PRODUCTION, UTILIZATION, AND NUTRITIONAL QUALITY OF NORTHERN BOBWHITE FOODS IN WESTERN OKLAHOMA

By

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TABLE OF CONTENTS

Chapter Page

LIST OF TABLES

Table Page

Chapter V

LIST OF FIGURES

CHAPTER I

INTRODUCTION

This thesis is composed of 4 manuscripts formatted for submission to selected scientific journals. Each manuscript is complete as written and does not require additional support material. The order of arrangement for each manuscript is text, literature cited, tables, and figures. Chapter II, "Producing northern bobwhite food on sandy soils in semiarid mixed prairies", and Chapter V, "Production and nutritional quality of western ragweed seed in response to fertilization", are written in the format of the Wildlife Society Bulletin. Chapter III, "Utilization and nutritional benefits of supplemental food to northern bobwhites in western Oklahoma" is written in the format of the Journal of Wildlife Management. Chapter IV, "Protein quality of some common northern bobwhite foods and their ability to meet essential amino acid requirements", is written in the format of the Canadian Journal of Zoology.

CHAPTER II

PRODUCING NORTHERN BOBWHITE FOOD ON SANDY SOILS IN SEMIARID MIXED PRAIRIES

The quality and quantity of wildlife habitat has decreased due to expanding human populations. Increased hunting pressure on remaining habitats forces wildlife managers to search for cost effective ways to increase production and better utilize wildlife habitat. The northern bobwhite (Colinus virginianus) is the most sought after game bird in Oklahoma; 120,000 hunters may harvest up to 3.5 million bobwhites annually (DeMaso 1992).

Although bobwhites have many requirements, food is generally considered a critical limiting factor and of paramount importance in management strategies (Tobler 1973). Prescribed burning, disking, fertilization, and planting of agricultural food plots have been used to attempt to improve food availability and quality for bobwhite (Moore 1972, Derdeyn 1975, Buckner and Landers 1979, Webb and Guthery 1983, Guthery 1986:59, Koerth et al. 1986, Guthery et al. 1987, Dailey 1988, Hansmire et al. 1988). Most of the research on the benefits of these techniques has been conducted in the southeastern U.S. piney wood or south Texas coastal plain and prairie ecosystems.

Information on various management options to increase food production is lacking for the southern mixed prairie. This area has a semiarid, continental climate in which seeded, cultivated food plots are subject to drought and prone to failure as a result of poorer than expected growing conditions. We assessed the effectiveness and cost of seeding, disking, burning, and fertilization to stimulate seed production of cultivated and native plants that are important to bobwhite on sandy soil prairies in western Oklahoma.

STUDY AREA

Our study was conducted on 3 ranches within a 10 km^2 area in Woods County in northwestern Oklahoma, about 15 km west of Cleo Springs. Mean annual temperature was 15.3 C and ranged from 1.3 C in January to 28.4 C in July. Mean annual precipitation was 64.2 cm and ranged from 0.8 cm in December to 16.5 cm in June (Nat. Oceanic Atmos. Admin. 1987). Soils were dune and deep sands, primarily Tivoli fine sand, Tivoli loamy fine sand, Likes loamy fine sand, and Pratt loamy fine sand. Slopes ranged from 0-8%. Soils were excessively drained and were rapidly permeable on upland terraces. Primary landuse was cattle grazing.

The native vegetation on the 3 ranches was mixed prairie with an overstory of sand sagebrush (Artemisia filifolia). Grasses were dominated by sand dropseed (Sporabolus crytandrus), little bluestem (Andropogon scoparius), sand bluestem (A. hallii), sand paspalum (Paspalum stramineum), and various panicums (Panicum spp.). Forbs included western ragweed (Ambrosia psilostachya), prairie sunflower (Helianthus petiolaris), Texas croton (Croton texensis), broadleaf croton (C. glandulosus), erect dayflower (Commelina erecta), queensdelight stillingia (Stillingia sylvatica), clammy groundcherry (Physalis heterophylla), intermediate pricklepoppy (Argemone intermedia), and perennial wildbean (Strophostyles umbellata). Woody vegetation included black locust (Robinia pseudoacacia), woolleybucket bumelia (Bumelia lanuginosa), netleaf hackberry (Celtis reticulata), eastern redcedar (Juniperus virginiana), western soapberry (Sapindus drummondii), sand plum (Prunus angustifolia), fragrant sumac (Rhus aromatica), and smooth sumac (R. glabra). Plant nomenclature follows Scott and Wasser (1980).

MATERIALS AND METHODS

Eight disjunct sites of similar soil, slope, existing plant communities, and cattle stocking rates were enclosed with a 50- x 100-m (0.5-ha) fence to exclude livestock. Soil samples were collected in each location and a soil fertility analysis with fertilization recommendations was conducted by the Oklahoma State University Soils Testing Lab. Vegetation production was determined in November 1988 by hand clipping vegetation standing crop within 1-m^2 quadrats (Bonham 1989:199-200). Ecological condition of vegetation (USDA 1976) on study sites was assessed immediately before clipping each quadrat using the dry weight-rank method (Gillen and Smith 1986) to determine species composition by weight. Sites were subsequently divided into 6 20- x 25-m plots with a 3-m buffer zone between each plot. Plots were randomly assigned to 1 of the following treatments: (1) seedbed preparation plus planting a 3-seed (common sunflower [Helianthus annuus], sorghum almum [Sorghum almum], and Illinois bundleflower [Desmanthus illinoensis]) mixture with fertilization; (2) seedbed preparation plus planting the 3-seed mixture without fertilization; (3) winter disking (disturb soil to a depth of 10 cm) with fertilization; (4) winter disking without fertilization; (5) winter burn; and (6) untreated control.

Common sunflower is drought tolerant and classified as a reseeding annual; sorghum almum is a tall, perennial, sprangle-topped forage sorghum; and Illinois bundleflower is a hard seedcoated perennial legume (R. Turner, Turner Seed Co., pers. commun.). These species were chosen for experimental plantings because together they meet theoretical criteria for a semi-perennial food plot mix (Smart et al. 1972). Illinois bundleflower was commercially scarified by Johnston Seed Co. (Enid, Okla.). We conducted germination trials on random samples of each commercially purchased seed type. A sample of sunflower seed also was cold stratified by storing it in a cold (-5 C), humid (80% relative humidity) environment for 45 days prior to the germination trials to ensure germination (M. D. Porter, Samuel Roberts Nobel Found., pers. commun.). Seeding rates of 0.6 kg PLS (pure live seed)/ha bundleflower, 1.1 kg PLS/ha sunflower, and 1.4 kg PLS/ha sorghum were used as suggested by Guthery (1986:69).

Plots assigned treatment numbers 1, 2, 3, and 4 were mowed with a rotary mower on 30 January 1989 to remove brush and shrub topgrowth that might hinder cultivation. Treatments 1 and 2 were then tilled, and the seedbed was prepared for planting. Type EL rhizobium inoculate was added to the bundleflower seed (190 g inoculant/45 kg seed). Proper proportions of sunflower and bundleflower seeds were mixed and drilled into the soil approximately 1.5 cm using a 2-m wide cultipacker drill on 25 February 1989 to allow time for cold stratification of sunflower seed. Sorghum almum was broadcast onto these plots on 15 May 1989 using a hand-held broadcast spreader. On 30 January 1989, plots that received treatments 3 and 4 were passed over 1 time with a 2-m wide offset disk that disturbed soil to a depth of about 10 cm. Plots receiving treatments 1 and 3 were fertilized with 55 kg N/ha and 56 kg P/ha using a hand held broadcast spreader on 25 February 1989. Plots assigned treatment 5 were burned with a headfire (ambient conditions = 13-21 C and 26-38% relative humidity) on 31 January 1989. Controls were untreated and were excluded from livestock grazing. No treatments were repeated in 1990 to allow analysis of effects 1 year post-treatment.

Seed production was estimated with modified seed traps (Davison et al. 1955). Seed traps were constructed from 15-cm diameter x 15-cm deep plastic flower pots with 5 1.2-cm drain holes, 20- x 20-cm squares of 1.2- x 1.2-cm galvanized hardware cloth, and 10- x 10-cm squares of insect screen. Pots were buried to ground level and insect screen was placed in the bottom of the pot and molded to fit. Hardware cloth was placed over the top of the pot and held in place by 4 15-cm galvanized wire stakes. Traps caught seeds as they fell from plants, excluded animals, and allowed water to drain from the pot to prevent spoilage. Nine seed traps were set out in 3 x 3 trap grids on each of the 48 plots (i.e., 432 seed traps total) in May 1989. Seed traps were emptied every 4 weeks from July 1989 to February 1990 and July 1990 to February 1991. Contents of the 9 traps/plot were composited into a #2 paper bag, dried to a constant weight at 75 C, and sorted with screens to 1 mm. All known bobwhite food seeds (Baumgartner et al. 1952) were sorted and weighed by species to 0.1 mg. Seed production was calculated by multiplying the area of the top of the seed trap with the weight of seed removed from traps and converting the product to kg/ha. Vegetative biomass of forbs, grasses, and woody plants produced on each treatment was estimated in October of 1989 and 1990 by clipping and the dry-weight-rank method (Gillen and Smith 1986, Bonham 1989:199-200).

We determined treatment effect on weight of seed and vegetation biomass produced using a randomized complete block design with sites as blocks in each of 2 years. Tukey's HSD tests were used to test for significant differences among treatment means within years. Statistical analyses were made with SAS procedure ANOVA (SAS Inst., Inc. 1985). All F-tests were considered significant at $P < 0.05$. Seed production on tilled (treatments 1-4) vs. untilled (treatments 5 and 6), fertilized (treatments 1 and 3) vs. unfertilized (treatments 2, 4, 5, and 6), and burned (treatment 5) vs. unburned (treatments 1-4, and 6) was compared using orthagonal contrasts (Peterson 1985:89).

RESULTS

Germination trials of commercially purchased sorghum almum, scarified Illinois bundleflower, and cold stratified common sunflower averaged >75%. During initial assessments of the study sites in September 1988, total standing crop biomass was 895 ± 580 (SE) kg/ha; existing plant communities were 53 ± 17% similar to climax vegetation and contained a mean of 28 ± 9% standing western ragweed, which was the dominant forb species on all sites. Plots on 1 of the 8 sites were destroyed in March 1989 and 3 additional sites were destroyed in March of 1990 by farming and ranching operations. As a result, 7 sites were analyzed in 1989 and 4 sites in 1990.

Except during April 1989, at or above normal (40-yr average) precipitation occurred during the 1989 growing season (Mar-Sep), but below normal precipitation occurred during the 1990 growing season (Fig. 1). In spite of generally favorable growing conditions following planting in 1989, only common sunflower germinated on treatments 1 and 2.

Vegetation Production

More total vegetation was produced in 1989 than 1990 on all treatments except burned plots (Table 1). Forb biomass produced in 1989 on plant with fertilize and disk with fertilize was not different ($\underline{P} > 0.05$) but was greater ($\underline{P} = 0.0001$) than other treatments. Forb biomass in 1990 remained significantly greater on plant with fertilizer than disk without fertilizer, burn, and control, but was not different than plant without fertilizer and disk with fertilizer. Grass and woody plant biomass were not significantly different between treatments in 1989 or 1990.

Seed Production

Seed from western ragweed, Texas croton, broadleaf croton, erect dayflower, sunflower, crabgrass (Digitaria spp.), perennial wildbean, panicums, sand paspalum, and queensdelight stillingia were collected in traps. In 1989, planting with fertilization produced more ($\underline{P} = 0.0022$) seed than burn and control; all other treatments were not different (Table 2). Western ragweed was the dominant seed producing species on all treatments except plant with fertilizer. Planting without fertilization produced less total quantities of seed and significantly less common sunflower seed than planting with fertilizer; however, common sunflower and western ragweed still dominated. Seed production was similar on plant without fertilizer, disk with fertilizer, and disk without fertilizer.

Seed production of common sunflower was highest on plant with fertilizer; it was followed by western ragweed, broadleaf croton, erect dayflower, and Texas croton (Table 2). However, western ragweed seed production was greater than common sunflower on plant without fertilizer followed by erect dayflower, sand paspalum, and broadleaf croton. Western ragweed had a higher seed production on disk with fertilizer than did common sunflower on plant with fertilizer. Western ragweed led seed production on 5 of 6 treatments.

Seed drop from plants was greatest during September/October of the 1989-90 season (Fig. 2). July/August production was considerably less followed by November/December and January/February time periods, respectively. Very little seed dropped during January/February.

Seed production on all treatments was less in 1990-91 than in 1989-90. Planting with fertilization produced more ($\underline{P}$ = 0.0102) seed than burn; all other treatments were not different. Seed production on plant with fertilizer in 1990-91 was 21.75 ± 3.88 kg/ha compared to 133.24 ± 39.16 kg/ha for 1989-90. Plant without fertilizer produced only slightly less total seed but significantly less common sunflower seed than plant with fertilizer. Control sites produced slightly more seed than burn sites during the growing season 1 year post-fire.

Under drought conditions, western ragweed and Texas croton were the dominant seed producing species on all treatments in 1990-91. The majority of western ragweed seed fell in July/August; however, drop of Texas croton seed peaked during September/October, and seed drop by both species decreased by January/February.

Seed production was greater on tilled than untilled treatments during 1989-90 ($\underline{P}$ = 0.008) and 1990-91 ($\underline{P}$ = 0.0013) growing seasons. Fertilized tilled sites produced more ($\underline{P}$ = 0.0100) seed than unfertilized tilled sites in 1989-90 but failed to produce more ($\underline{P}$ = 0.8802) seed in 1990-91. Burning did not produce more seed than unburned controls during 1989-90 ($\underline{P}$ = 0.7928) or 1990-91 ($\underline{P}$ = 0.3937).

DISCUSSION

Cultivated food plots are commonly planted for bobwhites on both private land and state game management areas. Ellis (1972) reported that 88% of 25 state wildlife agencies utilized food plots as a bobwhite management technique. Although popular, annual food plots are expensive to establish and maintain and many fail increase food production. Guthery (1986:59) suggested that areas with <55 cm of annual rainfall are poor choices for food plots unless they can be irrigated; this estimate would vary with precipitation/evaporation ratios and other factors. An effective habitat management program needs to be economical and to insure that adequate foods will be produced regardless of the amount of rainfall.

Our study was conducted in a semiarid environment where annual precipitation averages 64 cm. Annual precipitation received during this study was 75 cm in 1989 and 53 cm in 1990, and precipitation/evaporation ratios were high, suggesting that this region is a marginal candidate for food plots. Although above normal precipitation was received during the growing season of 1989, only 1 of 3 species planted germinated, matured, and produced seed. Deep sandy soils in this climate are not suited to cultivated food producing plants; however, native food plants are ecologically adapted to survive under stress conditions.

Although food plots are not regarded by managers as effective procedures for increasing bobwhite densities (Guthery 1986:59), they may be effective at (1) improving inferior habitat where food is limiting, (2) carrying birds through weather emergencies, and (3) supplying specific nutrients during critical periods (Robel et al. 1974, Guthery 1986:59). When it is assumed that natural food supplies limit bobwhite populations, planting of food plots is often done to supplement the natural food supply (Tobler 1973).

Our first year results suggest that planting with fertilization substantially supplemented the natural food supply, but planting without fertilization did not provide more food than stimulating native species with disturbance and fertilization. Second year results indicated only slight reseeding of common sunflower on fertilized plots, which did not add significantly to the food base 1 year post-treatment.

Soil fertility on many bobwhite management areas is often so low that food producing plants may be stunted or fail to produce appreciable amounts of seed (Derdeyn 1975). Annual fertilization is often necessary to achieve maximum yield/area (Valentine 1989:363). Benefits of fertilization were obvious the first season of our study with fertilized treatments producing significantly more vegetation and food than unfertilized treatments. However, in the second season, effects of fertilization were small. Most N can be used in the first year if precipitation is adequate (Valentine 1989:381). Deep, infertile, sandy soils with leaching may have played a significant role in the expenditure of fertilizer between growing seasons.

An alternative to annual cultivated food plots would be to stimulate early successional native plants by a soil disturbance such as disking (Derdeyn 1975, Buckner and Landers 1979, Webb and Guthery 1983, Guthery et al. 1987). Pioneer and middle stage successional plants that occupy disturbed sites such as ragweeds, crotons, and sunflowers may not be palatable to cattle, especially when mature (Guthery 1986:72) and would not necessarily need to be fenced. However, most planted agricultural crops are highly palatable to livestock; consequently, when food plots are located in areas where livestock grazing is the primary landuse, fencing is a costly (ca. $500/ha) necessity.

The practice of disking creates lower successional communities dominated by forbs and improves food supplies as well as canopy cover for bobwhites (Jackson 1969, Turrentine 1971, Derdeyn 1975, Buckner and Landers 1979, Webb and Guthery 1983). Disking reduces perennial vegetation thus benefiting annual vegetation and reduces plant litter accumulation which may impede a quail's ability to find seed (Fulbright and Fulbright 1988). Tobler (1973) concluded that food plots of sorghum and wheat on sandy soil sites in western Oklahoma were inferior to native plant species in their ability to provide food for bobwhite during winter. Dailey (1988) found no differences in seed production between planted and fertilized food plots and disked and fertilized areas in Missouri.

During the first year, winter disking without fertilization produced only slightly more seed than winter burn or control; however, winter disking with fertilization produced only slightly more seed than disking without fertilizer but significantly more forb biomass. This was explained by an explosive growth of redroot amaranth (<u>Amaranthus</u> <u>retroflexus</u>) and common Russianthistle (<u>Salsola kali</u>) in response to fertilization on some plots that had a seed source and was reflected in a high standard error for disk and fertilize forb vegetation production in 1989 (Table 1). Seeds of these plants were not included in seed production estimates because of their small size and infrequent use by bobwhite (Baumgartner et al. 1952). Western ragweed produced more seed than the planted common sunflower when fertilized. Texas croton exhibited drought tolerance, matured later, and dispersed seed over a longer period of time compared to other species during the second growing season post-treatment.

Burning is an effective vegetation management tool in many ecosystems. Important shrubs, grasses, and forbs decrease as sagebrush (Artemisia spp.) increases on a range site (Harniss and Murray 1973). Prescribed fire is often used in sagebrush/grass communities to reduce sagebrush cover, which in turn reduces competition for light and moisture to other plant species (Patton et al. 1988). Herbaceous vegetation production can be increased from 50 to 75% after sand sagebrush control in northwestern Oklahoma (McIlvain et al. 1955). Standing crops of ragweed and croton can be significantly increased on sandy soils with winter burns in south Texas (Box and White 1969, Koerth et al. 1986, Hansmire et al. 1988). Seed producing forbs can be maintained at desirable numbers by burning at 2 to 5-year intervals (Lewis and Harshbarger 1986). Fire acts as a scarification agent on the hard seed coat of legumes which stimulates germination and increases the legume component of the post-fire plant community (Cushwa et al, 1967, Buckner and Landers 1979). Burning is most effective in areas where the annual rainfall exceeds 66 cm (Guthery 1986:75).

Our study, however, indicated that winter prescribed fire on semiarid, sandy soil sites in western Oklahoma did not produce significantly more bobwhite food than untreated controls possibly due to the fact that sand sagebrush quickly resprouted and grew vigorously after the burn to outcompete forbs for moisture and other nutrients. Perennial wild bean was the only legume being monitored by seed traps and did not show a significant increase in either year post-burn.

Cost Estimates

Most labor, materials, and equipment used in our study were donated so costs (except for fertilizer) were impossible to extrapolate into actual management situations. Thus, we used the cost estimations of Guthery (1986). The cost of fertilization at rates used in our study was about $64/ha. Guthery (1986:69) estimated that the pro-rated (20 year) annual cost of establishing and maintaining 0.4 ha (1 acre) food plots including fencing, lost grazing, seedbed preparation, seed, seeding, maintenance, and miscellaneous is about $545/ha. This estimate does not include fertilization, which would bring the annual cost to about $610/ha. Guthery (1986:74) estimated that in certain programs, if brush removal is not necessary, the annual cost of disking is about $21/ha; fertilization of disked strips would bring the annual cost about $85/ha. The annual cost of burning small plots is about $14/ha (Guthery 1986:75).

Using Guthery's (1986) cost estimates of planted food plots, rangeland disking, and prescribed burning, and our estimated cost of fertilization and seed production for the growing season immediately following treatment, the following seed production cost estimates can be calculated:

1) Planting with fertilization = $4.57/kg seed produced.
2) Planting w/out fertilization = $8.33/kg seed produced.
3) Disking with fertilization = $0.93/kg seed produced.
4) Disking w/out fertilization = $0.36/kg seed produced.
5) Winter burn = $0.42/kg seed produced.

Planted food plot estimates include pro-rated costs of fencing but the disking estimates do not. Our seed production estimates are from areas protected from livestock grazing, which could bias estimates of seed produced on disked areas grazed by livestock.

SUMMARY

Our study suggests that tillage of deep sands in semiarid environments of western Oklahoma produced more bobwhite food and vegetation biomass than winter burning probably due to aggressive resprouting of sagebrush and lack of native legume seed banks on burned plots. Tillage with fertilization produced significantly more forb biomass than tillage without fertilization. Only 1 of 3 species of a planted food plot mix germinated, matured, and produced seed. Planting a food plot mix produced more bobwhite food only when fertilizer was applied. Effects of fertilization were realized only for the growing season immediately following treatment.

Our results indicate that winter disking with fertilization was the most cost effective management practice on these semiarid, sandy soil sites to produce the most food/area. Benefits of this technique may not be apparent 1 year post-treatment if adequate rainfall causes depletion by plant uptake, or if N is leached from the root zone. In drier years, fertilizer carryover may prolong the benefits into the second year.

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Table 1. Standing crop biomass (kg/ha dry weight) of forbs, grasses, woody, and total vegetation following planting with fertilization, planting, disking with fertilization, disking, winter burning, and control, Woods County, Oklahoma, during the 1989 and 1990 growing seasons (n = 7/treatment in 1989; n = 4/treatment in 1990).

Year	Vegetation class							
	Forb		Grass		Woody		Total	
Treatment	X	SE	X	SE	X	SE	X	SE
1989								
Plant & fert	6,530A[a]	554	707A	264	0A	0	7,236A	526
Plant	2,405B	385	773A	256	327A	327	3,505AB	574
Disk & fert	5,221A	1,206	1,010A	665	9A	9	6,239AB	911
Disk	2,188B	468	935A	389	68A	44	3,192AB	578
Burn	1,251B	239	1,362A	566	0A	0	2,613B	558
Control	1,116B	239	1,473A	441	1,836A	1,836	4,425AB	2,029

Table 1. Continued.

Year Treatment	Forb $\underline{X}$	Forb SE	Grass $\underline{X}$	Grass SE	Woody $\underline{X}$	Woody SE	Total $\underline{X}$	Total SE
$\underline{F}$	9.74		1.84		0.94		2.50	
$\underline{P}$	0.0001		0.6898		0.4889		0.0119	
1990								
Plant & fert	1,237A	366	751A	181	26A	26	2,013A	297
Plant	729AB	226	1,418A	354	26A	26	2,173A	274
Disk & fert	458AB	203	1,018A	699	382A	382	1,858A	505
Disk	247B	72	1,777A	438	911A	674	2,935A	603
Burn	136B	62	2,539A	1,104	0A	0	2,675A	1,063
Control	294B	189	1,321A	413	121A	121	1,736A	304

Table 1. Continued.

Year	Vegetation class							
	Forb		Grass		Woody		Total	
Treatment	$\underline{X}$	SE	$\underline{X}$	SE	$\underline{X}$	SE	$\underline{X}$	SE
F	3.50		1.50		1.07		1.07	
P	0.0119		0.3405		0.3553		0.6019	

[a]Treatment means within a column followed by the same letter do not differ (*P* > 0.05) based on Tukey's HSD test.

Table 2. Seed trap estimates of seed production (kg/ha) of forbs and grasses following planting with fertilization, planting, disking with fertilization, disking, winter burning, and control in Woods County, Oklahoma, 1989-91 (n = 7/treatment in 1989, n = 4/treatment in 1990).

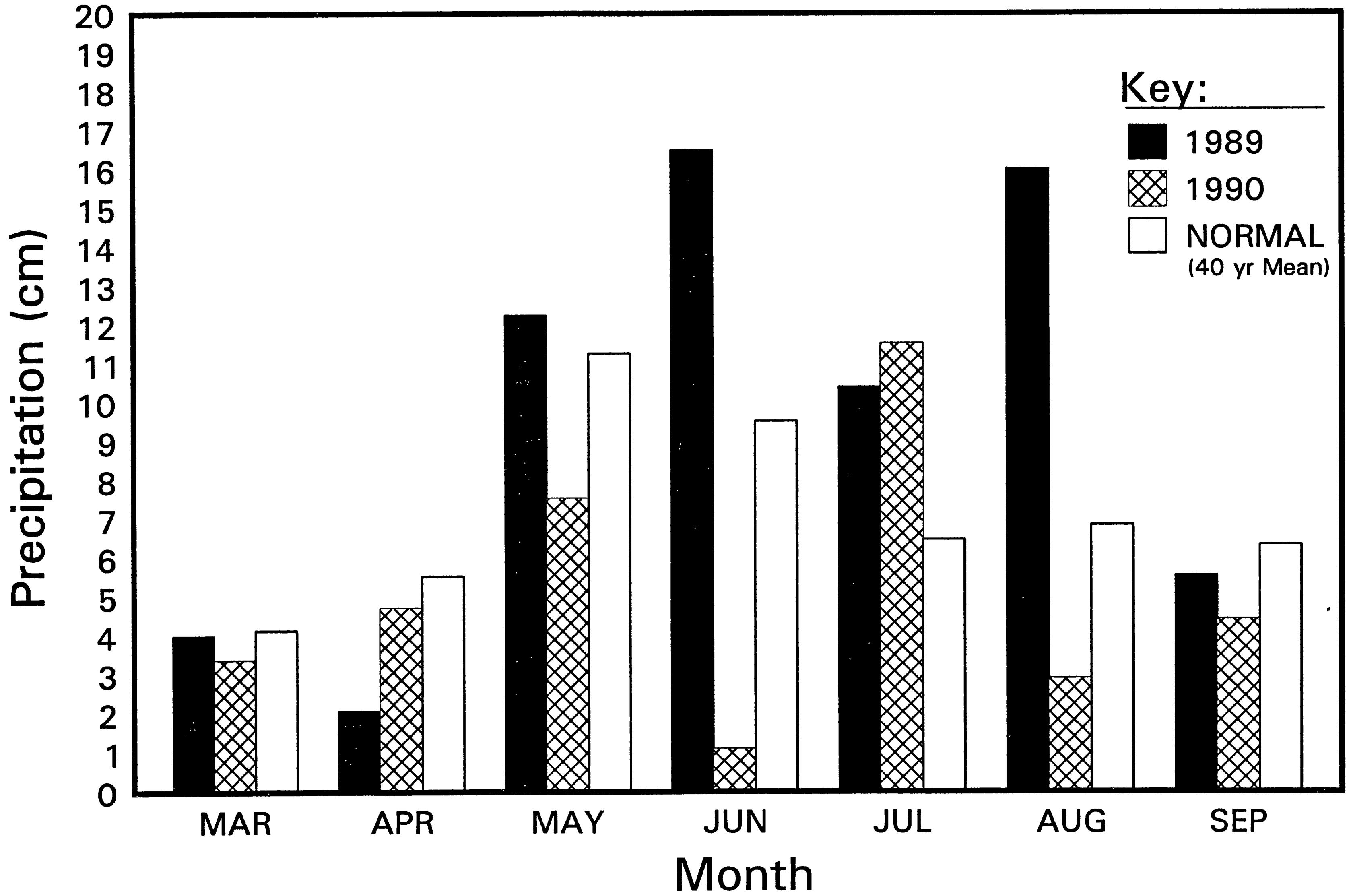
Year	Treatment													
	Plant & fert		Plant		Disk & fert		Disk		Burn		Control			
Species	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	F	P
1989														
Broadleaf croton	4 7A[a]	1 88	2 2AB	0.52	2 2AB	1 06	2 6AB	0 81	1 8AB	0.54	1.1B	0.21	2.22	0 0782
Crabgrass	1 3A	1.20	0.7A	0.69	0 2A	0.16	0.3A	0 24	0.4A	0.24	0.4A	0.29	0.99	0.4413
Erect dayflower	3.5A	1.27	3 5A	1 41	1 7A	0.61	6.9A	2.00	3.1A	1 40	3 9A	1 52	1 65	0.1766
Panicum	0.2A	0 09	0 2A	0.16	0 2A	0.16	5 5A	5 45	0.3A	0 19	0 3A	0 25	0.95	0 4622
Perennial wildbean	0 0A	0.00	1 5A	1.13	0 1A	0.11	1.1A	0.53	0.6A	0.56	0 7A	0.47	1.07	0.3948
Queensdelight stillingia	0 7A	0.71	0.0A	0.00	17 0A	16.99	0 0A	0 00	1.8A	1 54	0.8A	0 79	0 93	0 4726
Sand paspalum	1 2A	0.98	3 4A	2 10	1 3A	0 85	5 1A	3 11	3 4A	2.51	1.6A	1 03	0 93	0 4743
Common sunflower	63.5A	25.76	14.7B	7.58	0 0B	0.01	1.3B	1 33	0.0B	0.04	0 0B	0 03	5 92	0 0006
Texas croton	2.1A	1.07	1.1A	0.41	0 9A	0.30	0.2A	0.09	0 8A	0.56	0.5A	0 36	1.72	0.1603
Western ragweed	56 1AB	17.63	38.2AB	8.70	67 0A	25.58	36.2AB	7.89	19.9AB	4 19	16 1B	2.54	2.98	0.0267
COMBINED	133.2A	39 16	65.4AB	9.79	90.6AB	26.65	59 1AB	8 50	32.2B	5.77	25 4B	3 74	4 87	0 0022

Table 2 Continued.

Year	Treatment													
	Plant & fert		Plant		Disk & fert		Disk		Burn		Control			
Species	X	SE	X	SE	X	SE	X	SE	X	SE	X	SE	F	P
1990														
Broadleaf croton	2 0A	0 76	3.7A	1 20	1 1A	0 65	1 8A	0 71	0.3A	0 23	1 3A	0 73	2 38	0 0882
Crabgrass	0 5A	0 17	0.1A	0.05	0 2A	0.08	0 4A	0 29	0.2A	0 18	0.3A	0 18	0 55	0.7394
Erect dayflower	1 9A	1 67	0 5A	0.21	0.6A	0 58	0 8A	0 20	0 0A	0.01	0 3A	0 13	0 92	0.4964
Panicum	5 1A	2.99	0 8A	0.71	0.1A	0 08	2 4A	1.84	0.7A	0 38	3 3A	2.69	1 32	0.3095
Perennial wildbean	0 0A	0 00	0 0A	0.00	0 1A	0.11	0 0A	0 00	0.2A	0.11	0 0A	0 00	1.97	0 1418
Queensdelight stillingia	0 7A	0.69	0.2A	0.24	0.0A	0.00	0 0A	0 00	0.0A	0 00	0 0A	0 00	0.84	0.5399
Sand paspalum	0 4A	0.26	0.7A	0.24	0 6A	0.41	0 6A	0.33	0.7A	0.46	0 1A	0.09	0 63	0.6832
Common sunflower	2 0A	0 51	0 5B	0.31	0.6B	0 39	0.0B	0.00	0 2B	0 22	0.0B	0 00	6.44	0.0022
Texas croton	5 1A	2.42	4 5A	1.50	2 7A	1.03	5 3A	2.80	1.4A	0.78	1.3A	0 59	1 30	0.3168
Western ragweed	4 2A	1.79	6 1A	1 51	5.0A	2.21	5.1A	1.37	0.9A	0 31	1.7A	0.88	3 13	0.0394
COMBINED	21.8A	3.88	17.2AB	4.02	11.1AB	3 20	16.5AB	1.92	4.6B	1 79	8.3AB	2.53	4 54	0.0102

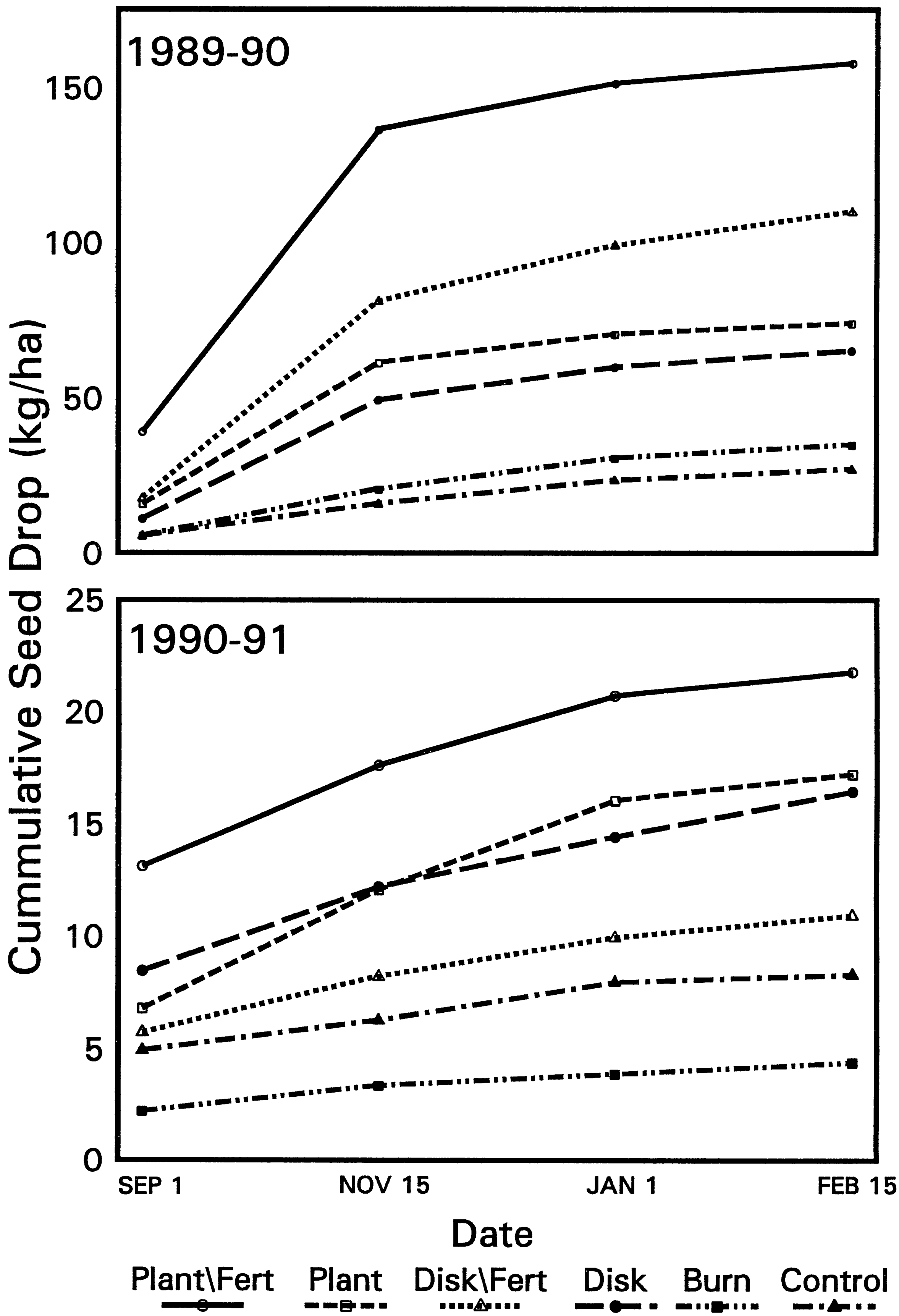
[a]Treatment means within a row followed by the same letter do not differ (P > 0 05) based on Tukey's HSD test.

Fig. 1. Precipitation received in Woods County, Oklahoma, during the March-September growing season of 1989 and 1990 compared to normal (40 yr mean) monthly precipitation.



Precipitation (cm)
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Key:
1989
1990
NORMAL
(40 yr Mean)
MAR
APR
MAY
JUN
JUL
AUG
SEP
Month

Fig. 2. Cumulative seed drop (kg/ha) over time by seed trap estimates in Woods County, Oklahoma, during the March-September growing season of 1989-90 and 1990-91.


1989-90
1990-91
Cummulative Seed Drop (kg/ha)
150
100
50
0
25
20
15
10
5
0
SEP 1
NOV 15
JAN 1
FEB 15
Date
Plant\Fert
Plant
Disk\Fert
Disk
Burn
Control

CHAPTER III

UTILIZATION AND NUTRITIONAL BENEFITS OF SUPPLEMENTAL FOOD TO NORTHERN BOBWHITES IN WESTERN OKLAHOMA

Abstract: Utilization and nutritional benefits derived from the consumption of supplemental food by northern bobwhites (Colinus virginianus) were studied in western Oklahoma during 1989 and 1990. Bobwhites were seasonally harvested on 3 ranches from supplementally-fed populations (<250 m from a food plot or feeder) and control populations (>900 m from supplemental food). Bobwhites relied on supplemental food for >15% of their diet in only 1 of 6 seasons. Supplemental feeding did not significantly increase body weight or levels of body fat. Supplemental feeding influenced the nutritional ecology of bobwhite as evidenced by significant differences in concentrations of fat, crude protein, and 10 essential amino acids in crop digesta. Although crude protein requirements were apparently met in all seasons, diets of control and supplemented birds were deficient in ≥1 essential amino acids for growth or breeding. The sulfur-containing amino acids, methionine + cystine, were consistently the most limiting nutrients in the diet, ranging from 0-52% deficient. We found no

evidence that supplemental feeding programs using feeders and food plots benefited bobwhites in western Oklahoma.

Management strategies to improve habitat for northern bobwhite usually involve manipulation of limiting factors such as food or cover (Robel and Arruda 1986). Several of these strategies are popular despite the lack of adequate evaluation of their efficacy. One such example is the ubiquitous use of supplemental feeding programs (e.g., food plots and feeders) that presumably provide additional seed sources. The rationale for such a program is that natural seed production can limit survival during especially stressful periods that induce elevated nutritional demands on birds. However, biological evidence in support of such a premise remains elusive in the wildlife literature (Doerr 1988). Nutritional stress in winter often results in weight loss, reduced fat reserves, and increased mortality of bobwhite in their northern range (Robel et al. 1979b). Birds may benefit from supplemental feeding programs throughout the year during prolonged periods of drought in the southern part of their range (Guthery 1986).

Among the many nutrients thought to be periodically limiting in the diet of gallinaceous birds, protein has been suggested as 1 of the most critical (Beckerton and Middleton 1982). Protein concentrations in seed of many supplemented grains, as well as native plants, are low (Deyoe and Shellenberger 1965, VanEtten et al. 1967, Hang et al. 1980) in comparison to extremely high dietary requirements of quail for growth (24%) and reproduction (20%) (Natl. Res. Counc. 1984). Despite the concern about protein nutrition, the nutritional ecology of bobwhite, especially during the breeding season, remains poorly understood. Adequate evaluations of the quality of proteins in native and supplemental food sources are required to better understand relationships between this nutrient category and population dynamics. This necessitates the acquisition of information regarding the essential amino acid (EAA) composition of diets and forages, which dictates the biological value of a protein (Oser 1959).

Our objective was to evaluate the use and nutritional benefits derived from the consumption of supplemental food by northern bobwhite in western Oklahoma in 1989-1990. Specifically, we examined seasonal changes in the botanical composition and nutritional quality of diets and body condition indices of birds harvested from populations receiving supplemental food and those that were not. Special consideration was given to assessing the ability of seasonal diets to meet EAA requirements of quail for growth, maintenance and breeding.

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STUDY AREA

Our study was conducted on 3 ranches within a 10 km^2 area in Woods County in northwestern Oklahoma. Climate was semiarid, continental; mean annual temperature was 15.3 C and ranged from 1.3 C in January to 28.4 C in July. Mean annual precipitation was 64.2 cm and ranged from 0.8 cm in December to 16.5 cm in June. Precipitation during our study was 75.4 cm in 1989 and 52.9 cm in 1990 (Nat. Oceanic Atmos. Admin. 1987). Soils were dune and deep loamy fine sands.

Native vegetation on the study area was mixed prairie with an overstory of sand sagebrush (Artemisia filifolia). Dominant grasses were sand dropseed (Sporabolus crytandrus), little bluestem (Andropogon scoparius), sand bluestem (A. hallii), sand paspalum (Paspalum stramineum), and various panicums (Panicum spp.). Dominant forbs included western ragweed (Ambrosia psilostachya), prairie sunflower (Helianthus petiolaris), Texas croton (Croton texensis), broadleaf croton (C. glandulosus), erect dayflower (Commelina erecta), queensdelight stillingia (Stillingia sylvatica), clammy groundcherry (Physalis heterophylla), intermediate pricklepoppy (Argemone intermedia), and perennial wildbean (Strophostyles umbellata). Woody vegetation included black locust (Robinia pseudoacacia), woolleybucket bumelia (Bumelia lanuginosa), netleaf hackberry (*Celtis reticulata*), eastern redcedar (*Juniperus virginiana*), western soapberry (*Sapindus drummondii*), sand plum (*Prunus angustifolia*), fragrant sumac (*Rhus aromatica*), and smooth sumac (*R. glabra*). Plant nomenclature follows Scott and Wasser (1980).

Primary landuse for this area was livestock production; cattle grazing occurred at various stocking rates. Management for bobwhite on all 3 ranches typified such practices on private land in western Oklahoma and consisted of supplemental feeding through the use of numerous annual food plots and quail feeders. Supplemental food was primarily sorghum, wheat, rye, millet, and mung bean grain; feeders were kept full year-round.

MATERIALS AND METHODS

Bobwhite were collected with firearms seasonally (Feb, Jul, and Nov of 1989-1990) on areas with and without supplemental food. Birds collected <250 m from a food plot or feeder were considered to be from supplementally-fed populations. Birds collected >900 m from a food plot or feeder were considered controls (Robel 1969). Birds were collected after 1000 hr to afford them an opportunity to fill their crops. We attempted to collect equal numbers of quail from control and supplemented populations from each of the 3 ranches during collection periods. Collected birds were individually placed in sealed plastic bags, labeled, and frozen until necropsy.

Body Condition Analysis

Postmortem examination of specimens included recording sex, age, and weights (0.1 mg) of whole body, liver, gizzard, gizzard fat, spleen, adrenal glands, and reproductive organs. The small intestine was flushed of digesta and returned to the carcass; the crop and gizzard were removed and processed separately. Carcass and digesta in the crop and gizzard were dried by lyophilization. Carcasses were ground to a fine consistency in a food processor to obtain a complete mix. Concentrations of water, fat, and ash in the carcass was determined using procedures outlined by Lochmiller et al. (1982). Percent body protein was determined by difference (Cambell and Leatherland 1980).

Food Habit and Diet Quality Analysis

Dried food items in each crop were classified into categories (seed, fruit, leaves and flowers, insect, and debris) and weighed to 0.1 mg before grinding. Items such as grit or unidentifiable material were classified as debris. Seeds were identified using Landers and Johnson (1976) and a reference seed collection. Diet composition data were summarized seasonally and the importance of each food item was calculated using percent dry weights.

Compositing within treatments of crop digesta samples weighing <1.0 g was necessary prior to nutritional analysis (Jenks et al. 1989). Digesta samples were ground to a powder consistency using a micro-grinding mill. Subsamples of digesta from the crop and gizzard were analyzed for concentrations of crude fat by ether extraction for 6 hr in a Soxhlet Apparatus (Grodzinski et al. 1975), total nitrogen by micro-Kjeldahl analysis (crude protein was calculated using a correction factor of 6.25) (Williams 1984).

Amino Acid Analysis

Fat-extracted digesta from the crop was weighed to approximately 40 mg of protein and placed in 25 x 150-mm test tubes with Teflon caps and hydrolyzed in 15 ml 6N HCL at 110 C for 24 hr. One ml hydrolyzed sample was filtered through a 0.45 μm syringe filter (Acrodisc CRPTF, Fisher Scientific, Plano, Tex. 75074). An internal standard (25 μl methionine sulfone) was added to 75 μl of filtered hydrolosate before derivatization. Pre-column derivatization of amino acids was accomplished using phenylisothiocynate to produce phenylthiocarbamyl amino acids (Pico-Tag Workstation, Millipore Corporation, Milford, Mass. 01757) and re-filtered through a 0.45 μm syringe filter. Concentrations of 17 individual amino acids were determined using high pressure liquid chromatography (HPLC) (Waters Model 820 system controller and Model 501 pumps). Chromatographic conditions were the following: Waters Pico-Tag Silica/C18 (15 cm X 3.9 mm) column; column temperature 38 C; flow rate 1.0 ml/min; pumps back pressure 5500 psi, system sensitivity 489 mv/s (recorder) and 0.5 absorbance units full scale (Waters Model 484 UV detector, set at 254 nm); sample size 4 μl; run time 28 min. Solvents used were

Eluent A and Eluent B (catalog number 88108 and 88112, respectively, Millipore Corporation, Milford, Mass.) with Pump A and Pump B delivering Eluents A and B, respectively. Solvent conditions and gradients used for separation of amino acids were those described by Cohen et al. (1988). A casein reference protein (from bovine milk, no. C-0376, Sigma Chem Co., St. Louis, Mo.) of a known amino acid composition was hydrolyzed and analyzed along with crop samples for quality control.

Tryptophan, an EAA comprising <1.0% of the total dry weight of seeds (Harrold and Nalewaja 1977), was not measured because it was destroyed by acid hydrolysis (Gehrke et al. 1985). Some loss (ca. 15%) of methionine and cystine occurred as well due to varying degrees of destruction during acid hydrolysis (Spindler et al. 1984, Elkin and Griffith 1985). Glycine was listed as an EAA because it is considered to be essential or semiessential in poultry diets (Ensminger 1980:130, Patrick and Schaible 1981:98). Concentrations of methionine + cystine (met + cys), phenylalanine + tyrosine (phe + tyr), and glycine + serine (gly + ser) were compared to requirements because the requirement for 1 can be partially compensated for by the other (Natl. Res. Counc. 1984:5). Dietary deficiencies of EAA were elucidated by comparing EAA composition of crop digesta to published requirements for Japanese quail (Coturnix coturnix japonica). Previous studies have documented strong similarities between the EAA requirements of poultry and quail (Eggum and Beams 1986), so we assumed that requirements of Japanese quail and northern bobwhite were similar. Requirements of EAA for growing, breeding, and maintenance in bobwhite are only partially known (Allen and Young 1980, Natl. Res. Counc. 1984, Eggum and Beams 1986).

Nonprotein Nitrogen Determination

Nonprotein nitrogen (NPN) was assumed to be all nitrogen not incorporated into 1 of the 17 amino acids detected by HPLC (Bell 1963, Synge 1963). Nitrogen concentration of true protein in each sample was determined as the sum of all amino acid nitrogen; NPN was calculated as the difference between total nitrogen (Kjeldahl analysis) and amino acid nitrogen (HPLC analysis).

Statistical Analyses

Due to small sample sizes ($\underline{n}$ = 9-26), data were pooled for 1989 and 1990 by treatment and season. Differences in body condition indices and measures of diet quality between control and supplemented populations were determined using the general linear models (GLM) procedure of SAS (PROC GLM; SAS Inst., Inc. 1988). A 2-way analysis of variance (ANOVA) was used to compare sex and treatment means within each season. All statistical tests were considered significant at $\underline{P} < 0.05$.

RESULTS

Body Condition Analysis

Adult northern bobwhite (n = 212) were collected from control (n = 114) and supplemented (n = 98) populations during 1989 and 1990; 24 had empty crops. Supplemented birds (overall $\bar{x}$ = 185.0 ± 1.3 [SE] g) were not heavier (P > 0.05) than control (184.3 ± 1.4 g) birds during any season (Table 1). The heaviest supplemented bird weighed 216 g, and the heaviest control bird weighed 241 g; both were reproductively active females collected in July. No differences (P > 0.05) in percent body fat of bobwhite were observed between control and supplemented populations during any season.

Gizzard fat and liver weights of bobwhite collected on supplemented areas were heavier (P = 0.031 and P = 0.003) than controls in February only. Gizzard weights of bobwhite collected from control populations were heavier (P < 0.05) than those from supplemented populations in February and November. Spleen and gonad/ovary weights of bobwhite from control areas were heavier (P < 0.05) than those from supplemented areas in November. All body indices except gizzard weight differed (P < 0.05) among seasons. Females had heavier (P < 0.05) whole body, gizzard fat, liver, and adrenal weights than males in July only.

Diet Composition

Sufficient quantities of digesta in crops for chemical analyses were obtained from 106 birds on control areas and

82 birds on supplemental areas. Thirty-five different species of seeds from 13 forb genera, 9 grass genera, 4 legume genera, and 7 genera of woody plants were identified in the diet (Table 2). Diets contained seeds of 22 different species of plants in winter, 22 in summer, and 23 in fall. Identified seeds included: spurge (Euphorbia sp.), Texas croton, broadleaf croton, western ragweed, giant ragweed (Ambrosia trifida), prairie sunflower, erect dayflower, prostrate knotweed (Polygonum aviculare), mentzelia (Mentzelia sp.), queensdelight stillingia, narrowleaf gromwell (Lithospermum incisum), redroot amaranth (Amaranthus retroflexus), clammy groundcherry, intermediate pricklepoppy, poison ivy (Toxicodendron radicans), sand paspalum, panicums, crabgrass (Digitaria spp.), rescue brome (Bromus catharticus), Johnsongrass (Sorghum halepense), millet, wheat, rye, sorghum, tickclover (Desmodium spp.), roundhead lespedeza (Lespedeza capitata), mung bean, perennial wildbean (Strophostyles umbellata), pine (Pinus sp.), woolleybucket bumelia, black locust, netleaf hackberry, grape (Vitis sp.), fragrant sumac, and smooth sumac.

Supplemental foods were only identified in the crops of bobwhite collected ≤250 m of a feeder or food plot (Table 2). Supplemental foods (mainly wheat) comprised (83% of the total diet and 85% of quail crops) a large portion of the supplementally-fed diet in February 1990; however, no supplemental foods were identified in February 1989 (Table

3). Consumption of supplemental foods in summer (15% of diet) and fall (4% of diet, all consumed in 1989 only) was limited and included primarily mung bean, rye, and sorghum. Native foods comprised a large proportion of the diet of both supplemental and control populations during all seasons except February 1990. Insects and seed from sunflower, panicums, and erect dayflower were readily consumed in summer; woolleybucket bumelia, western ragweed, croton, and sunflower seeds were selected in fall; and, winter diets were dominated by woolleybucket bumelia, western ragweed, tickclover, and black locust (Table 2).

Nutritional Quality

There was evidence that supplemental feeding influenced the the nutritional ecology of northern bobwhite populations (Table 4). Concentrations of high energy fats in crops collected from control populations exceeded ($\underline{P} < 0.05$) levels in birds from supplemental areas in winter and summer. The 3x greater fat levels observed among birds from control populations in winter were largely attributed to the consumption of woolleybucket bumelia and western ragweed as opposed to wheat (Table 2). Chemical analysis of 3 separate crops containing exclusively 7.5 g of woolleybucket bumelia, 3.7 g western ragweed, and 3.7 g wheat yielded fat estimates of 24.8%, 21.4%, and 1.0%, respectively. Differences in diet quality between populations also were apparent for crude protein concentrations, which were greater ($\underline{P} < 0.05$) on supplemental areas in winter and control areas in summer

(Table 4). The average diet of bobwhite from supplemental populations in winter consisted of >10% black locust (38% crude protein). Consumption of insects (>45% crude protein) was nearly 2x greater on control than supplemental areas in summer (Table 2).

We observed significant differences in the quality of dietary protein between bobwhite populations as indicated by EAA composition of crop digesta (Table 4). Nine of 12 measurements of EAA in the diets of supplementally-fed bobwhite in winter were greater ($\underline{P} < 0.05$) than levels among controls; only arginine, glycine, or glycine+serine concentrations did not differ. Differences were reversed in summer when concentrations of all EAA were greater ($\underline{P} < 0.05$) in crop digesta of bobwhite collected from control than supplemental areas. Essential amino acid concentrations of diets did not differ between populations in fall.

Comparing crude protein concentrations in crops to estimated dietary requirements of quail (Table 5) suggested that protein nutrition was adequate for maintenance in fall and winter and breeding or growth in summer on both treatment areas. Seasonal comparisons of EAA concentrations in crops to dietary requirements of quail were contradictory and suggested that the quality of proteins were inadequate to avoid malnutrition. Essential amino acid requirements for maintenance in fall and winter and growth or breeding in summer were not completely satisfied, and methionine+cystine was consistently the first limiting essential amino acid (LEAA) on both supplemental and control areas.

Winter maintenance requirements for all EAA were satisfied by diets consumed by supplementally-fed bobwhite, but deficiencies of histidine (18%) and methionine+cystine (30%) characterized diets of birds from control areas. Diets of bobwhite from control areas were only deficient in methionine+cystine (38 and 39%, respectively) for growth and breeding in summer. Bobwhite from supplemented areas had summer diets deficient in methionine+cystine (14%) for maintenance and methionine+cystine (52%), threonine (21%), and leucine (1%) for growth. Diets in the fall were deficient only in methionine+cystine (27, 23%) on both control and supplemental areas.

Nonprotein nitrogen concentrations were generally high but did not differ ($\underline{P} > 0.05$) between treatments for any season (Table 4). Corrected crude protein estimates did differ between treatments with significantly greater concentrations in crop digesta of bobwhite on supplemental areas in winter ($\underline{P} = 0.018$) and control areas in summer ($\underline{P} = 0.001$).

Importance of Insects

Insects were consumed during all seasons but comprised >25% of the diet on both treatments in summer (Fig. 1). We examined the nutritional importance of insects in the diet by comparing those with a predominance of insects (22 crops contained >85% insects) to those with a predominance of seed

(n = 164) in the crop (Table 6). Insect-dominated crops provided greater ($P < 0.05$) amounts of EAA to the diet than seed-dominated crops. Compared to dietary requirements (Table 5), the average seed-dominated crop was deficient in all EAA except glycine+serine, phenylalanine+tyrosine, arginine, valine, and histidine (growth only) for growth and breeding. Insect-dominated crops were deficient in only methionine+cystine for breeding and growth. After accounting for nonprotein nitrogen levels which differed between seed- and insect-dominated crops, corrected crude protein concentrations averaged 15% and 28%, respectively ($P = 0.001$).

DISCUSSION

Our results indicate that northern bobwhite in western Oklahoma did not rely heavily upon supplemental foods which comprised >15% of their diet in only 1 (February 1990) of 6 collection periods. The only apparent benefits derived from supplemental food were elevated gizzard fat and liver weights in winter compared to controls. However, it is noteworthy that elevated body fat levels were not observed and nutrient analyses indicated greater concentrations of fat in the diet of controls compared to bobwhite from supplemental populations during these same collection periods. Elevated liver weights could be a reflection of the higher crude protein concentrations in the winter diets of supplementally-fed quail as this dynamic organ is known to fluctuate in size with feeding rates and diet quality in birds (Ankney 1977, DuBowy 1985). No other morphological differences could be attributed to supplemental feeding in other seasons.

Supplemental feeding during the summer breeding season appeared to have a negative impact on the nutritional ecology of bobwhite. Quail continued to use supplemental foods in summer as indicated by 15% mung bean and rye in diets of bobwhite collected ≤250 m of feeders and food plots. These supplemented foods appeared to be consumed at the expense of insects (25 vs. 42% dry weight of diet). Consequently, crude protein and EAA concentrations of diets reflected predominantly vegetative diets on supplemental areas as compared to controls. Deficiencies of EAA were most apparent for growing and breeding birds during this nutritionally demanding season (Andrews et al. 1973, Allen and Young 1980).

Wood et al. (1986) reported that bobwhite in south Texas were able to meet minimum requirements of crude protein for reproduction in spring and summer by consuming mixed diets of seed and insects, but protein quality was not addressed. Similarly, Hurst and Poe (1985) found that levels and ratios of EAA differed significantly between seed species consumed by eastern wild turkeys (Meleagris gallopavo), and unlike seeds, insects consumed by poults provided adequate concentrations of EAA for growth. Our observations that crops containing >85% insect biomass provided the best mix of EAA for meeting requirements for growth and reproduction also support these findings.

Of all the EAA required in the diet of northern bobwhite, the sulfur-containing amino acids methionine+cystine were consistently the most limiting (0-52% deficient). Sulfur-containing amino acids were also deficient (43% for growth, 44% for breeding) in insect-dominated diets in summer. Analytical inaccuracies attributed to acid hydrolysis unavoidably plagued our determinations of methionine and cystine in diets (Spindler et al. 1984, Elkin and Griffith 1985). However, substantial deficiencies remain apparent even after correcting results for the estimated 85% recovery rates (determined from casein quality controls) we achieved for these 2 amino acids.

MANAGEMENT IMPLICATIONS

Crude protein estimates provide a useful index of forage quality but often fail to present an adequate profile of the quality of proteins in the forage. Essential amino acid profiles reflected important deficiency problems despite apparently adequate concentrations of crude protein in diets of bobwhite in western Oklahoma. A primary reason for the discrepancy between actual crude protein concentrations and quality of proteins is the nonprotein nitrogen composition of diets. Nonprotein nitrogen sources are a highly varied group of compounds in plants and animals and include nitrogenous lipids, amides, purine and pyrimidine compounds, urea, and others (Maynard et al. 1979, Holt and Sosulski 1981). Nutritive value of these NPN-containing compounds is not entirely clear, but it may be only half the value of protein nitrogen-containing compounds (Synge 1963).

Estimates of crude protein and EAA requirements of quail were based on studies using isolated protein sources (corn and soybean meal) in formulated mixtures, which assumes that amino acids are 80-90% available (Natl. Res. Counc. 1984). Seeds of many wild plant species contain digestion inhibitors or toxins (Robbins 1983:237) and have digestibilities ranging from 40 to 90% (Robel et al. 1979a, 1979c). These traits will act in concert to further reduce the usefulness of crude protein as an accurate indicator of protein quality.

It appears that EAA deficiencies are common in diets of bobwhite. Deficiencies of any one EAA can result in reduced growth, survival, and reproductive performance (Robel 1979a, Allen and Young 1980, Harms and Buresh 1987, Tsiagbe et al. 1987, Straznicka 1990). Diversified diets containing a prominent legume or insect component provide the best opportunity to meet daily nutrient requirements. Management practices resulting in improved production of insects and a diverse forb component in the habitat should benefit bobwhite nutritionally. Monoculture food plots will not provide the nutrient diversity required by northern bobwhites in western Oklahoma.

We found no evidence that supplemental feeding programs using feeders and food plots benefited bobwhite in western Oklahoma. Our study indicates that the use of supplemental feeding programs that do not offer high quality protein sources should be discouraged in summer given the extremely high requirements of EAA for growth and reproduction at this time. Supplemental feeding in winter is also questionable given the disparity in concentrations of high energy fat between native seed sources and domestic varieties of grain commonly supplied in feeders.

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Table 1. Body condition indices of adult bobwhites as influenced by season and area of collection Quail collected <250 m from a food plot or feeder were considered supplemented and those collected >900 m from a food plot or feeder were considered controls. Quail were harvested in February (winter), July (summer), and November (fall) in Woods County, Oklahoma, 1989-1990

	Season															
	Winter					Summer					Fall					
	Control (n = 43)		Supplemented (n = 25)			Control (n = 35)		Supplemented (n = 35)			Control (n = 36)		Supplemented (n = 38)			Season effect
Index	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	P
Whole body, g	190 96	1 89	190.21	2.76	0 986	176.30	3.19	182 83	2.55	0.183	184 19	1 80	183 60	1 62	0.969	0 002
Liver, g	2 56	0 07	2.81	0.11	0 003	3 85	0.17	3 95	0 15	0.868	3 18	0 09	3.18	0 11	0 797	<0 001
mg/g body weight	13 51	0 41	14.94	0.57	0 003	21 68	0 69	21.44	0.60	0 536	17 26	0.44	17 36	0 61	0.747	<0.001
Gizzard, g	8 01	0 17	7.30	0 25	0 006	7 57	0 23	7.75	0 27	0.974	8.05	0 20	7 31	0 17	0 007	0 639
mg/g body weight	41 99	0 84	38.42	1.25	0 004	42 94	1.07	42.50	1 50	0.594	43.74	1 09	39 84	0.86	0.005	0.049
Spleen, mg	3 68	0 71	2.77	0 53	0 253	9 36	1.86	7.74	1 65	0.877	8 86	1 83	4 22	0 61	0 020	<0 001
mg/g body weight	0.19	0 04	0 15	0 03	0 283	0 55	0.11	0.42	0.09	0.867	0 47	0 09	0.23	0 03	0 016	<0 001
Adrenal gland, mg	1.29	0 07	1 37	0 11	0 318	1.94	0 22	1.90	0.18	0.960	1.43	0.12	1.38	<0 01	0.729	<0 001
mg/g body weight	0.07	<0 01	0.07	0 01	0 274	0.11	0.01	0.10	0.01	0 914	0 08	0.04	0 08	<0 01	0 752	<0 001
Gonad/ovary, mg	4.25	0 49	4.01	0.41	0 062	171.98	28.63	137.49	30.37	0 442	3 91	0.42	2 97	0 28	0.006	<0 001
mg/g body weight	0.22	0 03	0.21	0 02	0 083	9 24	1 30	7.15	1.41	0 319	0 21	0 02	0.16	0.01	0 002	<0 001
Gizzard fat, mg	17 06	2.02	25.55	3 67	0 031	10 15	2 11	12.11	1.65	0 567	9 91	1 14	8.07	0 97	0 185	<0 001
mg/g body weight	0 89	0.10	1 34	0.19	0 030	0.56	0 12	0.65	0.09	0.674	0 53	0.06	0.44	0 05	0 162	<0 001
Body fat, %	18 85	0 69	18.82	1 15	0 963	10 48	0.74	11.96	0 81	0 254	10 11	0 60	10 64	0 44	0 476	<0 001

Table 1. Continued.

	Season															
	Winter					Summer					Fall					
	Control (n = 43)		Supplemented (n = 25)			Control (n = 35)		Supplemented (n = 35)			Control (n = 36)		Supplemented (n = 38)			Season effect
Index	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	P
Body protein, %	71 24	0 68	71.26	0.97	0.814	78 09	0.66	76 67	0 72	0.210	78 71	0.54	78 16	0 44	0 419	<0 001
Body ash, %	9.93	0 17	9.92	0.25	0.390	11 42	0.21	11.37	0.20	0 953	11 19	0 22	11 03	0 21	0 727	<0 001
Body water, %	37 49	0.35	37.34	0 33	0.898	34 35	0.38	35.03	0 43	0.091	36 15	0.44	37.15	0.48	0.114	<0 001

[a]P-value for GLM F-statistic comparison of treatment means within a season.

Table 2. Overall composition of diets (% dry weight) of northern bobwhites collected <250 m from a food plot or feeder (supplemented) and those collected >900 m from a food plot or feeder (control) in February (winter), July (summer), and November (fall) in Woods County, Oklahoma, 1989-1990.

	Season					
	Winter		Summer		Fall	
	Supplemented	Control	Supplemented	Control	Supplemented	Control
Dietary item	(n = 21)	(n = 39)	(n = 29)	(n = 29)	(n = 32)	(n = 38)
Forb						
Spurge	0.00	1.09	0.00	0.00	0.00	0.00
Texas croton	0.05	0.12	0.94	4.49	35.58	13.15
Broadleaf croton	0.00	0.00	0.33	0.29	0.98	0.11
Western ragweed	0.38	20.61	0.04	0.00	7.47	19.25
Giant ragweed	0.00	0.00	0.00	0.00	0.93	0.00
Prairie sunflower	0.02	0.48	7.72	21.99	9.67	9.90
Erect dayflower	2.62	0.68	12.73	7.17	0.79	1.60

Table 2. Continued.

	Season					
	Winter		Summer		Fall	
	Supplemented	Control	Supplemented	Control	Supplemented	Control
Dietary item	(n = 21)	(n = 39)	(n = 29)	(n = 29)	(n = 32)	(n = 38)
Prostrate knotweed	0.00	0.00	0.00	4.17	0.00	0.00
Mentzelia	0.00	0.00	0.00	0.00	0.00	0.42
Queensdelight stillingia	5.43	0.65	1.70	1.04	0.18	2.65
Narrowleaf gromwell	0.00	0.02	1.40	1.56	0.00	0.07
Redroot amaranth	0.00	0.00	0.00	0.00	0.02	0.02
Clammy groundcherry	0.00	0.00	10.04	4.11	0.00	0.00
Intermediate pricklepoppy	0.00	0.00	1.52	0.32	0.47	0.21
Poison ivy	0.00	0.98	0.00	0.00	0.00	0.00

Table 2. Continued.

	Season					
	Winter		Summer		Fall	
	Supplemented	Control	Supplemented	Control	Supplemented	Control
Dietary item	(n = 21)	(n = 39)	(n = 29)	(n = 29)	(n = 32)	(n = 38)
Grass						
Sand paspalum	0.85	0.06	0.07	0.01	0.00	2.54
Panicum	0.01	0.00	18.75	7.19	0.00	0.02
Crabgrass	0.05	0.00	0.00	0.00	3.37	1.95
Rescue brome	0.00	0.00	0.00	0.00	1.05	0.63
Johnsongrass	0.00	0.00	0.11	0.00	0.00	0.00
Legume						
Tickclover	0.17	7.87	0.00	0.00	0.00	0.01
Roundhead lespedeza	0.01	0.00	0.00	0.00	0.00	0.00
Perennial wildbean	0.06	0.70	1.66	0.97	4.54	0.23

Table 2. Continued.

	Season					
	Winter		Summer		Fall	
	Supplemented	Control	Supplemented	Control	Supplemented	Control
Dietary item	(n = 21)	(n = 39)	(n = 29)	(n = 29)	(n = 32)	(n = 38)
Woody						
Pine	0.00	0.03	0.00	0.00	0.00	0.00
Woollybucket bumelia	9.59	58.41	0.00	0.00	27.33	38.31
Black locust	14.33	0.88	0.25	0.13	0.00	3.68
Netleaf hackberry	0.00	0.36	0.41	1.07	0.00	0.23
Grape	0.06	0.60	1.81	0.00	0.00	0.00
Fragrant sumac	0.72	0.00	0.16	0.16	0.00	0.00
Smooth sumac	0.07	0.00	0.00	0.00	0.00	0.00
Supplement						
Millet	0.00	0.00	0.00	0.00	0.05	0.00

Table 2. Continued.

	Season					
	Winter		Summer		Fall	
	Supplemented	Control	Supplemented	Control	Supplemented	Control
Dietary item	(n = 21)	(n = 39)	(n = 29)	(n = 29)	(n = 32)	(n = 38)
Wheat	47.20	0.00	0.35	0.00	0.00	0.00
Rye	0.00	0.00	4.31	0.00	0.00	0.00
Sorghum	8.71	0.00	0.14	0.00	3.41	0.00
Mung bean	4.83	0.00	9.84	0.00	0.48	0.00
Miscellaneous						
Insect	1.72	3.12	25.16	42.37	1.97	4.14
Green forb	1.03	2.53	0.00	0.00	0.72	0.05
Debris	2.09	0.83	0.54	2.95	0.00	0.00
Total Native	39.26	100.00	85.36	100.00	96.06	100.00
Total Supplement	60.74	0.00	14.64	0.00	3.94	0.00

Table 3. Occurrence of supplemental food in crops of northern bobwhite collected $\leq$250 m of a food plot or feeder during February (winter), July (summer), and November (fall) in Woods County, Oklahoma, 1989-1990.

Year Month	n	No. crops with supplemental feed	No. crops without supplemental feed
1989			
February	8	0 (0.0)[a]	8 (100.0)
July	10	3 (30.0)	7 (70.0)
November	14	3 (21.4)	11 (78.6)
1990			
February	13	11 (84.6)	2 (15.4)
July	18	4 (22.2)	14 (77.8)
November	18	0 (0.0)	18 (100.0)
Overall			
February	21	11 (52.4)	10 (47.6)
July	28	7 (25.0)	21 (75.0)
November	32	3 (9.4)	29 (90.6)

[a]Values in parentheses indicate percent of crops with or without supplemental food.

Table 4. Crude protein, fat, and amino acid concentrations (% dry weight) of bobwhite crops collected <250 m from a food plot or feeder (supplemented) and those collected >900 m from a food plot or feeder (control) in February (winter), July (summer), and November (fall) in Woods County, Oklahoma, 1989-1990

	Season															
	Winter					Summer					Fall					
	Control (n = 39)		Supplemented (n = 21)			Control (n = 29)		Supplemented (n = 28)			Control (n = 36)		Supplemented (n = 33)			Season effect
Parameter	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	P
Fat	22 41	0.97	6 87	1 65	<0.001	13 30	0.90	10 01	0.88	0 015	20 22	1.18	21 17	1 16	0.600	<0 001
Crude protein	16.84	0.98	24 48	2 83	0.004	35 37	2 34	28 12	2.30	0.014	18.51	0.96	19.44	0.94	0.413	<0 001
Essential amino acids																
Arginine	1 45	0.16	1 68	0.27	0 477	1.88	0 08	1.37	0 09	<0 001	1.48	0 11	1.59	0 13	0.552	0 781
Glycine	0 85	0.05	0 96	0.11	0 364	1.86	0.12	1 35	0 12	0 003	1.03	0.09	0 92	0 07	0 427	<0 001
Glycine + serine	1.76	0 12	2 05	0 23	0 277	3.28	0.19	2 67	0.23	0 018	1 62	0.11	1.74	0 12	0.357	<0 001
Histidine	0.25	0.03	0.40	0 07	0.010	0 65	0.05	0.42	0 03	0.001	0.41	0 05	0 41	0 05	0 973	<0 001
Isoleucine	0.56	0.05	0.81	0.11	0 015	1 32	0.07	0.99	0.08	0 002	0 72	0.05	0 75	0.05	0.644	<0 001
Leucine	1.21	0.07	1 69	0 19	0 007	2.11	0.11	1 68	0 13	0.010	1.16	0 09	1.28	0.09	0 318	<0.001
Lysine	0.86	0.07	1.40	0 27	0.014	1.72	0 09	1 34	0 12	0 013	0 79	0 07	0.80	0.07	0.852	<0 001
Methionine + cystine	0.29	0.03	0 44	0 08	0.041	0.47	0 01	0.36	0.04	0 002	0 31	0 03	0 32	0 04	0.846	0.015
Phenylalanine	0 75	0 05	1 24	0 15	<0.001	1 20	0 04	0.99	0.08	0.010	0.71	0.04	0.76	0 05	0.459	<0 001
Phenylalanine + tyrosine	1.78	0.12	3.93	0.44	<0.001	3 50	0 33	2.51	0 36	0.037	1.78	0.12	2.01	0.17	0.397	<0 001
Threonine	0.52	0 03	0 74	0 08	0 003	1 04	0.05	0.80	0 05	0 002	0 52	0 04	0 61	0 04	0 118	<0 001

Table 4 Continued

	Season															
	Winter					Summer					Fall					
	Control (n = 39)		Supplemented (n = 21)			Control (n = 29)		Supplemented (n = 28)			Control (n = 36)		Supplemented (n = 33)			Season effect
Parameter	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	X	SE	X	SE	P[a]	P
Valine	0 76	0 07	1 03	0 09	0 030	1.80	0 09	1 33	0.12	0 001	0 97	0 09	0 98	0 08	0.859	<0 001
Nonessential amino acids																
Tyrosine	1 04	0 09	2.69	0.32	<0 001	2.30	0 31	1.53	0 29	0.067	1 06	0.09	1 25	0.13	0.173	<0.001
Alanine	0.82	0 05	1.06	0.11	0.029	2.31	0.17	1.65	0.16	0.003	0.94	0 12	1 02	0 11	0.577	<0 001
Aspartic acid	1 69	0 13	1.96	0.24	0.307	2.35	0 11	1.85	0.12	0 003	1.45	0 08	1.68	0.11	0 076	<0.001
Glucine	2 99	0 19	4.00	0.29	0.005	3.91	0 15	3.05	0.19	0.001	2.97	0 24	3 42	0 28	0.191	0.332
Proline	0.97	0.07	1.56	0.09	<0.001	1.81	0.09	1.40	0.11	0 003	2.35	0.41	2 15	0 28	0.719	<0 001
Serine	0 90	0 07	1.08	0.12	0 205	1 42	0.09	1 32	0.11	0 308	0 60	0.04	0 81	0 07	0 003	<0 001
Nonprotein nitrogen	25 89	1.29	27.52	1.33	0 434	30.64	1 27	32.53	1 49	0.352	26.79	1 36	25.43	1.79	0 569	<0 001
Corrected crude protein	12.48	1.00	17.74	2.07	0.018	24.53	1.13	18 97	1.36	0.001	13.55	1.21	14.50	1.04	0 527	<0 001

[a]P-value for GLM F-statistic comparison of treatment means within a season.

Table 5. Estimated dietary requirements of crude protein and essential amino acids for growth, maintenance, and breeding of Japanese quail as a percentage of dry weight.

Requirement	Growth[c]	Maintenance[ad]	Breeding[c]
Crude protein	24.00	12.00	20.00
Arginine	1.25	0.72	1.26
Glycine	[b]	0.72	[b]
Glycine (plus serine)	1.20	[b]	1.17
Histidine	0.36	0.30	0.42
Isoleucine	0.98	0.54	0.90
Leucine	1.69	0.84	1.42
Lysine	1.30	0.62	1.15
Methionine (plus cystine)	0.75	0.42	0.76

Table 5. Continued.

Requirement	Growth[c]	Maintenance[ad]	Breeding[c]
Phenylanine (plus tyrosine)	1.80	0.90	1.40
Threonine	1.02	0.48	0.74
Tryptophan	0.22	0.12	0.19
Valine	0.95	0.60	0.92

[a]Calculated using a winter maintenance of 12% crude protein (Nestler et al. 1944).

[b]Requirement unknown.

[c]Natl. Res. Counc. 1984.

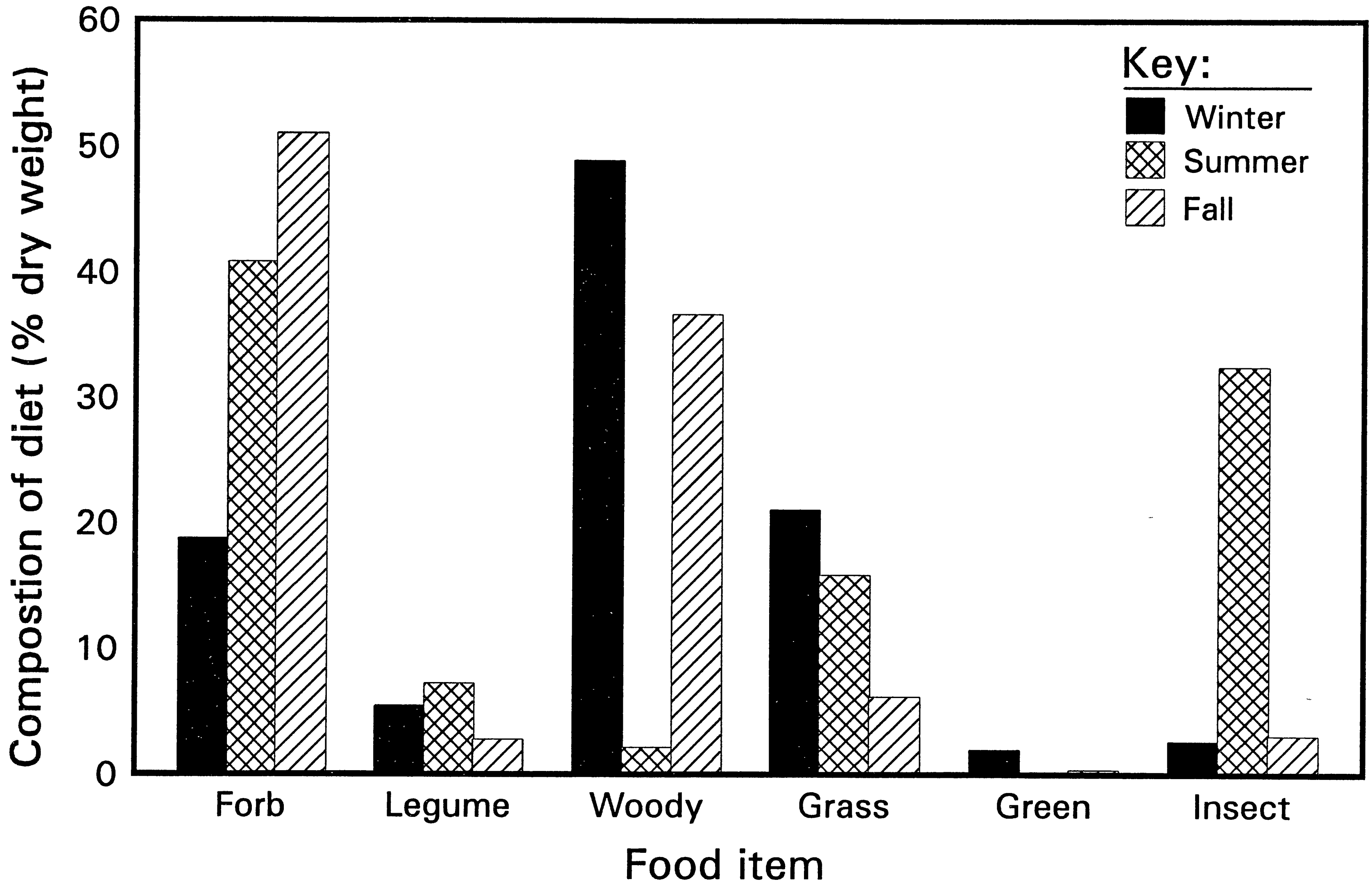
[d]Eggum and Beams 1986.

Table 6. Crude protein, fat, and amino acid concentrations (% dry weight) of bobwhite crops containing ≥85% insects (insect-dominated) and crops containing <85% insects (seed-dominated) from Woods County, Oklahoma, 1989-1990

Parameter	Seed-dominated crops (n = 164)		Insect-dominated crops (n = 22)		
	X	SE	X	SE	P[a]
Fat	17.47	0.67	11.14	0.41	0 0015
Crude protein	20 13	0.62	45.07	1.30	0.0001
Essential amino acids					
Arginine	1.52	0.07	1 88	0.11	0 0692
Glycine	1.01	0.04	2.15	0.12	0.0001
Glycine + serine	1.89	0.07	3.94	0.12	0.0001
Histidine	0.39	0 03	0.68	0.07	0.0001
Isoleucine	0.76	0.03	1 44	0.08	0.0001
Leucine	1.36	0.05	2.37	0.12	0.0001
Lysine	1.00	0.05	1.94	0 11	0.0001
Methionine + cystine	0.35	0.01	0.43	0.04	0 0808
Phenylalanine	0.86	0.03	1 20	0.07	0 0019
Phenylalanine + tyrosine	2 30	0.11	3.55	0.47	0.0096
Threonine	0 63	0 03	1.17	0 05	0.0001
Valine	1 00	0.04	2.03	0.11	0 0001
Nonessential amino acids					
Tyrosine	1 42	0 08	2.35	0.43	0.0203
Alanine	1.06	0.05	2.82	0 15	0 0001
Aspartic acid	1.70	0.05	2.53	0.12	0.0001
Glucine	3.25	0.11	3.95	0 20	0.0282
Proline	1.66	0 12	2.09	0.08	0 1990
Serine	0.89	0 04	1.78	0.08	0.0001
Nonprotein nitrogen	26.70	0 62	36 91	1 49	0 0001
Corrected crude protein	14.76	0 55	28.53	0.01	0.0001

[a]P-value for GLM F-statistic for treatment differences within crops.

Fig. 1. Overall composition (forb, woody, and grass seed, green vegetation, and insect) of bobwhite diets (% dry weight) as determined by crop analysis of birds collected in February (winter), July (summer), and November (fall), 1989-1990, Woods County, Oklahoma.



Compostion of diet (% dry weight)
60
50
40
30
20
10
0
Key:
Winter
Summer
Fall
Forb
Legume
Woody
Grass
Green
Insect
Food item

CHAPTER IV

PROTEIN QUALITY OF SOME COMMON NORTHERN BOBWHITE FOODS AND THEIR ABILITY TO MEET ESSENTIAL AMINO ACID REQUIREMENTS

Abstract: Northern bobwhite (*Colinus virginianus*) have a high dietary protein requirement to maintain normal growth and reproduction. Protein has been suggested to be one of the most important and limiting nutrients regulating northern bobwhite populations. Crude protein (CP) values for foodstuffs may overestimate useable protein or available essential amino acids (EAA) due to high nonprotein nitrogen (NPN) levels. We analyzed the protein quality of 21 common bobwhite foods by comparing amino acid concentrations of seed to requirements of quail and assigned biological values to seed species in accordance to their ability to meet daily intake requirements of 10 EAA. Despite apparently adequate crude protein content levels, deficiencies of EAA were detected in all seed species analyzed; legumes were the best source and grasses were the poorest source. Deficiencies of EAA to meet recommended maintenance requirements of adults ranged from 13% in legumes to 98% in grasses. A large percentage of the total nitrogen pool was composed of NPN

with values ranging from 25% (queensdelight stillingia [Stillingia sylvatica]) to 44% (redroot amaranth [Amaranthus retroflexus]). Computed biological values ranged from 69 (netleaf hackberry [Celtis reticulata]) to 93 (erect dayflower [Commelina erecta] and woolly croton [Croton capitatus]). Amino acid content is a better indication of forage quality than crude protein estimates when evaluating a seed's ability to meet nutritional requirements.

Northern bobwhites require a minimum of 23-28% crude protein in the diet for optimum growth and reproduction (Nestler et al. 1942, Baldini et al. 1950, Baldini et al. 1953, Tuttle et al. 1953, Scott et al. 1963, Andrews et al. 1973, Serafin 1977) and 11-12% crude protein for adult maintenance (Nestler et al. 1944). Survival and reproduction of upland game birds is dependent on the quality of protein in their diet (Nestler et al. 1942, White 1978, Beckerton and Middleton 1982, Wood et al. 1986, Servello and Kirkpatrick 1987). However, early studies of protein requirements of bobwhite were conducted without regard to amino acid requirements, despite the realization that amino acid composition of dietary protein was of greater nutritional importance than crude protein (Serafin 1977).

Dietary proteins are composed of about 20 amino acids that constitute the true protein value of forage. Ten of which are essential amino acids (EAA) in birds because they cannot be synthesized in sufficient quantities to meet cellular requirements and must be acquired from the diet (Munks et al. 1946, Robbins 1983:10). Methionine and lysine were reported to be the first limiting amino acids in pen-reared bobwhite diets (Baldini et al. 1953, Scott et al. 1963). Information about the EAA composition of many important food proteins consumed by upland game birds in the wild presently does not exist. Animals subjected to an EAA deficiency can be expected to exhibit decreased growth, reproduction, and survival (Baldini et al. 1953, Robel 1979a, Allen and Young 1980, Harms and Buresh 1987, Tsiagbe et al. 1987, Straznicka 1990).

Seeds of many cultivated food plants are deficient in meeting recommended requirements of EAA for many animal species (Deyoe and Shellenberger 1965, VanEtten et al. 1967; Hang et al. 1980). For example, cereal grains are generally poor sources of all EAA, and legumes are frequently poor sources of methionine, cystine, and threonine (Hang et al. 1980). Sedinger (1984) suggested that crude protein (6.25 x %N) can greatly overestimate the true protein content of Arctic green plants due a high nonprotein nitrogen (NPN) component. Similar relationships have been reported for seed grains of many cultivated varieties of plants (VanEtten et al. 1967, Holt and Sosulski 1981, Singh and Jambunathan 1981).

These observations have led us to postulate that EAA deficiencies in the diet of grainivorous upland game birds are common. We evaluated nutritional quality of seed proteins for some common plant species utilized by bobwhite in central and western Oklahoma (Baumgartner et al. 1952, Tobler and Lewis 1981). Profiles of EAA in seed proteins were compared to requirements for maintenance, growth, and reproduction of Japanese quail (*Coturnix coturnix japonica*).

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MATERIALS AND METHODS

Seed Sampling and Preparation

Mature seeds of common sunflower (*Helianthus annuus*), woolly croton, trailing wildbean (*Strophostyles helvola*), Illinois bundleflower (*Desmanthus illinoensis*), partridgepea senna (*Cassia fasciculata*), and rattlebox (*Crotolaria sagittalis*) were collected in Payne County in central Oklahoma. Redroot amaranth, giant ragweed (*Ambrosia trifida*), western ragweed (*A. psilostachya*), erect dayflower, clammy groundcherry (*Physalis heterophylla*), queensdelight stillingia, mung bean (*Phaseolus aureus*), perennial wildbean (*Strophostyles umbellata*), pearl millet (*Pennisetum glaucum*), Johnsongrass (*Sorghum halepense*), common sorghum (S. vulgare), sorghum almum (S. almum), black locust (Robinia pseudoacacia), woollybucket bumelia (Bumelia lanuginosa), and netleaf hackberry were collected in Woods County in northwest Oklahoma. Nomenclature follows Scott and Wasser (1980). Plant groups were classified as forbs, grasses, legumes, and woody species. Mature seed of each species was collected from ≥25 individual plants on ≥3 different sites in September 1989.

Seed samples were separated from extraneous plant material, dried by lyophilization, and ground to a fine powder using a micro-grinding mill. Pericarp was left intact and included in analysis on clammy groundcherry, woollybucket bumelia, and netleaf hackberry because bobwhite are known to consume whole fruits of these plants (Baumgartner et al. 1952).

Crude Fat and Crude Protein Determination

Crude fat concentration was assessed by ether extraction for 6 hr in a Soxhlet Apparatus (Grodzinski et al. 1975:288). Concentration of the total nitrogen pool (%N) was determined by micro-Kjeldahl analysis and crude protein (CP) determined by multiplying the percent nitrogen by the correction factor 6.25 (Williams 1984).

Amino Acid Analysis

Fat-extracted seed samples were weighed to approximately 40 mg of protein and placed in 25 X 150 mm test tubes with Teflon caps and hydrolyzed in 15 ml 6N HCL at 110 C for 24 hr. One ml of the hydrolyzed sample was filtered through a 0.45 μm syringe filter (Acrodisc CRPTF, Fisher Scientific, Plano, Tex. 75074). An internal standard (25 μl methionine sulfone) was added to 75 μl of filtered hydrolosate before derivatization. Pre-column derivatization of amino acids was accomplished using phenylisothiocynate to produce phenylthiocarbamyl amino acids (Pico-Tag Workstation, Millipore Corporation, Milford, Mass. 01757) and re-filtered through a 0.45 μm syringe filter. Concentrations of 17 individual amino acids were determined in derivatized seed samples using high pressure liquid chromatography (HPLC) (Waters Model 820 system controller and Model 501 pumps).

Chromatographic conditions were the following: Waters Pico-Tag Silica/C18 (15 cm x 3.9 mm) column; column temperature 38 C; flow rate 1.0 ml/min; pumps back pressure 5500 psi, system sensitivity 489 mv/s (recorder) and 0.5 absorbance units full scale (Waters Model 484 UV detector, set at 254 nm); sample size 4 μl; run time 28 min. Solvents used were Eluent A and Eluent B (catalog number 88108 and 88112, respectively, Millipore Corporation, Milford, Mass.) with Pump A and Pump B delivering Eluents A and B, respectively. Solvent conditions and gradients used for separation of amino acids were those described by Cohen et al. (1988). A casein reference protein (from bovine milk, no. C-0376, Sigma Chem Co., St. Louis, Mo.) of a known amino acid composition was hydrolyzed and analyzed along with seed samples for quality control.

Tryptophan, an EAA comprising <1.0% of the total dry weight of seeds (Harrold and Nalewaja 1977), was not measured because it is destroyed by acid hydrolysis (Gehrke et al. 1985). Some loss (about 15%) of methionine and cystine occurred as well due to varying degrees of destruction during acid hydrolysis (Spindler et al. 1984, Elkin and Griffith 1985). Concentrations of the sulfur-containing amino acids cystine and methionine were summed (met + cys) and presented as 1 value (Allen and Young 1980, Natl. Res. Counc. 1984). Glycine was listed as an EAA because it is considered to be essential or semiessential in poultry diets (Ensminger 1980:130, Patrick and Schaible 1981:98). The concentrations of phenylalanine + tyrosine (phe + tyr) and glycine + serine (gly + ser) were included in analysis because the nutritional requirement of the former can be partially compensated for by the later (Natl. Res. Counc. 1984:5). Concentrations of amino acids are reported as percentage of dry weight basis (%DW) and relative proportion of the total amino acid pool (g/16gN).

We compared the EAA composition of seed protein to the daily EAA requirements of quail to determine percent deficiency (Table 1). Due to the lack of complete EAA requirement information for bobwhites, we used requirement values for Japanese quail to assess protein quality (Allen and Young 1980, Natl. Res. Counc. 1984, Eggum and Beams 1986). Previous studies have documented strong similarities between the EAA requirements of poultry and quail (Eggum and Beams 1986).

Nonprotein Nitrogen Determination

Nonprotein nitrogen was assumed to be all nitrogen not incorporated into 1 of the 17 amino acids detected by HPLC (Bell 1963, Synge 1963). Nitrogen concentration of true protein in each sample was determined as the sum of all amino acid nitrogen; NPN was calculated as the difference between total nitrogen (Kjeldahl analysis) and amino acid nitrogen (HPLC analysis). A corrected crude protein (CCP) value was calculated after correcting total nitrogen estimates for NPN. Biological value of seed proteins was calculated by comparing ratios of EAA concentrations in seed protein to their respective amounts in whole egg protein (Oser 1959).

RESULTS

Forbs

Concentration of crude protein in the 8 species of forb analyzed in this study averaged 13% and ranged from a low of 8% for clammy groundcherry to 22% for queensdelight stillingia (Table 2). No forb provided sufficient crude protein to meet growth and development requirements of quail and only queensdelight stillingia met requirements for breeding. Maintenance requirements were met by 5 of the 8 species. Concentrations of extractable lipids were highly variable, ranging from 3 to 35% dry weight.

Although published protein requirements of quail for adult maintenance were apparently met by several forb species, no species provided all EAA in concentrations adequate for growth or breeding (Table 3). Queensdelight stillingia was the richest source of EAA, meeting the requirement for all EAA for adult maintenance, 4 of 10 for juvenile growth, and 4 of 10 for breeding. All other forb species failed to meet all EAA requirements for growth or breeding. Methionine + cystine was deficient in all seed and was by far the most limiting essential amino acid (LEAA) for growth, maintenance, and breeding. Queensdelight stillingia (first LEAA for growth was lysine) was an exception. Deficiencies of met + cys in seeds relative to requirements for growth and development averaged 79% and ranged from 41% in queensdelight stillingia to 95% for clammy groundcherry. Deficiencies of met + cys for maintenance and breeding averaged 64% and 80%, respectively with queensdelight stillingia as the best source (0 and 41% deficient) and clammy groundcherry as the poorest source (91 and 95% deficient).

The second and third most LEAA for growth requirements varied among plant species, but was usually histidine, threonine, leucine, isoleucine, phe + tyr, or met + cys. The second most LEAA for maintenance requirements were either histidine or glycine for all plant species except queensdelight stillingia (lysine). Second and third LEAA for breeding were either histidine, isoleucine, leucine, phe + tyr, or lysine, depending on the plant species.

Biological value of proteins in forb species averaged 85 and ranged from a low of 75 for clammy groundcherry to a high of 93 for woolly croton and erect dayflower (Table 2). Low biological values for forbs was easily explained by extremely high NPN values. The percentage of the total nitrogen pool not associated with the amino acid pool (NPN) was great (Table 2). Nonprotein nitrogen values for forbs averaged 35% and ranged from 25% (queensdelight stillingia) to 44% (redroot amaranth).

Grasses

Seeds of monocots were extremely poor sources of crude protein and EAA (Table 4). None of the 4 grass species provided sufficient protein to meet growth, maintenance, or breeding requirements. Concentrations averaged 8% and ranged from 6% (Johnsongrass) to 9% (sorghum almum). Concentration of extractable lipids averaged 4% dry weight, indicating a low energy content.

Concentrations of most EAA in the 4 species failed to meet even half of the dietary requirement for maintenance. Similar to forbs, met + cys was the first LEAA in grasses (except pearl millet) for growth, maintenance, and breeding requirements of quail. Arginine was the first LEAA in pearl millet for growth (83% deficient) and breeding (83% deficient); glycine was the first LEAA for maintenance. Deficiencies of met + cys in seed of the four species of grasses relative to requirements for growth and breeding averaged 87%; deficiencies for maintenance averaged 76% (range from 66 to 89%).

Arginine, threonine, lysine, or met + cys were generally the second and third most LEAA for growth, depending on plant species. For maintenance, the second and third most LEAA was either histidine, glycine, or arginine. Arginine and met + cys were the second most LEAA, and lysine and histidine were the third most LEAA for breeding.

Calculated biological values of grass species averaged 76 and ranged from a low of 71 for sorghum almum to a high of 80 for pearl millet. Nonprotein nitrogen values for grasses averaged 35% and ranged from 31% (Johnsongrass) to 37% (pearl millet).

Woody Plants

Crude protein in seed from the 3 species of woody plants analyzed averaged 19% and ranged from a low of 9% for woollybucket bumelia to 38% for black locust. Black locust had the greatest crude protein content of any seed species sampled and was the only woody species that provided sufficient crude protein for meeting growth, maintenance, and breeding requirements of quail. Concentrations of extractable lipids were highly variable and ranged from 7 to 26% of dry weight.

Black locust, a woody legume, was the only woody species sampled that met an EAA requirement of quail (Table 4). Black locust was only deficient in met + cys for maintenance and met arginine, gly + ser, histidine (growth only), lysine, leucine (breeding only), and phe + tyr requirements for growth and breeding. Methionine + cystine was the first LEAA for growth, maintenance, and breeding in all woody plant species sampled where deficiencies for growth and breeding averaged 90% and ranged from 80% in black locust to 95% for netleaf hackberry. Deficiencies met + cys for maintenance averaged of 82% of the requirement for the 3 woody species ranging from 63% for black locust to 91% for netleaf hackberry. The second most LEAA was threonine in all species for growth and isoleucine or histidine for breeding and maintenance. Isoleucine, phe + tyr, valine, or threonine was the third most LEAA in seed of woody plants for growth, breeding, or maintenance.

Biological values of proteins in seeds of woody plants were generally low, averaging 78 and ranging from a low of 69 for netleaf hackberry to a high of 82 for black locust and woollybucket bumelia. Nonprotein nitrogen values were also high and averaged 41%.

Herbaceous Legumes

Concentrations of crude protein ($\underline{x}$ = 25%) were greatest in legume seeds. All species provided sufficient crude protein to meet published maintenance requirements and 5 of 6 species met breeding requirements. Only 3 of 6 species met crude protein requirements for growth. Concentrations of extractable lipids were extremely low and ranged from 1 to 4% of dry weight.

All legumes met requirements for at least 8 EAA for maintenance (Table 5). Illinois bundleflower met all EAA requirements for maintenance. Partridgepea senna and rattlebox came close to meeting all EAA requirements for maintenance with the exception of met + cys which was the first LEAA for maintenance, growth, and breeding. Deficiencies of met + cys averaged 70% for growth and breeding and 50% for maintenance. The second and third most LEAA of seeds from legumes were highly variable among plant species; threonine was commonly the second most LEAA for growth and histidine or isoleucine for maintenance and breeding.

Proteins in legumes had an average biological value of 83 but ranged from a low of 78 for rattlebox to 90 for trailing wildbean. Concentrations of NPN in legumes ($\underline{x}$ = 33%) were generally lower than other forage classes.

DISCUSSION

In many wild herbivore populations the availability of nitrogenous nutrients may be the most limiting environmental resource regulating reproduction and mortality rates (White 1978). Bobwhite have a high dietary requirement for protein to maintain normal growth and reproduction (Nestler et al. 1942), and protein has been implicated as an important factor regulating chick survival (Hurst 1972). Much is known about the nutritional ecology of bobwhite, particularly their foods and feeding habits. Although crude protein in foods (Nestler et al. 1945, Newlon et al. 1964) and diets (crop contents; Wood et al. 1986) has been documented for bobwhite, little information exists on biological value of food proteins. Evaluation of biological value seemed warranted given the frequent occurrence of seeds in their diet and reportedly high concentrations of NPN constituents in many cultivated seed grains (VanEtten et al. 1967, Holt and Sosulski 1981, Singh and Jambunathan 1981). Similar concerns about high concentrations of NPN in tundra vegetation consumed by geese were expressed by Sedinger (1984).

A large fraction of the total nitrogen pool in seed of all plant species examined in this study was in the form of NPN. Concentrations of NPN were greatest for woody species followed by forbs, grasses, and legumes. Nonprotein nitrogen sources are a highly varied group of compounds in plants (Maynard et al. 1979, Holt and Sosulski 1981, Singh and Jambunathan 1981, Oka and Sasaoka 1985). We defined NPN as all nitrogen not incorporated (bound to protein or free amino acids) into 1 of the 17 amino acids detected by HPLC. The high NPN fraction of the total nitrogen pool reduced the usefulness of crude protein for estimating forage quality. For example, winter maintenance requirements for protein in adult bobwhite have been estimated at 12% (Nestler et al. 1944), which mung bean (19.1%) and perennial wildbean (22.7%) appear to meet. However, comparison of adult maintenance requirements for EAA to concentrations in mung bean and perennial wildbean revealed deficiencies for 2 of 10 EAA.

Of the 10 EAA required in the diet of quail, the sulfur-containing amino acids (methionine and cystine) were consistently the most limiting. Although Illinois bundleflower, partridgepea senna, rattlebox, black locust, and queensdelight stillingia were good sources of EAA for adult winter maintenance, only Illinois bundleflower fulfilled the met + cys maintenance requirement. In general, legumes were the best sources of EAA but grasses failed to meet any EAA requirement for maintenance. Our results agree with those of Hang et al. (1980) that legumes are deficient in met + cys and threonine.

All forage classes were deficient in meeting EAA requirements for reproduction and growth which accounts for the importance of the consumption of insects and other high protein foods by breeding and growing quail. Quail experience elevated protein and amino acid requirements for important physiological functions such as egg laying and muscle development during periods of breeding and growth (Andrews et al. 1973, Allen and Young 1980). Although insects may account for a large proportion of the spring and summer diet of bobwhites, significant quantities of seed are still consumed during these periods (Wood et al. 1986).

The ability of a dietary protein to support maintenance, growth, and reproduction of quail depends on how well they meet the overall relative needs for EAA (Oser

1959). Several techniques have been developed to evaluate the overall nutritional quality or biological value of proteins based upon their respective EAA profiles. We used the Essential Amino Acid Index (EAAI) of Oser (1959) which compares the ratios of EAA in a protein relative to their respective amounts in a high quality reference protein such as whole egg protein or casein. Oser (1959) found a strong regression relationship between the EAAI and biological value of a protein. Empirically derived biological values using Oser's (1959) regression against computed EAAI yielded higher values for forbs and legumes compared to woody plants and grasses.

Overall, woody, forb, and grass plant classes were deficient in 67, 74, and 98% of EAA, respectively for maintenance (Fig. 1). Legumes were deficient in only 13% of EAA and were the best sources for meeting EAA requirements for growth, maintenance, and breeding. Maintenance requirements for met + cys were met by only queensdelight stillingia and Illinois bundleflower. Histidine, isoleucine, and glycine were deficient in >60% and leucine, lysine, phe + tyr, threonine, and valine were deficient in >50% of the seeds we analyzed (Fig. 2). Arginine was the most abundant EAA in seed, except grasses (most limiting EAA), relative to maintenance requirements and was deficient in 38% of species analyzed. It is also important to note that published estimates of amino acid requirements were based on studies using isolated protein sources such as corn and soybean meal. This assumes that amino acids are 80 to 90% available (Natl. Res. Counc. 1984). However, seeds of many wild plant species have digestibilities ranging from 40 to 90% (Robel et al. 1979b, 1979c) because they contain digestion inhibitors or toxins (Robbins 1983:237) that reduce available protein. Thus published EAA requirements of quail may underestimate true dietary requirements of wild birds for growth, maintenance, and reproduction.

MANAGEMENT IMPLICATIONS

Although some seed species had sufficient crude protein to meet maintenance requirements, they failed to meet EAA requirements of quail due in part to a high NPN fraction. The use of crude protein should be used cautiously as an index to diet quality when evaluating foods of northern bobwhite.

Each of the 10 EAA required in the diet of northern bobwhite are important and deficiencies of any of them can result in suppressed growth, reproduction, and survival. Most seed samples were deficient in at least 1 EAA, but many seeds of grass, forb, and woody species were highly deficient in several EAA. Legume species were the best sources of EAA. Bobwhites probably compensate for a deficiency of 1 amino acid by consuming another forage adequate in that amino acid. Our data suggest that the use of monoculture food plots or supplemental feeders which offer little diet diversity may be of limmited value to bobwhite. Management strategies resulting in a diverse seed base and high insect densities will provide the best opportunity for meeting EAA requirements of northern bobwhite for maintenance, growth, and reproduction.

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Table 1. Estimated dietary requirements of crude protein and essential amino acids for growth, maintenance, and breeding of Japanese quail as a percentage of dry weight.

Requirement	Growth[c]	Maintenance[ad]	Breeding[c]
Crude protein	24.00	12.00	20.00
Arginine	1.25	0.72	1.26
Glycine	[b]	0.72	[b]
Glycine (plus serine)	1.20	[b]	1.17
Histidine	0.36	0.30	0.42
Isoleucine	0.98	0.54	0.90
Leucine	1.69	0.84	1.42
Lysine	1.30	0.62	1.15
Methionine (plus cystine)	0.75	0.42	0.76

Table 5. Continued.

Requirement	Growth[c]	Maintenance[ad]	Breeding[c]
Phenylanine (plus tyrosine)	1.80	0.90	1.40
Threonine	1.02	0.48	0.74
Tryptophan	0.22	0.12	0.19
Valine	0.95	0.60	0.92

[a]Calculated using a winter maintenance of 12% crude protein (Nestler et al. 1944).

[b]Requirement unknown.

[c]Natl. Res. Counc. 1984.

[d]Eggum and Beams 1986.

Table 2. Crude fat, crude protein, nonprotein nitrogen (NPN), and corrected crude protein (CCP) composition (% dry weight), and biological value (BV) for 21 northern bobwhite foods collected in central and western Oklahoma, 1989.

Species	Crude fat	Crude protein	NPN[a]	CCP[b]	BV[c]
Forb					
Erect dayflower	2.75	15.37	30.12	10.74	93
Woolly croton	17.25	14.32	33.82	9.47	93
Queensdelight stillingia	35.28	22.07	24.71	16.62	91
Redroot amaranth	10.31	10.67	43.85	5.99	89
Giant ragweed	21.80	13.14	35.36	8.49	82
Western ragweed	21.28	12.12	37.23	7.61	82
Common sunflower	21.13	11.28	37.73	7.02	78
Clammy groundcherry	8.98	8.28	37.69	5.16	75
Overall mean	17.30	13.41	35.06	8.71	85
Grass					
Pearl millet	4.16	7.96	36.94	5.02	80
Common sorghum	4.50	7.54	35.41	4.87	79
Johnsongrass	2.57	6.43	31.19	4.42	75
Sorghum almum	4.40	8.70	34.83	5.67	71
Overall mean	3.90	7.66	34.59	5.01	76

Table 2. Continued.

Species	Crude fat	Crude protein	NPN[a]	CCP[b]	BV[c]
Woody					
Black locust	12.59	38.11	41.96	22.12	82
Woollybucket bumelia	26.20	8.71	40.13	5.21	82
Netleaf hackberry	6.85	9.78	39.70	5.90	69
Overall mean	15.20	18.87	40.60	11.21	78
Legume					
Trailing wildbean	1.43	22.28	33.04	14.92	90
Mung bean	1.74	19.06	34.55	12.48	85
Partridge pea senna	2.95	28.63	34.44	18.77	84
Perennial wildbean	1.41	22.68	33.01	15.19	80
Illinois bundleflower	2.68	30.95	33.30	20.64	79
Rattlebox	3.54	27.78	28.65	19.82	78
Overall mean	2.30	25.23	32.83	16.95	83

[a]Nitrogen not incorporated in the 17 amino acids detected by high pressure liquid chromotography.

[b]Crude protein concentration corrected for nonprotein nitrogen.

[c]Calculated by comparing ratio of essential amino acids of seed protein relative to their respective amounts in whole egg protein (Oser 1959).

Table 3 Essential and nonessential amino acid concentrations of seeds from 8 species of forb collected from central and western Oklahoma, 1989

Amino acid		Forb species: Common sunflower	Woolly croton	Redroot amaranth	Giant ragweed	Western ragweed	Erect dayflower	Clammy groundcherry	Queensdelight stillingia
Essential									
Arginine	%DW	0 61	1.29	0.53	0 95	0 74	1.14	0.57	2 86
	g/16gN	7 86	12 73	9.55	10 16	8.96	8 67	10 46	14.52
Glycine	%DW	0 53	0.47	0.44	0 46	0 43	0.73	0.29	1.03
	g/16gN	15 84	10 79	18 28	11 45	12 07	12.86	12 26	12 10
Glycine (plus serine)	%DW	0 96	1.01	0.73	0 94	0 85	1.34	0 56	1 98
	g/16gN	24 91	19 63	26.84	19 78	20.72	20.58	20.16	20 16
Histidine	%DW	0 11	0.24	0.12	0 20	0.16	0.24	0 07	0 50
	g/16gN	1 55	2.68	2 49	2.42	2.21	2.05	1 47	2.86
Isoleucine	%DW	0 31	0.42	0.23	0 39	0.33	0 51	0 23	0 80
	g/16gN	5 26	5.51	5.54	5 48	5 37	5 21	5 54	5 40
Leucine	%DW	0 51	0.63	0 38	0.64	0 58	0 98	0 38	1 28
	g/16gN	8 69	8.28	9.00	9 03	9 29	9.92	9 13	8.60
Lysine	%DW	0 47	0 69	0.41	0.50	0 57	0 84	0 35	0.73
	g/16gN	7.15	8.11	8.70	6 41	8.24	7 63	7 62	4 42

Table 3. Continued.

Amino acid		Forb species: Common sunflower	Woolly croton	Redroot amaranth	Giant ragweed	Western ragweed	Erect dayflower	Clammy groundcherry	Queensdelight stillingia
Methionine									
(plus cystine)	%DW	0.11	0 16	0.08	0 10	0.09	0.22	0 04	0.45
	g/16gN	1.64	1 87	1.73	1.31	1 32	1 99	0.83	2 68
Phenylalanine	%DW	0.36	0 50	0.25	0.48	0 41	0 83	0 24	0.87
	g/16gN	4 92	5.17	4.67	5.41	5.23	6.70	4.70	4 65
Phenylalanine									
(plus tyrosine)	%DW	0.55	0.80	0.45	0.69	0 56	1.46	0 33	1.33
	g/16gN	7.17	8 05	8 17	7.58	6.93	11.32	6 46	6.92
Threonine	%DW	0.31	0.40	0.22	0.34	0 31	0 52	0 22	0.70
	g/16gN	5.87	5 82	5 88	5.25	5.53	5 77	5.75	5.16
Valine	%DW	0.36	0.57	0.29	0.44	0.38	0.70	0.30	1.32
	g/16gN	6.93	8.33	7.87	6.96	6.78	7.97	8.06	9 95
Nonessential									
Tyrosine	%DW	0 18	0 30	0.20	0.21	0 14	0.63	0.10	0.46
	g/16gN	2 24	2.87	3 50	2.17	1.69	4.62	1.75	2.26
Alanine	%DW	0 32	0 43	0.25	0.37	0.34	0.67	0.33	0.82
	g/16gN	8.13	8 24	8.66	7.62	8.01	9.95	11 66	8 08

Table 3 Continued

Amino acid		Forb species: Common sunflower	Woolly croton	Redroot amaranth	Giant ragweed	Western ragweed	Erect dayflower	Clammy groundcherry	Queensdelight stillingia
Aspartic acid	%DW	0 82	1 26	0 52	1 07	1 02	1 45	0 75	2 43
	g/16gN	13 71	16 18	12 26	14.87	16.23	14 49	18 02	16 11
Glucine	%DW	1 76	1 80	0.90	2 28	1.78	2 23	0.86	3 70
	g/16gN	26.68	20.97	19.13	28 72	25.47	20 17	18 66	22.19
Proline	%DW	0 38	0 44	0.26	0.45	0 43	0 63	0.33	0 78
	g/16gN	7 45	6 60	7 19	7.32	7 96	7.29	9.18	5 95
Serine	%DW	0.43	0 54	0 29	0 48	0 43	0 61	0 26	0 96
	g/16gN	9.07	8 85	8 55	8.43	8 66	7.71	7.90	8 05

Table 4 Essential and nonessential amino acid concentrations of seeds from 4 species of grass and 3 species of woody vegetation collected from central and western Oklahoma, 1989

		Grass species				Woody species		
Amino acid		Johnsongrass	Pearl millet	Common sorghum	Sorghum almum	Black locust	Woollybucket bumelia	Netleaf hackberry
Essential								
Arginine	%DW	0 23	0 22	0 26	0.24	2 39	0 47	0 78
	g/16gN	3 99	3 44	3.76	3 22	11.49	8 77	13 64
Glycine	%DW	0 25	0.19	0 22	0 21	1 12	0 27	0 24
	g/16gN	10 01	6.89	8.21	6 66	12 47	11 61	9 91
Glycine (plus serine)	%DW	0 48	0 51	0 49	0.56	2 01	0.49	0.53
	g/16gN	16 48	15.49	15 88	14.46	19.59	18.73	18.41
Histidine	%DW	0 08	0 09	0 13	0.12	0 49	0 09	0 10
	g/16gN	1 56	1 68	2.25	1 76	2 64	1 79	1 94
Isoleucine	%DW	0 27	0.26	0 24	0 25	0 70	0.27	0.17
	g/16gN	6 06	5 44	5 08	4 49	4 45	6 67	3 93
Leucine	%DW	0 60	0 77	0.77	0 98	1 62	0.42	0.34
	g/16gN	13 61	16 36	15 30	17 62	10.33	10 25	7.85
Lysine	%DW	0 39	0.23	0 25	0 25	1.48	0 39	0.29
	g/16gN	7 90	4.36	4.64	4.00	8.46	8 66	5 97

Table 4 Continued

Amino acid		Grass species: Johnsongrass	Grass species: Pearl millet	Grass species: Common sorghum	Grass species: Sorghum almum	Woody species: Black locust	Woody species: Woollybucket bumelia	Woody species: Netleaf hackberry
Methionine								
(plus cystine)	%DW	0.05	0.14	0 10	0.11	0.15	0 04	0 04
	g/16gN	0.97	2 68	2.00	1.82	0 88	0 90	0.79
Phenylalanine	%DW	0.28	0 35	0.32	0.37	0 88	0 22	0.23
	g/16gN	5.14	5.89	5.36	5.28	4 45	4.32	4 29
Phenylalanine								
(plus tyrosine)	%DW	0.45	0.48	0.55	0.61	2 42	0.40	0.53
	g/16gN	7.95	7.95	8 75	8.45	11.57	7.41	9 11
Threonine	%DW	0.20	0.24	0 23	0.24	0 68	0.22	0.16
	g/16gN	5 10	5.72	5 12	4.71	4 75	6.06	4 02
Valine	%DW	0 35	0.33	0.30	0.32	0.83	0.34	0.22
	g/16gN	8 86	7.95	7.27	6.55	5 95	9.30	5.68
Nonessential								
Tyrosine	%DW	0 17	0.13	0.23	0.24	1.54	0.17	0.29
	g/16gN	2 82	2.05	3 39	3.16	7.11	3.09	4.83
Alanine	%DW	0 44	0.51	0 53	0.64	0.77	0 31	0.19
	g/16gN	14.83	15 80	16.75	17.01	7.28	11.16	6.64

Table 4. Continued

Amino acid		Grass species: Johnsongrass	Grass species: Pearl millet	Grass species: Common sorghum	Grass species: Sorghum almum	Woody species: Black locust	Woody species: Woollybucket bumelia	Woody species: Netleaf hackberry
Aspartic acid	%DW	0.59	0 50	0 46	0 49	2 49	0.58	0 90
	g/16gN	13.32	10 50	9.69	8 76	15.65	14.12	20.55
Glucine	%DW	0.95	1.32	1 26	1.58	4 05	0.84	0 91
	g/16gN	19.34	24.97	21 89	25 44	23 04	18.47	18 88
Proline	%DW	0 50	0 44	0.52	0.72	0 95	0 38	0 59
	g/16gN	13 01	10.65	14.63	14 73	6.91	10.71	15.59
Serine	%DW	0.23	0.32	0.28	0.35	0.89	0 23	0.29
	g/16gN	6 46	8.61	7 67	7 79	7.13	7.12	8 49

Table 5 Essential and nonessential amino acid concentrations of seeds from 6 legume species collected from central and western Oklahoma, 1989

		Legume species					
Amino acid		Trailing wildbean	Mung bean	Partridgepea senna	Illinois bundleflower	Perennial wildbean	Rattlebox
Essential							
Arginine	%DW	1.35	0.97	2.12	2 06	1 29	2 38
	g/16gN	7 71	6.70	10.18	8.56	7 08	10.10
Glycine	%DW	0 71	0 60	1.02	1.19	0.80	1 07
	g/16gN	9 35	9.59	11.41	11.47	10.16	10.52
Glycine (plus serine)	%DW	1.62	1 42	2.19	3.63	1 97	2 50
	g/16gN	18.07	18.99	20.69	28.28	20 87	20 60
Histidine	%DW	0 38	0.32	0.41	0.50	0 28	0 62
	g/16gN	2 41	2.49	2.22	2.33	1.75	2.97
Isoleucine	%DW	0 83	0.54	0.85	0.75	0.67	1.02
	g/16gN	6 29	4.97	5.41	4 15	4 87	5 77
Leucine	%DW	1.48	1.11	1.64	1.58	1 39	1 70
	g/16gN	11 21	10.22	10.46	8.72	10.14	9 59
Lysine	%DW	1.42	1 26	1.54	1.56	1.49	1 77
	g/16gN	9.66	10.40	8 81	7.71	9.76	8 92

Table 5 Continued

Amino acid		Legume species: Trailing wildbean	Mung bean	Partridgepea senna	Illinois bundleflower	Perennial wildbean	Rattlebox
Methionine							
(plus cystine)	%DW	0 16	0.13	0 24	0 53	0.16	0 17
	g/16gN	1 09	1 01	1 35	2 91	1.04	0 84
Phenylalanine	%DW	0 97	0 85	0 85	0 93	1 01	0 85
	g/16gN	5 85	6 20	4.30	4 06	5 86	3.80
Phenylalanine							
(plus tyrosine)	%DW	1 62	1.42	2.19	3 63	1.97	2.50
	g/16gN	12 21	9 87	7.90	7 22	11.76	6 80
Threonine	%DW	0 54	0 57	0 79	0.73	0.61	0.85
	g/16gN	4 55	5 74	5 53	4.45	4 90	5 27
Valine	%DW	0 89	0 69	0.87	0.89	0.72	0 92
	g/16gN	7 55	7 09	6.23	5 47	5.93	5.79
Nonessential							
Tyrosine	%DW	1 16	0 55	0 78	0.79	1 12	0.74
	g/16gN	6 36	3 67	3.61	3 17	5.91	3 01
Alanine	%DW	0 70	0 64	0.86	0 88	0.74	0 82
	g/16gN	7 80	8.62	8 12	7.18	8.00	6 76

Table 5 Continued

Amino acid		Legume species: Trailing wildbean	Mung bean	Partridgepea senna	Illinois bundleflower	Perennial wildbean	Rattlebox
Aspartic acid	%DW	2.01	1.87	2 42	3.50	2 24	2 82
	g/16gN	15 01	16.85	15.18	19.04	16 14	15 60
Glucine	%DW	3 39	2 60	4 21	4.20	3 60	5 50
	g/16gN	22.95	21.27	23.93	20.68	23 44	27.57
Proline	%DW	0 75	0 84	0 96	1.00	0.88	1.00
	g/16gN	6 49	8.79	6.97	6.29	7.31	6 41
Serine	%DW	0.92	0.82	1.17	2 44	1.17	1.44
	g/16gN	8 72	9 40	9.28	16.82	10.71	10 09

Fig. 1. Percentage of the 10 essential amino acids deficient in the average woody, grass, forb, and legume plant species used by northern bobwhites for maintenance. Seeds were collected from central and western Oklahoma in September 1989.

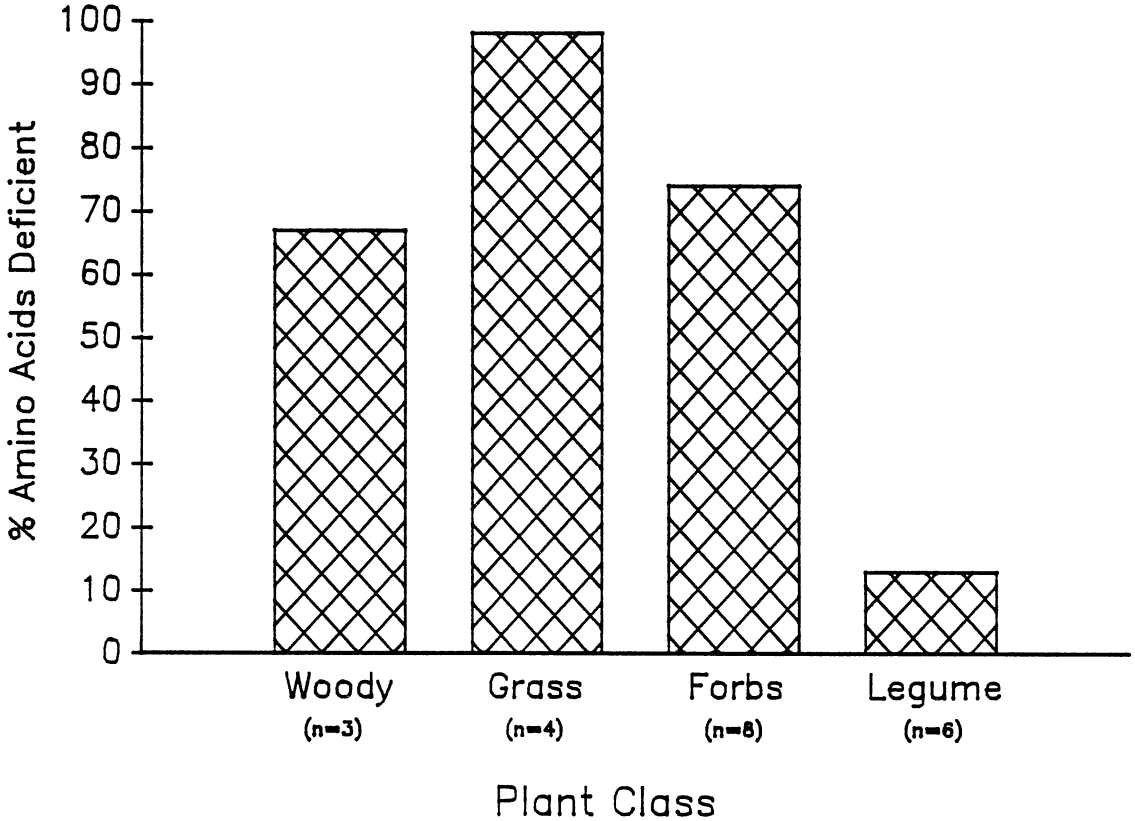
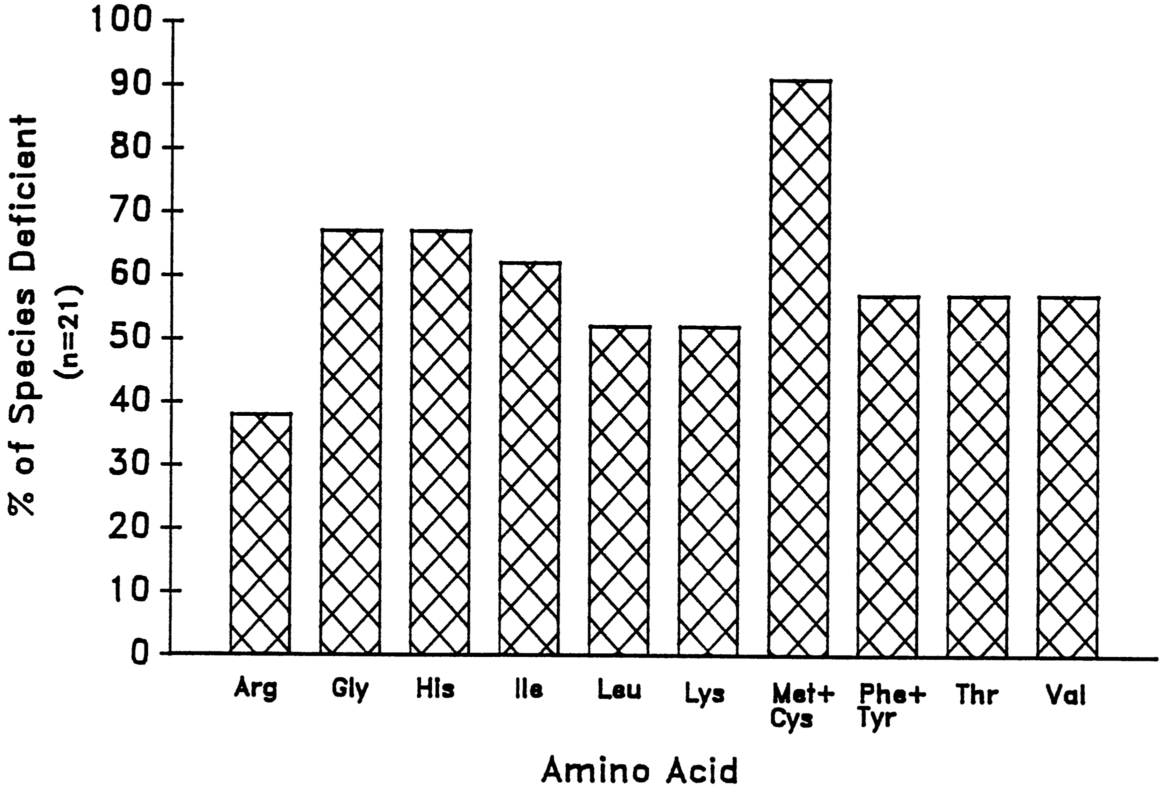

100
90
80
70
60
50
40
30
20
10
0
% Amino Acids Deficient
Woody
(n=3)
Grass
(n=4)
Forbs
(n=8)
Legume
(n=6)
Plant Class

Fig. 2. Percentage of 21 bobwhite foods deficient in each of 10 essential amino acids required for maintenance by northern bobwhite. Seeds were collected in central and western Oklahoma in September 1989.


100
90
80
70
60
50
40
30
20
10
0
% of Species Deficient
(n=21)
Arg
Gly
His
Ile
Leu
Lys
Met+ Cys
Phe+ Tyr
Thr
Val
Amino Acid

CHAPTER V

PRODUCTION AND NUTRITIONAL QUALITY OF WESTERN RAGWEED SEED IN RESPONSE TO FERTILIZATION

Strip disking to stimulate growth of native forb species used by northern bobwhite (Colinus virginianus) is a common practice used by wildlife managers (Derdeyn 1975, Buckner and Landers 1979, Webb and Guthery 1983). Fertilizers are often used when disking to increase soil nutrients which ultimately increases primary production (Moore 1972, Derdeyn 1975, Dailey 1988). Numerous studies have documented that application of fertilizer to soils can also improve the nutritional quality of forage (Szuts et al. 1988).

Crude protein levels in some plant species appear to respond favorably to fertilization (Bird and Olson 1972; Deosthale et al. 1972; Patrick and Hoskins 1974; Eppendorfer 1977, 1978; Dubetz and Gardiner 1979, 1980; Kirkman et al. 1982; Meredith et al. 1984; Meredith and Gaskins 1984,; Szuts et al. 1988). However, less is known about how fertilizers influence other important nutrients, such as essential amino acids (EAA). Results from studies on cultivated varieties of plants are equivocal, with fertilization either increasing (Bird and Olson 1972; Dubetz and Gardiner 1979, 1980), decreasing (Deosthale et al. 1972; Eppendorfer 1977, 1978; Dubetz and Gardiner 1979, 1980; Kirkman et al. 1982; Szuts et al. 1988), or not affecting (Patrick and Hoskins 1974, Meredith et al. 1984, Meredith and Gaskins 1984) amino acid profiles.

The importance of western ragweed (Ambrosia psilostachya) in the diet of bobwhites (Baumgartner et al. 1952, Robel 1969) and their high dietary requirement for EAA (Eggum and Beames 1986) prompted us to explore the use of disking and fertilization to improve its nutritional quality on rangelands in western Oklahoma. Specifically, we examined effects of nitrogen and phosphorus fertilization on production and protein quality of seeds from western ragweed on semiarid, non fertile, deep-sand sites.

STUDY AREA AND METHODS

Our study was conducted on 3 ranches in Woods County, Oklahoma, from August 1988 to February 1990. Soils were dune and deep sands dominated by Tivoli fine sand, Tivoli loamy fine sand, Likes loamy fine sand, and Pratt loamy fine sand with 0-8 % slopes. Precipitation received during 1989 was 75.4 cm. Study sites were located on grazed rangeland where vegetation consisted mainly of little bluestem (Andropogon scoparius) and sand sagebrush (Artemisia filifolia). Western ragweed was the dominant forb on all study sites. A fence to exclude livestock was constructed around each of 7 study sites. Each study site was divided into 2 20- x 25-m plots (with a 3-m buffer zone between plots) which were randomly assigned to either winter disking or winter disking with fertilization treatments. Plots were mowed and passed over once with an offset disk to disturb soil to a depth of 10 cm on 30 January 1989. Soil samples were used to establish fertilization rates (Oklahoma State University Soils Testing Lab) which were applied at a rate of 55 kg N/ha and 56 kg P/ha using a hand held broadcast spreader on 25 February 1989.

Seed Production Estimates

Seed production from western ragweed was assessed by 2 methods. Average production of seed per individual plant was estimated by harvesting mature seed from individual plants collected before seed-drop in August 1989. Twenty 1-m^2 quadrats were randomly placed on each plot and overall plants enumerated. The ragweed plant closest to the upper left-hand corner of each quadrat was collected. Seed was separated from each plant after drying (65 C), weighed to 0.1 mg, and average weight of seed/plant calculated for each treatment. Seed production also was estimated using a modification of the seed trap described by Davison et al. (1955). Traps were buried systematically along 3 x 3 grids within each plot and contents emptied at 4-week intervals from August 1989 to February 1990. Contents of each trap were dried (65 C), and whole seed separated manually from hulls, enumerated, weighed to 0.1 mg, and converted to kg/ha. Seed hulls or seed without endosperm were attributed to insect predation. Seed production estimates were calculated using weights of whole seed and hulls without consideration of insect predation. Whole seed and seed hulls were nutritionally analyzed separately.

Nutritional Analysis

Compositing of seed from plots within treatments was necessary prior to nutritional analysis when seed traps yielded <1.0 g dry weight of western ragweed seed. Seeds were dried further by lyophilization and ground to a fine powder using a micro-grinding mill. Fat was assessed by ether-extraction for 6 hr in a Soxhlet Apparatus (Grodzinski et al. 1975:288). Concentration of the total nitrogen pool (%N) was determined by micro-Kjeldahl analysis (Williams 1984) and converted to crude protein (CP = %N x 6.25).

Fat-extracted seed samples were hydrolyzed in 6N HCL at 110 C for 24 hr. An internal standard (25 μl methionine sulfone) was added to 75 μl of filtered hydrolosate before pre-column derivatization of amino acids using phenylisothiocynate to produce phenylthiocarbamyl amino acids (Pico-Tag Workstation, Millipore Corporation, Milford, Mass. 01757). Concentrations of 17 individual amino acids were determined in derivatized seed samples using high pressure liquid chromatography (HPLC) (Waters Model 820 system controller and Model 501 pumps). Chromatographic conditions were the following: Waters Pico-Tag Silica/C18 (15 cm X 3.9 mm) column; column temperature 38 C; flow rate 1.0 ml/min; pumps back pressure 5500 psi, system sensitivity

489 mv/s (recorder) and 0.5 absorbance units full scale (Waters Model 484 UV detector, set at 254 nm); sample size 4 μl; run time 28 min. Solvents used were Eluent A and Eluent B (catalog number 88108 and 88112, respectively), Millipore Corporation (Milford, Mass.) with Pump A and Pump B delivering Eluents A and B, respectively. Solvent conditions and gradients used for separation of amino acids were those described by Cohen et al. (1988). A casein reference protein (from bovine milk, no. C-0376, Sigma Chem Co., St. Louis, Mo.) of a known amino acid composition was hydrolyzed and analyzed along with seed samples for quality control. Tryptophan is destroyed by acid hydrolysis (Gehrke et al. 1985), and therefore, was not measured. Nonprotein nitrogen (NPN) was assumed to be all nitrogen not incorporated into 1 of the 17 amino acids detected by HPLC (Bell 1963, Synge 1963). Nitrogen concentration of true protein in each sample was determined as the sum of all amino acid nitrogen; NPN was calculated as the difference between total nitrogen (Kjeldahl analysis) and amino acid nitrogen (HPLC analysis).

We assessed the influence of fertilizer on production and nutritional quality of western ragweed seeds using a completely randomized block design with sites as blocks. ANOVA used the general linear models (GLM) procedure of SAS (SAS Inst., Inc. 1985) and all tests were considered significant at $\underline{P} < 0.05$.

RESULTS AND DISCUSSION

Fertilization of disked plots increased ($\underline{P} < 0.05$) seed production of individual ragweed plants (0.51 ± 0.01 [SE] g/plant for disking; 1.16 ± 0.03 g/plant for disking with fertilizer). Production estimates using seed traps was also improved ($\underline{P} < 0.05$) by fertilization (36.2 ± 7.89 kg/ha for disking; 67.0 ± 25.48 kg/ha for disking with fertilizer).

Fertilization had no influence ($\underline{P} > 0.05$) on concentrations of fat and crude protein in whole seed or seed hulls (Table 1). Overall, concentrations of crude protein in whole seeds averaged 12.8 ± 0.13% compared to 4.8 ± 0.11% for hulls. Amino acid analysis of whole seed and seed hulls showed no change ($\underline{P} > 0.05$) in either essential or nonessential amino acid concentrations due to fertilization when expressed as either percent dry weight (%DW) or relative proportion of the total amino acid pool (g/16 g N) (Table 1). Percentage of the total nitrogen pool determined to be NPN was also not influenced ($\underline{P} > 0.05$) by fertilization. Western ragweed contained a large NPN fraction which averaged 40.4 ± 1.05%. Correcting crude protein values for the NPN fraction yielded an estimate for true protein in whole seeds of 7.6 ± 0.15%. Concentrations of the NPN fraction in seed hulls (46.4 ± 2.5%) were not greater ($\underline{P} = 0.055$) than whole seeds. No difference ($\underline{P} > 0.05$) in insect predation was observed between treatments; overall, 28.0 ± 1.36% of the seed produced showed evidence of insect predation.

We concluded that fertilization of disk strips can effectively increase seed production of western ragweed on deep, unfertile, sandy soils. However, fertilization had no effect on nutritional quality of seeds produced. Conflicting results reported on the effect of fertilizer on the quality of plant proteins within the literature could be attributable to differences of climate and soils, growth habits of different plant species, type and rates of fertilizers, and stages of maturity when plants are harvested for analysis.

SUMMARY

Western ragweed is one of the most important food plants to bobwhite throughout much of its range. Management efforts should be directed towards efficient techniques to increase production of seed without negatively influencing the nutritional quality of seed. This paper presents evidence that the practice of fertilizing disked strips on semiarid sandy soil sites can increase seed production of western ragweed by 100%. Western ragweed whole seed was determined to contain about 13% crude protein and 21% fat and the application of nitrogen and phosphorus fertilizer had no influence on quality of seed proteins or crude fat.

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Table 1. Estimated fat, crude protein (CP), nonprotein nitrogen (NPN), corrected crude protein (CCP), essential amino acid (EAA), and nonessential amino acid (NEAA) concentrations as percent dry weight of fertilized and unfertilized whole seeds and seed hulls of western ragweed, Woods County, Oklahoma, 1990.

	Whole seed				Seed hull			
	Unfertilized (n = 4)		Fertilized (n = 5)		Unfertilized (n = 1)		Fertilized (n = 2)	
Variable	X	SE	X	SE	X	SE	X	SE
Fat	21.23	0.485	21.29	0.270	4.01		3.57	0.425
CP	12.61	0.132	12.89	0.127	4.56		4.97	0.114
EAA								
Arginine	0.705	0.052	0.743	0.015	0.102		0.120	0.023
Histidine	0.181	0.013	0.185	0.004	0.044		0.043	0.009
Isoleucine	0.366	0.027	0.383	0.007	0.125		0.122	0.015
Leucine	0.569	0.037	0.579	0.013	0.209		0.202	0.025
Lysine	0.367	0.015	0.372	0.017	0.169		0.159	0.029

Table 1. Continued.

	Whole seed				Seed hull			
	Unfertilized (n = 4)		Fertilized (n = 5)		Unfertilized (n = 1)		Fertilized (n = 2)	
Variable	X	SE	X	SE	X	SE	X	SE
Methionine								
(plus cystine)	0.055	0.012	0.055	0.008	0.009		0.009	0.004
Phenylalanine	0.371	0.024	0.390	0.009	0.116		0.117	0.016
Threonine	0.274	0.016	0.281	0.016	0.118		0.116	0.016
Valine	0.395	0.032	0.422	0.009	0.149		0.146	0.016
Glycine	0.440	0.307	0.435	0.012	0.160		0.160	0.019
NEAA								
Tyrosine	0.153	0.013	0.182	0.025	0.048		0.049	0.011
Alanine	0.342	0.021	0.358	0.011	0.145		0.145	0.019
Aspartic acid	0.805	0.052	0.845	0.015	0.273		0.270	0.043
Glucine	1.732	0.118	1.726	0.040	0.317		0.350	0.064

Table 1. Continued.

	Whole seed				Seed hull			
	Unfertilized (n = 4)		Fertilized (n = 5)		Unfertilized (n = 1)		Fertilized (n = 2)	
Variable	X	SE	X	SE	X	SE	X	SE
Proline	0.450	0.033	0.438	0.019	0.149		0.152	0.021
Serine	0.363	0.025	0.364	0.033	0.150		0.158	0.019
NPN[a]	40.51	1.449	40.31	0.661	45.69		47.10	2.562
CCP[b]	6.65	0.420	6.82	0.184	1.93		1.97	0.298

[a]Nitrogen not incorporated into the 17 amino acids detected by high pressure liquid chromotography.

[b]Crude protein concentration corrected for nonprotein nitrogen.

VITA

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