southern Great Plains Field Station, Woodward, Oklahoma.

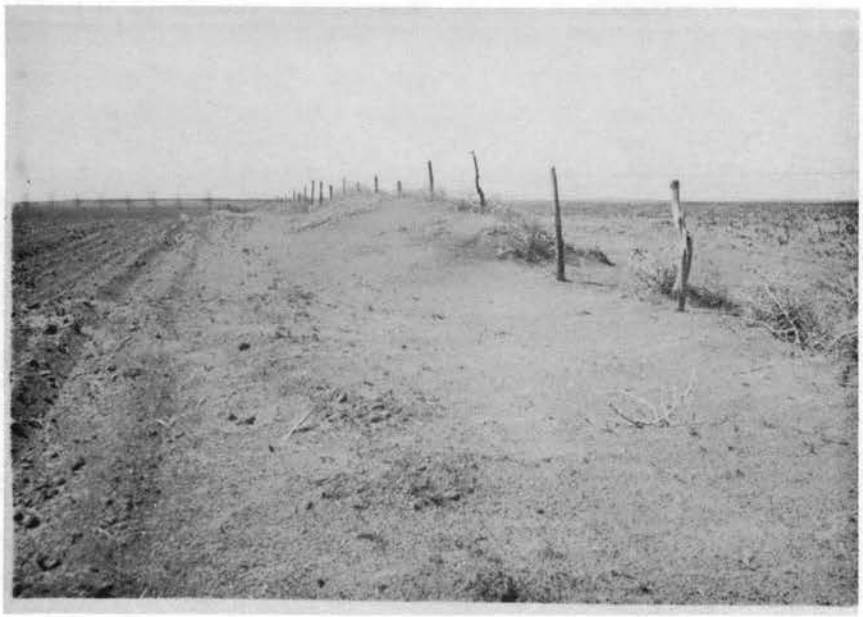

Figure 18. View showing intensive use of land for farming on the High Plains. Note the lack of soil cover or wildlife cover, and the soil which has drifted along the fence. Near Boise City, Oklahoma.

Table 21. The Chemical Composition of Certain Seeds or Fruits From Western Oklahoma.

(Analyses made by Agricultural Chemistry Research Department, Oklahoma A. and M. College.)

Plant	Ash	Protein	Fat	Fiber	N.F.E.*	Ca	P
Rough-Leaf Dogwood	4.32	6.23	13.77	38.39	37.29	1.20	.154
American Elder	3.79	13.39	9.82	37.00	36.00	.62	.378
Illinois Bundleflower	4.45	34.45	1.65	12.59	46.86	.30	.472
Roundhead Lespedeza	3.55	48.37	5.05	14.75	28.28	.15	.441
Bladdersenna	4.09	41.22	2.81	17.34	34.54	.25	.348
Tatarian Honeysuckle	4.53	8.15	16.32	7.06	63.94	.65	.259
Common Buckthorn	2.58	21.79	23.88	20.16	31.59	.55	.248
Wand Lespedeza	3.84	35.81	3.03	17.34	39.98	.24	.378
Hybrid Hackberry	35.89	10.58	1.47	9.31	42.75	11.95	.160
Lilac Chastetree	5.27	8.55	2.88	43.90	39.40	.78	.231
Silky Prairie Clover	3.92	27.61	1.09	11.64	55.74	.32	.302
Tephrosia	4.94	44.34	2.28	10.98	37.46	.42	.371
Anil Indigo	3.28	30.00	1.18	11.66	53.88	.29	.380
Western Indigo	6.73	35.22	.62	10.07	47.36	.64	.402
Winterberry Euonymus	3.07	21.22	39.50	13.66	22.55	.47	.276

* Nitrogen-free extract

all of the plants rating well on other criteria rate well also as regards chemical composition of seeds or fruits. These plants are Illinois bundleflower, common buckthorn, wand lespedeza, silky prairieclover, tephrosia, western indigo, and winterberry euonymus.

One statement of Errington's (1936) seems worthy of note in this connection. He says that he does "...not know of any food which is wholly complete in itself to supply the lifelong nutritional needs of quail...and I doubt if such exists..." Thus, it seems that no matter how high the nutritional value of a food, a variety of foods must still be present in the wild to sustain bobwhite. This suggests again the necessity of not concentrating all of our attention in habitat improvement work on one or a few species of plants.

Culture of Plants.

It was beyond the scope of the present investigation to develop methods for propagation and establishment of the different plants here considered. There is already much information readily available on general methods of culture for both woody and herbaceous species, and on special methods of culture of certain specific plants. For other species seldom, if at all, propagated information is scanty. This is particularly true of native plants and much work must be done before methods of culture will be sufficiently known. The same is true of introduced plants which have been under trial only a short time.

Particularly needed are methods for quick, cheap

establishment of the plants on sites where they may be needed. However, present information indicates that on many of the sites of northwestern Oklahoma satisfactory methods are available for establishment of plants. This even includes methods for large-scale, economical revegetating of abandoned farm lands or run-down ranges (Savage, Smith, and Costello, 1948).

Sources which give useful information on methods of propagation and establishment of herbaceous plants include Ahlgren (1949), Bailey (1944), Chaffin and Woodward (no date), Flory and Marshall (1942), Harlan and Elder (1952), Harlan, Elder, and Chesmore (1952), Jepson (1944), McIlvain and Savage (1951), McKee and McNair (1939), Savage (1939), Savage, Smith, and Costello (1948), Stoesz (1952), Wheeler (1950), and Wolff (1950).

Useful information on methods of propagation and establishment of trees and shrubs are given by Bailey (1944), Engstrom and Stoeckeler (1941), Forest Service (1948), Johnson (1950, 1951a, 1951b, and no date), Johnson and Cobb (1926), Munns and Stoeckeler (1946), Oklahoma Planning and Resources Board (1948), Olson (1935), and Yerkes (1945). A wealth of miscellaneous cultural information on woody and herbaceous species is contained in the books edited by Stefferud (1948 and 1949).

Notes Concerning Additional Plants.

Some notes are given below concerning 62 species which did not appear to meet the criteria established. More than 350 plant species were considered during the present

investigation. Of this number, 51 species with desirable attributes for habitat improvement work are described above. The 62 species in the following annotated list, in addition to the 51 species treated earlier, are of some interest because of their use by quail or because of their importance to farmers and stockmen. The relative use which bobwhite made of these species for winter food is shown in Tables 7-11.

1. American Elder. Medium sized shrub. An infrequent species in the bottomland game type. Usually on areas with moist soil and usually in the shade of trees.

2. American Elm. One of the dominants of the bottomland game type. Probably the most abundant larger tree in the region. Not as drought tolerant as Chinese elm, but more desirable in other ways. Began flowering March 1, and seed was formed a few weeks later.

3. Apache-Plume. A small shrub. Its dense growth form makes it of value in the control of erosion. Might be useful in the western part of the Panhandle, especially on poor soils.

4. Apricot. Small tree of open habit. Fairly well adapted to the climate. Planted some in shelterbelts, but numerous other species have a better shape and are more drought resistant.

5. Bigtop Dalea. A good-sized, erect legume. Eaten little by livestock. Common on gravelly or rocky knolls.

6. Black Currant. Suckers freely. Prefers sandy areas. Growth form similar to aromatic sumac. Defoliated during the hot weather of 1951. Prefers considerable moisture.

7. Broom Snakeweed. An aggressive, rhizomatous weed. Highly unpalatable to livestock. Stands of it and western ragweed are principal indicators of overgrazing. Grows considerably better on heavier soils; tolerates low fertility. Seeds very small but many produced.

8. Buffalo Gourd. A trailing vine common along roadsides and other disturbed areas. Seeds large and leaves very large.

9. Bush Morningglory. Low, spreading forb with stiff stems and branches. Frequent on any disturbed place especially on infertile soil. Eaten some by livestock.

10. Butterfly Milkweed. A leafy, large forb. Very palatable to livestock. Not common. Prefers sandy soil.

11. China Fleecevine. A robust, woody, vine. Has been grown for some time at the U. S. Field Station, Woodward; appears adapted thus far. Has a dense mass of branches, stems and leaves that should provide rabbit or other wildlife cover.

12. Climbing False Buckwheat. Uncommon; occurs on moist areas where there are woods or brush. Climbs on trees and shrubs. Produced heavy crop of large black seeds, many of which remained on the plant until after April 1. Often forms dense clumps where it has climbed over other plants.

13. Pokeberry. Found in the woods where the water supply is good. A large forb. Makes a tremendous annual growth. Rarely found.

14. Common Smoketree. Of a form and size similar to winterberry euonymus. Seems well-adapted at Woodward; not observed elsewhere.

15. Common Witchgrass. An invader abundant in abandoned fields but common in pastures as well. More often seen on sandy soils. Rather unpalatable to livestock.

16. Coralberry. Abundant in the understory of ravines and bottomlands. Frequently used by quail as loafing cover. Berries remain on the plants until spring.

17. Desert Willow. Formerly much used in the most windward row of shelterbelts. Extremely hardy and well-adapted. Growth form poor for deflecting wind. Quail occasionally seen using it for cover. Long pods which persist on the shrubs into winter.

18. Fall Panicgrass. Found occasionally on abandoned fields but rare elsewhere. A taller, more spindly grass than common witchgrass.

19. Fall Witchgrass. Quite common. Each plant forms a dense mat near the ground. Seed stalks break off after maturity. More often on sandy lands.

20. False Indigobush. Spindly shrub with branches concentrated near top of plant. Grows in woods, along edge of streams, and other wet places.

21. Flowering Quince. A small shrub, about 4 feet high. Compact form and thorns suggest it for low hedge. Requires considerable moisture.

22. Forsythias. Several species observed. Spindly shrubs with too open a growth form to be useful for wildlife cover and control of erosion.

23. Goldenweed. One of the dominants, with sunflowers, in the earliest seral stages. Abundant along roadsides,

abandoned fields, and even found some in sandy land pastures. Drought resistant. Produces heavy crop of seeds which are relatively large for a composite. Some of the seeds retained through the winter on the plants. Unpalatable to livestock.

24. Green Bristlegrass. Abundant in disturbed places. Grows on many soil types but seems more common on sands and loams. Produces heavy seed crop, most of which is shed early. Relatively unpalatable to livestock.

25. Halfshrub Eveningprimrose. Small, erect forb, partly shrubby at base. Tolerates drought and many types of soil. Grazed considerably by livestock.

26. Honey Locust. Has many good qualities and has been widely planted on uplands and elsewhere but the growth form is open. Requires considerable moisture but not as much as many trees growing naturally in the bottomlands. The variety with thorns is a potent barrier to livestock passage.

27. Indian Rushpea. Small, succulent legume with delicate leaves. Not abundant. Does well on rather saline soils. Occasionally forms dense mats. Does not seem to be relished well by livestock. Seeds were matured and shattered by July 13.

28. Johnsongrass. Abundant on wetter sites; not common on upland. Usually associated with denuded or disturbed areas, such as highway ditches. Seeds large.

29. Lilac Chastetree. A rapid growing shrub with fair basal density. Has many large woody seeds held through the winter. Hardy at Woodward.

30. Lotebush. A medium sized shrub seen in extreme southwestern Oklahoma. Was found there on heavy soils. The growth form is dense with many interlocking branches and vicious thorns. Probably not adapted to the climate of northwestern Oklahoma. According to information received, it was tested at Woodward, Oklahoma and found not hardy.

31. Netleaf Hackberry. Common on sand dunes in the sandsage and shinnery oak game types. Grows on drier sites than bumelia. Holds seeds all winter. A scraggly, large shrub with few branches. Perhaps the most drought tolerant, native large shrub.

32. New Mexican Forestiera. Open mass of branches spreading in various directions. Prefers moist sites. Might be useful in gully control. Grows well at Woodward.

33. Pale Desertthorn. A spreading shrub which suckers freely. Grows fairly well at Woodward; probably suitable in the western part of the Panhandle. Thorny.

34. Partridge Pea. Abundant on disturbed areas of sandy soil; not common elsewhere. Holds seeds well through the winter. Palatable to cattle. Growth begins late, about May 1. Seeds retained a long time within the pods; many seeds destroyed by weevils.

35. Plains Wildindigo. Common on various soils. One of the most unpalatable plants to livestock. Seeds large but few produced per plant.

36. Prairie Sunflower. Very abundant especially on disturbed sites (Figure 5). The principal component of abandoned fields during the first two to three years of succession.

Much more abundant on sandy than loamy soils although common on latter. Infrequent on heavy soils where its place is taken by common sunflower. Many seeds matured by August 1. Many seeds became wormy.

37. Pricklepoppy. Good-sized, leafy herb. Somewhat spiny; unpalatable to livestock.

38. Riddell's Groundsel. A common forb in early or middle stages of succession. Makes considerable growth; most of the foliage clustered near the ground level. Grows better in winter than most of the native plants, and is abundant. Said to be mildly poisonous to livestock, but often seen to be grazed, at least in winter. Nevertheless, it increases somewhat and is considered undesirable in pastures.

39. Rocky Mountain Juniper. Symmetrical small tree with several stems coming up from one system of roots (Figure 15). Foliage is more bluish in color than that of eastern redcedar. Native to the western part of the Panhandle. In that region it should be used in preference to eastern redcedar. Like the latter, it grows well on very poor soils and needs comparatively little moisture.

40. Rosering Gaillardia. Abundant on disturbed areas and common elsewhere. Individual plant produces considerable herbage. Greens early. Eaten some by livestock when young.

41. Roughleaf Dogwood. Desirable growth form for hedges and control of wind erosion, but requires considerable water. Commonly restricted to the bottomland community.

42. Roundhead Lespedeza. Rare in region. Very tall and spindly. Holds seed well through the winter. Requires fairly

moist soil.

43. Russian Olive. Planted sparingly in the region. Large berries which persist through the winter. Has an open growth form, especially nearer ground; hence poor wind retarding ability.

44. Saltbush. A medium sized shrub with a good shape for controlling wind erosion and for providing wildlife cover. Has vicious thorns. If adapted climatically, may be excellent hedge plant. However, it suckers freely. Tolerates saline soils. Not observed in this region but has been elsewhere. According to tests made by others it shows much promise and survived well during droughts of the '30's.

45. Sand Dropseed. The most common dropseed in the region but not plentiful. Prefers sandy soils. Produces large numbers of very small seeds; apparently seldom eaten by bobwhite. Of fair to poor livestock forage value.

46. Sand Mentzelia. Common on sandy soils, especially where somewhat disturbed. Frequent on hard land. Seldom eaten by livestock. Holds some of its seeds well through the winter. Drought resistant.

47. Sandsage. A small shrub; branches herbaceous near the tips (Figures 6 and 14). Starts growth in February but the plants are erratic in this respect; some green early and many other do not. Browsed somewhat by livestock. Increases, however, under most present rates of grazing; under very heavy grazing decreases or remains static. Important in shielding other more succulent plants from livestock, and in sand dune stabilization. May provide some cover for bobwhite

while they are feeding.

48. Sericea Lespedeza. Has been cultivated considerably at the Field Station, Woodward, Oklahoma. Appears somewhat adapted climatically.

49. Shinnery Oak. Many species which are difficult to distinguish. From low shrubs "shin high" to small trees (Figure 7). Produces heavy crop of large acorns. May grow on elevated mounds of soil; apparently blowing sand is caught by the clumps of plants, and then the plants grow up through them. Produced heavy crops of acorns in 1951, and in 1952, but most of them became wormy shortly after they dropped to the ground. Practically no acorns were available after January 1, because of damage by insects, and because of consumption by various other animals. Resistant to chemical sprays. Restricted to the more infertile sandy soils.

50. Silky Sophora. Small plant with sparse foliage. Flowers early, then plant soon dies and withers away. Found on heavier soils. Apparently unpalatable to livestock. Common.

51. Small Wildbean. Abundant on disturbed soils particularly fields recently abandoned. More common on moister sites. Occasionally found in dense mats. Palatable to livestock. A possibility for a soil improving crop to be sown with wheat, and for a general soil cover crop. It is an annual, but reseeds itself quite well.

52. Snow-on-the-Mountain. Not common in the region. Restricted to moister areas. Not grazed by livestock, at least when older. Seeds large but not many produced per plant.

53. Soapberry. A moderately desirable, small tree. Common in ravines in mixedgrass game type; usually not in the bottomlands. Drought resistant and tolerant of poor soils. Some of the large, peculiar looking berries held on the tree until spring. The pulp of the fruit becomes hard when dry but rapidly imbibes water and swells when wet. Frequently saw robbins and other birds eating the berries in spite of their relatively large size. The tree might be valuable for certain purposes, such as a small tree for shelterbelts.

54. Sumpweed. A leafy, coarse forb found on creek floodplains and similar moist sites. Especially dense stands observed on heavy soil along the Cimarron River bottoms near Waynoka. Not generally common but is on special sites. Seeds large and heavy crop produced. Unpalatable to livestock.

55. Sycamore. Planted some in shelterbelts of western Oklahoma, particularly in southern half of region. Well-suited for this except requires considerable moisture.

56. Texas croton. Most common croton in region. Vigorous, fairly large herb. Abundance suggests overgrazing (Figure 20). Rare during the fall of 1951, but common the following summer; indicates the fluctuations in abundance of some plants under varying weather conditions. Seeds large; became ripe near end of July.

57. Trailing Krameria. Very rarely seen in region, although native. A trailing legume highly palatable to livestock. Seeds enclosed in a tough pod covered with spines. More often noted on heavier soils; grew well on gravelly hills.

58. Western Ragweed. Very abundant (Figure 19). Indicator of overgrazing; however, young plants may be eaten by livestock, and even the older plants if grazing pressure is severe. Found on many types of soil and on dry as well as moist sites. Individual plants produce few seeds. Seeds practically all shed by January 1.

59. White Sweetclover. Larger and less succulent than yellow sweetclover. Also begins growth, flowers, and dies later than yellow sweetclover. Not as desirable as the latter because it requires considerably more water, and produces somewhat less desirable type of forage. Invades disturbed areas.

60. Winter Honeysuckle. A medium sized, somewhat scraggly shrub. A desirable honeysuckle, but requires more moisture than Amur honeysuckle. Somewhat denser near ground level than the latter.

61. Vine Mesquitegrass. A grass which is infrequent in the region. Found generally on wetter areas, for example, creek bottoms, and ravines. Has a fairly dense, spreading growth near the ground. Highly regarded in the southwestern United States for erosion control and forage. Seeds fair size; matured near end of July.

Table 22. List of Plant Names Used in This Report

Common Name	Scientific Name
Alfalfa	Medicago sativa L.
Alkali Muhly	Muhlenbergia asperifolia (Nees & Mey.) Parodi
American Elder	Sambucus canadensis L.
American Elm	Ulmus americana L.
Amur Honeysuckle	Lonicera maackii Maxim.
Anemone	Anemone sp.
Anil Indigo	Indigofera suffruticosa (L.) Mill.
Apache-Plume	Fallugia paradoxa (Don) Endl.
Apricot	Prunus armeniaca (Lam.) L.
Aromatic Sumac	Rhus aromatica Ait. (= R. trilobata Nutt
Aster	Aster sp.
Austrian Pine	Pinus Nigra Arnold
Austrian Winterpea	Pisum sativum L., var. arvense Poir.
Ball Cactus	Neobessya sp.
Bee-Plant	Cleome serrulata Pursh
Beggarticks	Bidens sp.
Berlandier Daisy	Berlandiera texana DC.
Bermudagrass	Cynodon dactylon (L.) Pers.
Biennial Gaura	Gaura biennis L.
Big Bluestem	Andropogon gerardi Vitmin
Bigtop Dalea	Dalea laxiflora Pursh
Black Currant	Ribes odoratum Wendland
Black Locust	Robinia pseudo-acacia L.
Bladdersenna	Colutea arborescens L.
Blue Gramagrass	Bouteloua gracilis (HBK.) Lag.
Blue Panicgrass	Panicum antidotale Retz.
Bluestem	Andropogon sp.
Bluets	Hedyotis nigricans (Lam.) Fosberg
Bristlegrass	Setaria sp.
Broom Snakeweed	Xanthocephalum sarothrae (Pursh) Shinner
Buffalobur	Solanum rostratum Dunal
Buffalogourd	Cucurbita foetidissima HBK.
Buffalograss	Buchloe dactyloides (Nutt.) Engelm.
Bumelia	Bumelia lanuginosa (Michx.) Pers.
Bush Morningglory	Ipomoea leptophylla Torr.
Butterfly Milkweed	Asclepias tuberosa L.
Buttonweed	Diodia teres Walt.
Camphor Weed	Heterotheca latifolia Buckl.
Canada Wildrye	Elymus canadensis L.
Carpetweed	Mollugo verticillata L.
Cheat Brome	Bromus tectorum L.
Chess Brome	Bromus secalinus L.
China Fleecevine	Polygonum auberti L.
Chinese Elm	Ulmus pumila L.

Table 22. --Continued

Common Name	Scientific Name
Cicer Milkvetch	Astragalus cicer L.
Clammyweed	Polanisia sp.
Climbing False Buckwheat	Polygonum scandens L.
Cocklebur	Xanthium sp.
Common Buckthorn	Rhamnus cathartica L.
Common Lespedeza	Lespedeza striata (Thunb.) H. & A.
Common Smoketree	Cotinus coggygria Scop.
Common Witchgrass	Panicum capillare L.
Common Yellow Oxalis	Oxalis stricta L.
Coralberry	Symphoricarpos orbiculatus Moench
Corn	Zea mays L.
Cottonwood	Populus sargentii Dode
Cowpea	Vigna sinensis (L.) Savi
Crabgrass	Digitaria sanguinalis (L.) Scop.
Cristatella	Cristatella sp.
Croton	Croton sp.
Cultivated Lespedeza	Lespedeza sp.
Curlycup Gumweed	Grindelia squarrosa (Pursh) Dunal
Cutleaf Eveningprimrose	Oenothera laciniata Hill
Dayflower	Commelina sp.
Deervetch	Lotus americanus (Nutt.) Bisch.
Desert Willow	Chilopsis linearis (Cav.) Sweet
Dock	Rumex sp.
Dogwood	Cornus sp.
Downy Paintbrush	Castilleja sessiliflora Pursh
Dropseedgrass	Sporobolus sp.
Eastern Redcedar	Juniperus virginiana L.
Engelmann Daisy	Engelmannia pinnatifida T. & G.
Erect Dayflower	Commelina erecta L.
Eriogonum	Eriogonum sp.
European Privet	Ligustrum vulgare L.
Eveningprimrose	Oenothera sp.
Fall Panicgrass	Panicum dichotomiflorum Michx.
Fall Witchgrass	Leptoloma cognatum (Schultes) Chase
Falsegaura	Stenosiphon linifolius (Nutt.) Britton
False Indigobush	Amorpha fruticosa L.
Fieldcress	Rorippa islandica (Oeder ex Muir) Borbas
Flowering Quince	Chaenomeles lagenaria (Loisel.) Koidz.
Forsythia	Forsythia spp.
Foxtail Barley	Hordeum jubatum L.
Gaura	Gaura sp.
Gayfeather	Liatris punctata Hook.
Giant Ragweed	Ambrosia trifida L.
Giant Sandgrass	Calamovilfa gigantea (Nutt.) Scribn. & Merr.
Goldenweed	Prionopsis ciliata Nutt.

Table 22. --Continued

Common Name	Scientific Name
Gourd	Cucurbita sp.
Green Ash	Fraxinus pennsylvanica Marsh., var. subintegerrima (Vahl.) Fern.
Green Bristlegrass	Setaria viridis (L.) Beauv.
Groundcherry	Physalis sp.
Groundplum Milkvetch	Astragalus caryocarpus Ker
Hairy Goldaster	Heterotheca villosa (Pursh) Shinners
Hairy Vetch	Vicia villosa Roth.
Halfshrub Eveningprimrose	Oenothera serrulata Nutt.
Heath Aster	Aster ericoides L.
Henbit Deadnettle	Lamium amplexicaule L.
Honey Locust	Gleditsia triacanthos L.
Hybrid Hackberry	Celtis occidentalis L. x C. laevigata (DC.) Willd.
Hymenopappus	Hymenopappus sulphureaus Rydb.
Illinois Bundleflower	Desmanthus illinoensis (Michx.) MacM.
Indiangrass	Sorghastrum nutans (L.) Nash
Indian Ricegrass	Oryzopsis hymenoides (Roem. & Schult.) Ricker
Indian Rushpea	Hoffmanseggia densiflora Benth.
Ironplant Goldenweed	Machaeranthera pinnata (Nutt.) Shinners
Ironweed	Vernonia baldwinii Torr.
James Nailwort	Paronychia jamesii T. & G.
Japanese Brome	Bromus japonicus Thunb.
Johnsongrass	Sorghum halpense (L.) Pers.
Johnnyjumpup Violet	Viola kitaibeliana Roem. & Schultz, var. Rafinesquii (Greene) Fern.
Jujube	Ziziphus jujuba Mill.
Junegrass	Koeleria cristata (L.) Pers.
Knotweed	Polygonum sp.
Korean Lespedeza	Lespedeza stipulacea Maxim.
Lacebark Elm	Ulmus parvifolia Jacq.
Lambert Loco	Oxytropis lambertii Pursh
Lamb's-Quarter	Chenopodium sp.
Leadplant Amorpha	Amorpha canescens Pursh
Lilac Chastetree	Vitex agnus-castus L.
Little Barley	Hordeum pusillum Nutt.
Little Bluestem	Andropogon scoparius Michx.
Lotebush	Condalia obtusifolia (Hook.) Weberb.
Louisiana Sage	Artemisia ludoviciana Nutt.
Lovegrass	Eragrostis sp.
Low Poppymallow	Callirhoe involucrata (Nutt. ex Torr.) Gray
Matrimony Vine	Lycium halimifolium Mill.
Meadow Fescue	Festuca elatior L.

Table 22. --Continued

Common Name	Scientific Name
Mentzelia	Mentzelia sp.
Mesquite	Prosopis juliflora (Swartz) DC., var. Torreyana Benson
Milkpea	Galactia sp.
Missouri Goldenrod	Solidago missouriensis Nutt.
Missouri Milkvetch	Astragalus missouriensis Nutt.
Narrowleaf Goldaster	Heterotheca villosa (Pursh) Shinners
Needleandthread	Stipa comata Trin. & Rupr.
Neptunia	Neptunia lutea (Leavenw.) Benth.
Netleaf Hackberry	Celtis reticulata Torr.
New Mexican Forestiera	Forestiera neomexicana Gray
Nightshade	Solanum sp.
Nutrush	Scleria sp.
Oak	Quercus sp.
Oats	Avena sativa L.
Osage Orange	Maclura pomifera Schneid.
Pale Desertthorn	Lycium pallidum Miers
Panicgrass	Panicum sp.
Partridge Pea	Cassia fasciculata Michx.
Penstemon	Penstemon sp.
Pigweed	Amaranthus sp.
Pinnate Tansymustard	Descuraina pinnata (Walt.) Britt.
Pitcher Sage	Salvia azurea Lam.
Plains Bluegrass	Poa arida Vasey
Plains Wildindigo	Baptisia leucophaea Nutt.
Poison Ivy	Rhus radicans L.
Pokeberry	Phytolacca americana L.
Prairie Acacia	Acacia angustissima (Mill.) Kuntze
Prairieclover	Dalea sp.
Prairie Groundsel	Senecio plattensis Nutt.
Prairie Sunflower	Helianthus petiolaris Nutt.
Pricklepoppy	Argemone intermedia Sweet
Pricklypear	Opuntia sp.
Puccoon	Lithospermum sp.
Purple Prairieclover	Dalea purpurea Vent.
Ragweed	Ambrosia sp.
Red Sage	Artemisia glauca Pall.
Redtop	Agrostis sp.
Rescue Brome	Bromus catharticus Vahl.
Resinous Skullcap	Scutellaria resinosa Torr.
Riddell Groundsel	Senecio riddellii T. & G.
Rocky Mountain Juniper	Juniperus scopulorum Sarg.
Rosering Gaillardia	Gaillardia pulchella Foug.
Roughleaf Dogwood	Cornus drummondii C. A. Meyer
Roundhead Lespedeza	Lespedeza capitata Michx.
Russian Mulberry	Morus alba L., var. tatarica Loud.
Russian Olive	Elaeagnus angustifolia L.

Table 22. --Continued

Common Name	Scientific Name
Russian Thistle	Salsola kali L.
Rye	Secale cereale L.
Sainfoin	Onobrychis viciaefolia Scop.
Saltbush	Halimodendron halodendron Voss
Sand Bluestem	Andropogon hallii Hack
Sand Dropseed	Sporobolus cryptandrus (Torr.) Gray
Sand Lovegrass	Eragrostis trichodes (Nutt.) Nash
Sand Mentzelia	Mentzelia stricta (Osterhout) Stevens ex Jeffs and Little
Sand Paspalum	Paspalum ciliatifolium Michx., var. stramineum (Nash) Fern.
Sand Plum	Prunus angustifolia Marsh, var. Watsonii (Sarg.) Waugh
Sandsage	Artemisia filifolia Torr.
Scarlet Gaura	Gaura coccinea Nutt.
Scarlet Globemallow	Sphaeralcea coccinea (Pursh) Rydb.
Scribner's Panicgrass	Panicum oligosanthes Schultes, var. scribnerianum (Nash) Fern.
Scurfpea	Psoralea sp.
Sedge	Carex sp.
Sensitivebrier	Schrankia nuttallii (DC.) Standl.
Sericea Lespedeza	Lespedeza cuneata (Dumont) G. Don
Shepherdspurse	Capsella bursa-pastoris L.
Shinnery Oak	Quercus spp.
Sideoats Gramagrass	Bouteloua curtipendula (Michx.) Torr.
Silky Prairieclover	Dalea villosa (Nutt.) Spreng.
Silky Sophora	Sophora sericea Nutt.
Sixweeks Fescue	Festuca octoflora Walt.
Slimflower Scurfpea	Psoralea tenuiflora Pursh
Small Wildbean	Strophostyles leiosperma (T. & G.) Piper
Smooth Sumac	Rhus glabra L.
Snakeweed	Xanthocephalum sp.
Snow-on-the-Mountain	Euphorbia marginata Pursh
Soapberry	Sapindus drummondii H. & A.
Sorgum	Sorghum vulgare Pers.
Spiderwort	Tradescantia sp.
Spurge	Euphorbia sp.
Stemless Townsendia	Townsendia excapa (Richards) Porter
Stickseed	Lappula sp.
Stillingia	Stillingia sylvatica L.
Sumac	Rhus sp.
Summercypress	Kochia scoparia (L.) Schrad.
Sumpweed	Iva ciliata Willd.
Sunflower	Helianthus sp.
Sweet Clover	Melilotus sp.

Table 22. --Continued

Common Name	Scientific Name
Switchgrass	Panicum virgatum L.
Sycamore	Platanus occidentalis L.
Tall Dropseed	Sporobolus asper (Michx.) Kunth
Tatarian Honeysuckle	Lonicera tatarica L.
Tephrosia	Tephrosia virginiana (L.) Pers.
Texas Bluegrass	Poa arachnifera Torr.
Texas Croton	Croton texensis (Klotzsch) Muell. Arg.
Texas Panicgrass	Panicum texanum Buckl.
Threeawn	Aristida sp.
Tickclover	Desmodium sp.
Tragia	Tragia urticifolia Michx.
Trailing Krameria	Krameria secundiflora DC.
Trifoliate Orange	Poncirus trifoliata (L.) Raf.
Triodia	Triodia sp.
Trumpetcreeper	Campsis radicans (L.) Seem.
Tuber Falsedandelion	Pyrrhopappus scaposus DC.
Tumbleweed	Sisymbrium sp.
Upright Prairieconeflower	Ratibida columnifera (Nutt.) W. & S.
Verbena	Verbena pumila Rydb.
Vine Mesquitegrass	Panicum obtusm HBK.
Violet	Viola sp.
Virginia Wildrye	Elymus virginicus L.
Wand Lespedeza	Lespedeza intermedia (S. Wats.) Britt.
Waterhemp	Acnida tamariscina (Nutt.) Wood
Wavyleaf Thistle	Cirsium undulatum (Nutt.) Spreng.
Western Indigo	Indigofera leptosepala Nutt.
Western Ragweed	Ambrosia psilostachya DC.
Western Wheatgrass	Agropyron smithii Rydb.
Wheat	Triticum aestivum L.
White Polygala	Polygala alba Nutt.
White Sweetclover	Melilotus alba Desv.
Wild Four O'clock	Mirabilis nyctaginea (Michx.) MacM.
Wild Geranium	Geranium carolinianum L.
Wild Grape	Vitis sp.
Wild Lespedeza	Lespedeza sp.
Wild Onion	Allium sp.
Wild Parsley	Cymopterus acaulis (Pursh) Raf.
Winterberry Euonymus	Euonymus bungeanus Maxim.
Winter Honeysuckle	Lonicera fragrantissima Lindl. & Paxt.
Wislizenus Spectaclepod	Dithyraea wislizeni Engelm.
Woolly Loco	Astragalus mollissimus Nutt.
Woolly Plantain	Plantago purshii R. & S.
Yellow Bristlegrass	Setaria glauca (L.) Beauv.
Yellowspine Thistle	Cirsium ochrocentrum (Gray) Gray
Yellow Sweetclover	Melilotus officinalis (L.) Lam.
Yucca	Yucca glauca Nutt.

ROLE OF PLANTS IN LAND MANAGEMENT

Some General Considerations

The management of plants makes up most of the so-called habitat improvement practiced at the present for upland game, and the term "habitat improvement" is used in that sense in this report. Although this form of management has been followed somewhat for centuries, lately the practice of it has increased tremendously, and its advocacy has increased even more so.

In view of this trend, it may be well to inquire, "Of what good is habitat improvement?" There is general agreement that plant manipulation directed to this end can benefit wildlife. Graham (1947) reviews considerable literature indicating that viewpoint and adds a contribution of his own in the same vein. Gabrielson (1951) sums up such thinking when he says, "This activity is the most promising present development for the future of wildlife."

In spite of the present great interest and activity in habitat improvement, there are few concrete studies to show where, how, and to what extent it has benefited game. One reason for this is that it usually takes some years for plants to become established and make their influences felt. Another reason is that there have been few evaluations of the effects of such plant developments. The report of Steen (1950) is one of the few showing where food and cover

improvement has actually increased bobwhite populations. Other reports question the importance of food and cover in limiting bobwhite populations (Errington, 1945). In fact, concern is now being felt as to whether habitat improvement for wildlife is justified in view of its expense and the lack of proof that game has been increased (Allen, 1952). Nevertheless, if the care of land is improved, such plant manipulations should be worthwhile.

Habitat improvement, if properly carried out, may tend to increase the area of suitable bobwhite habitat. It also may increase the carrying capacity of the habitat in areas where quail already exist. Furthermore, it may improve the land by inhibiting erosion and by increasing the water absorptive capacity and the fertility of the soil.

It must be stressed that if aware of plants suitable for increasing farm income, landholders will eventually use many of these plants regardless of attitude toward game. Even if the plants are ultimately found not to benefit wildlife their use will still be worthwhile if they have benefited at least the land.

Where Desirable Plants Can Be Used

Shelterbelts.

Shelterbelts perhaps are one of the most important situations in northwestern Oklahoma where plants can be used to improve quail habitat and care of the land. In this report, the words shelterbelt and windbreak are used synonomously. According to Duck (1943) and Baumgartner (1947), lack of

cover is a serious problem for bobwhite in much of northwestern Oklahoma. Shelterbelts may help relieve the cover shortage in those areas which are deficient. The windswept High Plains, wherein most of the shortgrass game type lies, is particularly devoid of cover (Figures 2 and 18). The same is true of smaller areas in the mixedgrass type and of other game types.
In spite of the values of shelterbelts, one cannot escape the observation that there are many fewer of them in use in northwestern Oklahoma than are needed as aids for careful husbandry of the soil.

On the basis of present information, the more promising plants for use in shelterbelts, where the plants will enhance wildlife habitat, are as follows:

Eastern Redcedar
Chinese Elm
Russian Mulberry
Winterberry Euonymus
Common Buckthorn
Amur Honeysuckle
Jujube
Black Locust
Austrian Pine
Lacebark Elm

Rangeland Improvement.

Probably there are few quail in northwestern Oklahoma which do not live all or part of their life on rangelands or pastures. However, the abandonment of farmland on the one hand, and the heavy grazing of rangeland on the other, have reduced the vegetation of much of the region to any early stage of succession. Such lands are relatively unproductive for livestock and may be for quail (Figures 19 and 20).

Figure 19. A field abandoned about 15 years ago still occupied mainly by western ragweed. Clumps of little bluestem in background. Near Woodward, Oklahoma.

Figure 20. A field abandoned about 15 years ago and held in a low stage of succession by continued heavy grazing. Most of the taller plants are the unpalatable Texas croton. Near Woodward, Oklahoma.

The restoration of areas in low successional stages to ones in a higher condition should provide a great opportunity for improvement of the quail habitat. At the time these areas are being revegetated, certain plants beneficial to quail also can be sowed. Some of the plants more useful for attaining rangeland improvement, beneficial alike to the land and to wildlife, as understood at the present time, are as follows:

Sand Lovegrass
Sand Paspalum
Switchgrass
Groundplum Milkvetch
Missouri Milkvetch
Illinois Bundleflower
Western Indigo
Sensitivebrier
Tephrosia
Silky Prairieclover
Pitcher Sage
Engelmann Daisy
Missouri Goldenrod
Erect Dayflower

Other plants of possibly less general value for revegetating rangeland, but still worthy of consideration, are the following:

Blue Panicgrass
Scribner's Panicgrass
Tall Dropseed
Texas Bluegrass
Western Wheatgrass
Wand Lespedeza
Yellow Sweetclover
Slimflower Scurfpea
Sainfoin
Cicer Milkvetch
Leadplant Amorpha
Wild Four O'clock
Berlandier Daisy
Gayfeather
Scarlet Gaura

Borders.

Plants established at the borders of fields, shelterbelts, roadsides, and other places no doubt would be beneficial in preventing erosion, in reducing the growth of weeds which might invade such places, and in providing wildlife food and shelter. Plants useful for borders should, if possible, be those that can be readily established from seed. In addition, they should tolerate some mauling by farm machinery, and be suitable for erosion control. Any herbaceous plant designated earlier (Table 12) as meeting the criteria of usefulness, except for hairy vetch, might be employed as a border plant. Only a few herbaceous species will be mentioned as being particularly desirable for this purpose, but other frequently are suitable. Plants more desirable for borders, as presently known, are:

Western Wheatgrass
Sand Paspalum
Scribner's Panicgrass
Western Indigo
Sensitivebrier
Tephrosia
Leadplant Amorpha
Scarlet Gaura
Missouri Goldenrod
Silky Prairieclover
Sand Plum

Living Fences and Other Hedges.

A hedge used as a living fence has not been observed by me in northwestern Oklahoma. Nor was any comment heard from landholders or agricultural technicians indicating possible interest in living fences. Yet, reports from numerous states indicate the value of such hedges elsewhere, and observations suggest their probable value in northwestern Oklahoma.

Plants potentially suitable for living fences, on the basis of present information, are:

Trifoliate Orange
Matrimony Vine
Jujube
Bumelia
Common Buckthorn
Osage Orange
Sand Plum

As was mentioned earlier, several of these species have some objections which might be partially overcome by the selection of more desirable strains. The matrimony vine may turn out to be the more useful of the species given above, but further testing will be necessary to establish this.

Farmers may also be encouraged to adopt hedges as long-lived markers for contour lines in fields, for erosion control, and for ornamental purposes. Plants apparently more suitable for hedges other than living fences are the following:

Amur Honeysuckle
Bladdersenna
European Privet
Matrimony Vine
Sand Plum
Eastern Redcedar

Living fences and other hedges would likely provide much useful wildlife cover. If the plants produced food suitable for bobwhite or other game, that would be desirable. None of the plants given in the above lists is now known to furnish such food, but further study may show that several of them do.

Crops for Soil Cover and Soil Improvement.

There is often a need for a winter-growing plant that could occupy otherwise bare ground during the winter and thereby prevent wind erosion and that later could be plowed under for green

manure. Occasionally there is also some need for a summer-growing, soil cover crop, for use in rotations, which will enrich the soil.

Plants apparently useful as winter-growing crops for soil cover and soil improvement are:

Hairy Vetch
Austrian Winter Pea
Groundplum Milkvetch
Missouri Milkvetch

Plants possibly suitable as summer-growing crops for soil cover and soil improvement are:

Cicer Milkvetch
Sainfoin
Tephrosia
Western Indigo
Yellow Sweetclover
Sensitivebrier

Gully Control and Revegetation of Shallow Drainageways.

There is probably insufficient awareness of the amount of soil lost and inconvenience caused by eroding gullies or more shallow channels. However, landholders are more likely to revegetate the gently sloping drainageways running through cultivated fields.

Plants perhaps suitable for use in revegetation of shallow drainages are:

Texas Bluegrass
Western Wheatgrass
Switchgrass
Leadplant Amorpha
Sensitivebrier
Tephrosia
Missouri Goldenrod
Gayfeather
Scarlet Gaura

Plants apparently suitable for use in gully control are listed below:

Smooth Sumac
Matrimony Vine
Sand Plum
Aromatic Sumac
Bladdersenna
European Privet
Common Jujube
Trumpetcreeper

Other Habitat Improvements.

There are numerous remaining situations where certain plants could be used with benefit to game and to the land. The amount of improvement of these situations by farmers, public agencies, or other groups perhaps would be small. No detailed listing, therefore, will be made of the plants suitable for various other purposes. Information given in previous sections of this report may suggest species useful for certain purposes.

Some additional places where plants could be used are for the stabilization of banks of streams, ponds, or lakes, for the planting of "odd" areas, for post lots, ornamental purposes, honey production, and for wildlife food or cover patches. None of the plants mentioned as meeting necessary criteria appears suited for stabilization of the margins of areas containing water. This is because the plants here considered are primarily adapted to dry, upland sites. For planting "odd" areas or other places to wildlife cover, sand plum would be an excellent choice. Trumpetcreeper would provide excellent wildlife cover when used in conjunction with shrubs or trees. In the case of post lots, black locust has been widely used. If

a considerable demand develops for certain species, the species could then be raised as a cash crop. Additional uses for desirable species may occur, but, in the end, a strong incentive usually must be present before people would plant the species to improve wildlife habitat.

CONCLUSIONS

Man's use of the land has a tremendous effect on bobwhite food and cover in northwestern Oklahoma. Most of the winter food of quail was furnished by plants increased by farming and ranching activities. However, food habits studies reveal little concerning how much agriculture decreases quail food supplies. Few of the important winter foods of bobwhite, unfortunately, were produced by plants of apparent usefulness for habitat improvement.

Farmers and ranchers are in a commanding position to improve quail habitat in northwestern Oklahoma. Therefore, plants used for habitat improvement should generally benefit both agriculture and wildlife. Otherwise, there is little hope such plants will be established. It is not certain that habitat improvement always increases quail populations. Nevertheless, the growth of plants benefiting the bobwhite is worthwhile if the care of land is improved.

Man is morally obliged to leave the land, an important part of his environment, in at least as good a condition as he received it. As the Bible says, "A good man leaveth an inheritance to his childrens' children" (Proverbs 13:22). Well within the memory of many persons of the present generation there was a mass exodus from the "Dust Bowl" area, partly because man there was not using the soil in an entirely wise manner. Therefore, "The probability of survival of individual,

or groups of, living things increases with the degree with which they harmoniously adjust themselves to each other and their environment" (Leake, 1945). Wise use of land, as a result, is not only a moral responsibility for us, but also a matter of our individual and national survival. The use of certain plants in certain ways on the land offers promise of accomplishing this. If the welfare of quail and other wildlife is enhanced, that much greater is the achievement.

SUMMARY

1. The present investigation was undertaken to learn which plants are more suitable for improving bobwhite habitat and man's use of the land in northwestern Oklahoma.

2. The volumes and frequencies of certain major foods eaten by quail in the mixedgrass game type changed markedly during a two-months period of the winter. The use of only a few major foods remained approximately stable.

3. The average number of kinds of food taken by quail varied considerably between the different game types.

4. The average number of kinds of food eaten in the two game types studied declined with the advance of the winter.

5. The average volume of food eaten was similar in all game types except the mixedgrass type, where it was much less.

6. In view of the facts above, the quail environment, as regards food, appears to fluctuate decidedly in northwestern Oklahoma with respect to both time and place.

7. The mixedgrass game type appeared more deficient so far as bobwhite food was concerned than other areas of the region.

8. In communities of northwestern Oklahoma where quail eat a greater variety of foods, it is suggested that the environment is better than where the quail eat a smaller variety.

9. Man's use of land affects quail food and cover tremendously in the region investigated. Most of the more important winter quail foods are increased by present land-use.

10. The more important winter quail foods usually included sorgum, ragweed, spurges, sand paspalum, and bumelia, but the identity of the most used foods varied from community to community. In each community, a relatively few foods made up most of the volume consumed during fall and winter.

11. Fifty-one species, of more than 350 investigated, seem promising for improvement of land management and quail habitat. Native plants are more useful, in general, than introduced species.

12. The study of winter quail food revealed very few plants furnishing important amounts of food which were satisfactory on other grounds for habitat improvement.

13. Most of the plants judged potentially suitable are adapted to drought and coarser textured soils.

14. The majority of the suitable native species are decreased by present land-use. Almost all suitable non-native species must be cultivated.

15. None of the species considered desirable is abundant in the region and few are even common.

16. Not many plants produced seed or fruit during the severe summer drought of 1953, and most species showed little growth.

17. Eighty-five kinds of plants were winter-growing. The number of species and individuals of such plants was greater on heavier soils, on areas in higher stages of succession, and on moister sites.

18. Improved strains of certain species may be developed by plant breeding work, and this work should be useful in some

cases. More information is needed concerning desirable cultural practices.

19. Habitat improvement is not certain to increase quail populations in northwestern Oklahoma but nevertheless will be justified if land management is improved.

20. Landholders perhaps are the ones most likely to improve wildlife habitat to any extent in northwestern Oklahoma. Accordingly, the various plants will not be extensively propagated unless they increase farm income either directly or indirectly.

21. Shelterbelts and abandoned fields are the two main situations where landholders are more likely to establish desirable plants. Farmers and ranchers seem much less appreciative of the need for other types of habitat improvement.

22. Wise use of land is both a moral responsibility for man and also necessary for his survival. Certain plants properly employed may improve his care of land and thereby aid man, wildlife, and the land itself.

LITERATURE CITED

Ahlgren, Gilbert H. 1949. Forage crops. New York: McGraw-Hill Book Co., Inc. 418 pp.

Allee, W. C., Alfred E. Emerson, Orlando Park, Thomas Park, and Karl P. Schmidt. 1949. Principles of animal ecology. Philadelphia: W. B. Saunders Co. 837 pp.

Allen, Durward L. 1952. Wildlife and the business of farming. Journ. Soil and Water Cons., 7:223-226, 245.

Bailey, L. H. 1944. The standard cyclopedia of horticulture. 3 vols. New York: The Macmillan Co. 3639 pp.

------. 1949. Manual of cultivated plants. Rev. ed. New York: The Macmillan Co. 1116 pp.

------, and Ethel Zoe Bailey. 1941. Hortus second. New York: The Macmillan Co. 778 pp.

Baldwin, W. P., Jr. and C. O. Handley. 1946. Winter food of bobwhite quail in Virginia. Journ. Wildl. Mgt., 10:142-149.

Barbour, Roger W. 1951. Observations on fall and winter food of bob-white quail in Kentucky. Journ. Wildl. Mgt., 15:108.

Baumgartner, F. M. 1945. Management of bob-white on the oak-tall grass prairie, north central Oklahoma. Trans. Tenth N. Amer. Wildl. Conf. Pp. 185-190.

------. 1947. Management of the bobwhite quail in north central Oklahoma. Rept. Proc. Second Okla. Wildl. Conf. Pp. 52-59.

------, Meredith J. Morris, John L. Steele, and Jack E. Williams. 1952. Oklahoma bobwhite food relations. Trans. Seventeenth N. Amer. Wildl. Conf. Pp. 338-358.

Baumgras, Philip S. 1943. Winter food productivity of agricultural land for seed eating birds and mammals. Journ. Wildl. Mgt., 7:13-18.

Bigelow, J. M. 1856. General description of the botanical character of the country. In Reports of explorations and surveys Mississippi River to Pacific Ocean. Vol. 4. Ex. Doc. No. 78, 33rd Cong., 2nd. Sess. Senate. Pp. 1-4.

Blair, W. F. and T. H. Hubbell. 1938. The biotic districts of Oklahoma. Amer. Midl. Nat., 20:425-454.

Bruner, W. E. 1931. The vegetation of Oklahoma. Ecol. Monog., 1:99-188.

Bureau of Agricultural Economics. 1950. Generalized types of farming in the United States. U. S. Dept. Agr. Agr. Inform. Bull. No. 3.

Chaffin, Wesley. No date. A soil improvement program for Oklahoma. Okla. Agr. Ext. Serv. Cir. No. 412.

----- and R. O. Woodward. No date. A 4-H manual on legumes. Okla. Agr. Ext. Div. Cir. No. 400.

Chenault, Tandy P. 1940. The phenology of some bobwhite food and cover plants in Brazos County, Texas. Journ. Wildl. Mgt., 4:359-368.

Clements, F. E. and V. E. Shelford. 1939. Bio-ecology. New York: John Wiley & Sons, Inc. 698 pp.

Daniel, Harley A., Harry M. Elwell, and H. F. Murphy. 1942. Conservation and better land use for Oklahoma. Okla. Agr. Exp. Sta. Bull. No. B-257.

Davidson, J. F. 1952. The use of taxonomy in ecology. Ecology, 33:297-299.

Davison, Verne E. 1935. The Davison Ranch, Ellis County, Oklahoma, game bird project from February 1, 1932 to June 1, 1935. MS. 92 pp.

-----. 1942. Bobwhite foods and conservation farming. Journ. Wildl. Mgt., 6:97-109.

-----. 1949. Bobwhites on the rise. New York: Chas. Scribner's Sons. 150 pp.

Dice, Lee R. 1943. The biotic provinces of North America. Ann Arbor: Univ. Mich. Press. 78 pp.

-----. 1952. Natural communities. Ann Arbor: Univ. Mich. Press. 547 pp.

Duck, L. G. 1943. Seasonal movements of bobwhite quail in northwestern Oklahoma. Journ. Wildl. Mgt., 7:365-368.

----- and Jack B. Fletcher. 1944. A survey of the game and furbearing animals of Oklahoma. Okla. Game and Fish Comm., Pittman-Robertson Ser. No. 2, State Bull, 3. 144 pp.

Dyksterhuis, E. J. 1949. Condition and management of range land based on quantitative ecology. Journ. Range Mgt., 2:104-115.

Edminister, Frank C. 1950. Use of shrubs in developing farm wildlife habitat. Trans. Fifteenth N. Amer. Wildl. Conf. Pp. 519-548.

Engleman, J. E. and John C. Nelson. 1948. Check list of range plants for District Work Group I with headquarters at Woodward, Oklahoma. U. S. Dept. Agr., Soil Cons. Serv. (Mimeo.) 23 pp.

Engstrom, H. E. and J. H. Stoeckeler. 1941. Nursery practice for trees and shrubs suitable for planting on the prairie-plains. U. S. Dept. Agr., For. Serv. Misc. Pub. No. 434.

Errington, Paul L. 1930. Wisconsin quail investigation findings. Trans. Seventeenth Amer. Game Conf. Pp. 252-253.

-----. 1936. Differences in nutritive values of winter game foods. Proc. N. Amer. Wildl. Conf. Pp. 356-360.

-----. 1945. Some contributions of a fifteen-year local study of the northern bobwhite to a knowledge of population phenomena. Ecol. Monog., 15:2-34.

----- and F. N. Hamerstrom, Jr. 1936. The northern bob-white's winter territory. Iowa Agr. Exp. Sta. Res. Bull. No. 201.

Featherly, H. I. 1946. Manual of the grasses of Oklahoma. Bull. Okla. A. and M. College. Vol. 43, No. 21. 137 pp.

Fenneman, Nevin M. 1931. Physiography of western North America. New York: McGraw-Hill Book Co., Inc. 534 pp.

Finnell, H. H. 1939. Problem-area groups of land in the southern Great Plains. U. S. Dept. Agr., Soil Cons. Serv. 40 pp.

Fitzpatrick, E. G. and W. C. Boatright. 1938. Soil survey of Woodward County, Oklahoma. U. S. Dept. Agr., Bur. Chem. and Soils. Series 1932, No. 28.

Flory, Evan L. and Charles G. Marshall. 1942. Regrassing for soil protection in the southwest. U. S. Dept. Agr. Farmers' Bull. No. 1913.

Forest Service. 1948. Woody-plant seed manual. U. S. Dept. Agr. Misc. Pub. No. 654. 416 pp.

Gabrielson, Ira N. 1951. Wildlife management. New York: The Macmillan Co. 274 pp.

Gates, Frank C. 1937. Grasses in Kansas. Topeka: Rep. Kans. State Board Agr. Vol. 55, No. 220-A.

-----. 1941. Weeds in Kansas. Topeka: Rep. Kans. State Board Agr. Vol. 60, No. 243.

Glading, Ben, Harold H. Biswell, and Clarence F. Smith. 1940. Studies on the food of the California quail in 1937. Journ. Wildl. Mgt., 4:128-144.

Graham, Edward H. 1941. Legumes for erosion control and wildlife. U. S. Dept. Agr. Misc. Pub. No. 412. 153 pp.

-----. 1944. Natural principles of land use. New York: Oxford Univ. Press. 274 pp.

-----. 1947. The land and wildlife. New York: Oxford Univ. Press. 232 pp.

Gray, Anderson M. 1940. Winter foods of the bobwhite quail in the Black Belt soil province of Alabama. Ala. Dept. Cons.

Gregg, Josiah. 1845. Commerce on the prairies. Vol. 2. New York: J. and H. G. Langley. 327 pp.

Hanson, William R. 1950. Exploring the wildlife environment. N. Dak. Outdoors, 12:6-7.

Harlan, Jack R. and W. C. Elder. 1952. Establishment of grasses and legumes. Okla. Agr. Exp. Sta. Forage Crops Leafl. No. 1.

-----, W. C. Elder, and Roy Chesmore. 1952. Seeding rates of grasses and legumes. Okla. Agr. Exp. Sta. Forage Crops Leafl. No. 2.

Hesse, Richard, W. C. Allee, and Karl P. Schmidt. 1937. Ecological animal geography. New York: John Wiley & Sons, Inc. 597 pp.

Irving, Washington. 1926. A tour on the prairies. Ed. George C. Wills and Joseph B. Thoburn. Oklahoma City: Harlow Pub. Co. 251 pp.

James, Edwin. 1905. Early western travels 1748-1846. Ed. Reuben Gold Thwaites. Vol. 16. Part III of James's account of S. H. Long's expedition, 1819-1820. Cleveland, Ohio: The Arthur H. Clark Co. 291 pp.

Jepson, Hans G. 1944. Prevention and control of gullies. U. S. Dept. Agr. Farmers' Bull. No. 1813.

Johnson, E. W. 1950. Ornamental woody vines for the southern Great Plains. U. S. Dept. Agr. Farmers' Bull. No. 2015.

-----. 1951a. Ornamental shrubs for the southern Great Plains. U. S. Dept. Agr. Farmers' Bull. No. 2025.

-----. 1951b. Tree and shrub investigations in the southern Great Plains. Journ. For., 49:716-719.

-----. No date. Trees, shrubs, and vines for the southern Great Plains. (Mimeo.) 8 pp.

Johnson, Fred R. and F. E. Cobb. 1926. Tree planting in the Great Plains region. U. S. Dept. Agr. Farmers' Bull. No. 1312.

Kelsey, Harlan P. and William A. Dayton (eds.). 1942. Standardized plant names. 2nd ed. Harrisburg, Pa.: J. Horace McFarland Co. 675 pp.

Kincer, Joseph. 1936. Temperature, sunshine, and wind. In Atlas of American agriculture. U. S. Dept. Agr.

Korschgen, Leroy J. 1948. Late-fall and early-winter food habits of bobwhite quail in Missouri. Journ. Wildl. Mgt., 12:46-57.

Leake, C. D. 1945. Ethicogenesis. Sci. Monthly, 60:245-253.

Lee, Levon. 1948. The fall and winter food of the bobwhite in Oklahoma. Okla. Game and Fish Dept. 23 pp.

Lehmann, Valgene W. and Herbert Ward. 1941. Some plants valuable to quail in southwestern Texas. Journ. Wildl. Mgt., 5:131-135.

Leopold, Aldo. 1931. Report on a game survey of the North Central States. Washington: American Game Association 299 pp.

-----. 1933. Game management. New York: Chas. Scribner's Sons. 481 pp.

Marbut, C. F. 1936. Soils of the United States. In Atlas of American agriculture. U. S. Dept. Agr.

Martin, Alexander C. 1949. Procedures in wildlife food studies. U. S. Dept. Int., Fish and Wildl. Serv. Wildlife Leaflet No. 325.

-----, R. H. Gensch, and C. P. Brown. 1946. Alternative methods in upland game bird food analysis. Journ. Wildl. Mgt., 10:8-12.

McIlvain, E. H. and D. A. Savage. 1951. Fourteen-year summary of range improvement studies at the U. S. Southern Great Plains Field Station, Woodward, Oklahoma. (Mimeo.) 50 pp.

McKee, Roland and A. D. McNair. 1939. Winter legumes for green manure in the Cotton Belt. U. S. Dept. Agr. Farmers' Bull. No. 1663.

McMillan, Robert T. 1949. A study of farms in Oklahoma by size and economic class. Okla. Agr. Exp. Sta. Bull. No. B-330.

Munns, E. N. and Joseph H. Stoeckeler. 1946. How are the Great Plains shelterbelts? Journ. For., 44:237-257.

Nestler, Ralph B. 1949. Nutrition of bobwhite quail. Journ. Wildl. Mgt., 13:342-358.

Oklahoma Planning and Resources Board. 1948. Planting and care of forest trees. Div. Forestry. Pub. No. 6.

Oklahoma State Board for Vocational Education. 1950. Variations in farming within Oklahoma. Veterans Agr. Training. 50 pp.

Olson, D. S. 1935. The proposed tree plantations-their establishment and management. In Possibilities of shelterbelt planting in the plains region. U. S. Dept. Agr., Lake States For. Exp. Sta. 200 pp.

Park, Barry C. 1942. The yield and persistence of wildlife food plants. Journ. Wildl. Mgt., 6:118-121.

Patterson, Earl W. 1952. Variations in the importance of quail foods in western Oklahoma. Okla. Coop. Wildl. Res. Unit, Quar. Prog. Rep., 5:8-9.

Pelton, John F. 1951. Outline for ecological life history studies in trees, shrubs, and stem succulents. Ecology, 32:334-343.

Sampson, A. W. 1939. Plant indicators - concept and status. Bot. Rev., 5:155-206.

Savage, D. A. 1939. Grass culture and range improvement in the central and southern Great Plains. U. S. Dept. Agr. Cir. No. 491.

-----, James E. Smith, and D. F. Costello. 1948. Dry-land pastures on the plains. In Grass. Yearbook of Agriculture for 1948. U. S. Dept. Agr. Pp. 506-522.

Shantz, H. L. 1911. Natural vegetation as an indicator of the capabilities of land for crop production in the Great Plains area. U. S. Dept. Agr., Bur. Plant Ind. Bull. No. 201.

Snedecor, George W. 1946. Statistical methods. 4th ed. Ames, Iowa: Iowa State College Press. 485 pp.

Snider, L. C. 1917. Geography of Oklahoma. Okla. Geol. Surv. Bull. No. 27.

Spinner, George P. and James S. Bishop. 1950. Chemical analysis of wildlife foods in Connecticut. Journ. Wildl. Mgt., 14:175-180.

Steen, M. O. 1950. Road to restoration. Trans. Fifteenth N. Amer. Wildl. Conf. Pp. 356-362.

Stefferud, Alfred (ed.). 1948. Grass. Yearbook of agriculture for 1948. U. S. Dept. Agr.

-----. 1949. Trees. Yearbook of agriculture for 1949. U. S. Dept. Agr.

Stoddard, H. L. 1931. The bobwhite quail - its habits, preservation, and increase. New York: Chas. Scribner's Sons. 559 pp.

Stoesz, A. D. 1952. Harvesting, processing, and seeding of native grasses in the central and northern Great Plains. Agron. Journ., 44:378-383.

U. S. Department of Agriculture. 1938. Soils and men. Yearbook of agriculture for 1938. P. 1085.

Van Dersal, William R. 1938. Native woody plants of the United States. U. S. Dept. Agr. Misc. Pub. No. 303. 362 pp.

-----. 1940. Environmental improvement for valuable non-game animals. Trans. Fifth N. Amer. Wildl. Conf. Pp. 200-202.

Wahlgren, Harry F. 1941. Supplementary climatic notes for Oklahoma. In Climate and man. Yearbook of agriculture for 1941. U. S. Dept. Agr. Pp. 1073-1074.

Wainio, Walter W. and E. B. Forbes. 1941. The chemical composition of forest fruits and nuts from Pennsylvania. Journ. Agr. Res., 62:627-635.

Waterfall, U. T. 1952. A catalogue of the flora of Oklahoma. Okla. A. and M. Coll., Res. Foundation. 91 pp.

Weather Bureau. 1950. Climatological data, Oklahoma. U. S. Dept. Comm., Vol. 59, No. 13.

Weaver, John E. and Frederic E. Clements. 1938. Plant ecology. New York: McGraw-Hill Book Co., Inc. 601 pp.

Webb, William L. 1950. Biogeographic regions of Texas and Oklahoma. Ecology, 31:426-433.

Wheeler, W. A. 1950. Forage and pasture crops. New York: D. Van Nostrand, Co., Inc. 752 pp.

Wolff, Simon E. 1950. Harvesting and cleaning grass and legume seeds. U. S. Dept. Agr., Soil Cons. Serv. Agronomy Handbook, Sec. VI. (Multilithed).

Woodhouse, T. T. 1858. In Northern and western boundary line of the Creek country. House Ex. Doc. No. 104, 35th Cong., 1st Sess.

Wooten, E. O. and Paul C. Standley. 1915. Flora of New Mexico. Contr. U. S. Nat. Mus. Vol. 19. 794 pp.

Yerkes, Guy E. 1945. Propagation of trees and shrubs. U. S. Dept. Agr. Farmers' Bull. No. 1567.

VITA

William Roderick Hanson
candidate for the degree of
Doctor of Philosophy

Thesis: PLANTS FOR IMPROVING LAND-USE AND BOBWHITE HABITAT IN NORTHWESTERN OKLAHOMA

Major: Zoology

Minor: Botany

Biographical and Other Items:

Born: November 25, 1918 at Hanly, North Dakota

Undergraduate Study: State Teachers College, Dickinson, N. Dak., 1937-39; Montana State University, Missoula, Mont., 1941-43.

Graduate Study: Montana State University, 1946-47; University of California (Los Angeles), 1947-48; Oklahoma A. and M. College, 1950-53

Experiences: Ranching intermittently until 1946; taught elementary school, 1939-41; Army Air Corps, 1943-46; North Dakota Game and Fish Department, 1948-50

Honorary and Professional Societies: Ecological Society of America, The Wildlife Society, American Society of Mammalogists, American Ornithologists Union, American Association for the Advancement of Science, Phi Sigma, Phi Kappa Phi, and Member of the Society of Sigma Xi.

Date of Final Examination: May, 1953

THESIS TITLE: PLANTS FOR IMPROVING LAND-USE AND BOBWHITE HABITAT IN NORTHWESTERN OKLAHOMA

AUTHOR: William Roderick Hanson

THESIS ADVISER: Dr. A. M. Stebler

The content and form have been checked and approved by the author and thesis adviser. The Graduate School Office assumes no responsibility for errors either in form or content. The copies are sent to the bindery just as they are approved by the author and faculty adviser.

TYPIST: Betty Kyle