EVALUATION OF FORAGE SYSTEMS OF COOL SEASON LEGUMES AND SUDANGRASS

By

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EVALUATION OF FORAGE SYSTEMS OF COOL

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"He who is not thankful to the people through whom Allah (God) has granted his tidings is actually not thankful to Allah."

(Prophet Mohammad)

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CHAPTER I

INTRODUCTION

Species of the plant family, Leguminosae, have long been recognized by their ability to fix atmospheric N in the soil. Even before the discovery of the symbiotic relation between the Rhizobium and legume roots, it was known that growing legumes tended to increase soil productivity. Maintenance of soil productivity depends largely on those factors which are commonly referred to as farm practices, notably cultivation methods, use of fertilizer, and crop rotation.

Sequence of crops is an established agronomic practice. The benefits usually include maintenance of soil N and organic matter, more efficient use of water and plant nutrients, reduced soil erosion, partial control of plant pests, better distribution of labor, and increased crop yields.

The rotation of legumes with cereals has been recognized to be the foundation of the agricultural improvement. The benefits to be derived from the growing of legumes in rotation with small grains were recognized by the ancient Romans and are still practiced throughout the world.

The objectives of this study were (1) to evaluate winter forage production from five cool season species, (2) to evaluate sudangrass (Sorghum bicolor L.) production at different N fertility levels following the cool season species, and (3) to evaluate total productivity of these different systems.

CHAPTER II

REVIEW OF LITERATURE

Crop rotation is generally defined as a more or less regularly recurrent succession of different crops on the same land. Many advantages of legumes and grasses in rotation have been mentioned by different researchers. Legume and grass crops are generally recognized as soil building crops. The fact that the members of the legume family have the distinction and the valuable quality of being able to fix atmospheric N in soil is an important point for their promotion among farmers (Goltz, 1974).

Erdman (1953) reported the following as the average amount of N fixed by some legumes: sweet clover [Melilotus officinalis (L.) Lam.], 117 pounds; white clover (Trifolium repens L.), 103 pounds; hairy vetch (Vicia villosa Roth), 80 pounds; and annual lespedeza [Lespedeza striata (Thunb.) H. and A.], 85 pounds of N per acre. Reynolds (1949) recorded 55 and 14 pounds of N per acre fixed respectively in tops and roots of vetch when receiving no fertility treatment. After applying 40 pounds of P_2O_5 fertilizer per acre, 110 to 135 pounds of N was fixed by vetch.

Waksman (1950) declared that N fixation by legume plants was dependent somewhat on the amount of N available to plants from the soil. When soil N was higher less N would be fixed symbiotically. He indicated that about two-thirds of the N found in the legumes was fixed by the symbiotic organisms. Giobel (1926) proposed that inoculated legumes fixed N from the air only to the amount that the soil supply was insufficient for their needs. Greaves and Jones (1950) found no appreciable difference in the soil N after growing alfalfa (Medicago sativa L.) if the tops were removed compared to plowing the whole plant in the soil.

Brown (1964) mentioned that sweet clover, field peas [Pisum arvense (L.) Poir.] and rye (Secale cereale L.) used as green manure crops in dryland experiments had no effect on reducing the N and carbon losses from the soil. He finally claimed that inorganic N was more effective than the legume N in increasing the yield of subsequent crops.

The amount of root material produced by legumes in soil is an important factor in improving the soil conditions. In soils, low in organic matter, incorporation of excessive amounts of carbonaceous material, such as grass, weed, or straw, frequently depress the yield of following crops. Soil bacteria and fungi compete in drawing the limited supply of soil nitrates and thus decrease the amount available for plant growth.

Henson and Hollowell (1960) reported that added organic matter from plowing annual legumes into the soil improved the physical conditions, increased the water holding capacity of soil, and helped beneficial micro-organisms to flourish in it. De Vries and Webber (1962) mentioned that the moisture retained by the cultivated layer of Guelph loam both after 3 days and after 14-20 hours of free drainage was found to increase as the percentage of organic matter increased.

Nielson et al. (1953) found that legumes released fixed phosphorous when they were plowed under. Other benefits reported were an increased total soil organic matter, improved soil structure, and increased soil pH. However, Pieters and McKee (1938) pointed out that incorporating a single green manure crop could not be expected to add materially to the total organic matter of soil. They agreed that greenmanuring helped to maintain the total quantity of organic matter, but it did not actually increase it.

In any cropping system, the order in which the crops are grown and the agronomic practices are of particular importance. Haynes and Thatcher (1955) stated that the three year rotation of corn (Zea mays L.), wheat (Triticum aestivum L.), and red clover (Trifolium pratense L.) brought about no effect on corn productivity compared to continuous corn.

Hobbs (1971) compared continuous sorghum (Sorghum bicolor L.) and continuous wheat with a rotation comprising sorghum, wheat, wheat, alfalfa and alfalfa. He concluded that the cereal yield did not increase with the rotation system on a Geavy Silty clay loam, upland soil. The highest yield was produced in a monoculture system. Schafer and Smith (1926) reported that yield of wheat following peas was less than wheat following summer fallow, but greater than when it was preceded by corn or sunflower (Helianthus annuus L.). However, Doll and Link (1957) indicated that various legumes in a three year rotation of legume, corn, and wheat tended to increase the production of corn and wheat in a long term period.

Roberts (1937) stated that in 10-year rotation of cowpeas [Vigna sinensis (L.) Savi ex Hassk.] and corn the average corn production was 26.7 bushels per acre on non-legume plots and 34.4 bushels on the plots with cowpeas. Tidmore and Sturkie (1936) reported that when cotton (*Gossypium hirsutum* L.) and corn were grown on respective areas each year, vetch increased the yield of corn to 34.4 bushels and cotton seed to 1008 pounds per acre through a (corn-vetch-cotton) cropping system compared to 16.3 bushels and 795 pounds respectively in a corn-cotton system.

Harper (1962) declared that corn yield following vetch and sweet clover was higher than one following other legume crops. He also remarked that corn yield was increased less than two bushels more per acre when all of the legume residue was returned to the soil compared to yields obtained when the legume crops were cut for hay.

Sturkie (1962) mentioned that applying 80 pounds of N to corn preceded by a winter legume did not increase the corn yield compared to corn plots receiving no N fertility levels.

However, Harper (1962) came to the conclusion that 60 pounds of N per acre applied to plots of corn, preceded by cowpeas cut for hay, increased the corn yield from 23.1 to 25.2 bushels per acre.

Doll (1963) studied the effect of different legumes on corn yield in rotation system while three levels of N, 0, 30, and 60 pounds per acre, were applied to the corn. He concluded that approximately 30 pounds of N per acre should be applied to corn following a good legume crop.

Rye is a versatile cold hardy crop with shorter germination period under low temperature in comparison to other small grains. It is more productive on infertile, sandy, or acid soils than are wheat, oats, or barley. This crop is more productive on light loam and sandy soils than on heavy clay soils with poor drainage (Briggle, 1959).

Fowler and Gusta (1977) reported that 'Frontier' rye planted on August 21 had significantly more production as well as better cold tolerance than that planted on September 19 in Saskatoon, Canada. Gusta and Fowler (1976) declared that Frontier rye and winter wheat planted in fall (August 21) shortly after acclimation in cold weather did deacclimate rapidly in response to warm temperature and still had the capacity to reharden in a short period. They recorded a close correlation between cold hardiness and water content in plants.

Sneva and Hyder (1963) declared that the best time for harvesting of rye was early flowering stage. They recorded a 50% loss of crude protein in hay within three weeks beyond the flowering stage. Studying the effect of N fertilizer on rye, they concluded that on areas of high precipitation 15 to 30 pounds of N per acre might be profitable.

Denman and Arnold (1970) stated that on a seasonal basis rye was the top forage producer among small grain forages grown in Oklahoma during the fall and early winter months. They further mentioned that rye produced the most total forage of the small grain species followed in order by barley (Hordeum vulgar L.), wheat, and oats (Avena sativa L.). They recorded an average yield of 3049 pounds of oven dry forage of rye per acre for two years' experiments conducted in 1968-69 and 1969-70 in Perkins, Oklahoma.

Hairy vetch is most winter hardy among different vetch species and is well adapted to regions limited between 10^{o} and 20^{o} northern latitudes. This specie doesn't make as much winter growth as less winter hardy species (Henson and Hollowell, 1960).

Gooding (1951) reported that hairy vetch was more winter hardy than common vetch and it was more tolerant to acid soils where sweet clover and alfalfa were difficult to grow. Roland and Schath (1934) stated that in regions where temperatures do not fluctuate widely or where there is protection from snow, Hungarian (Vicia pannoncia Crantz), woollypod (Vicia dasycarpa Ten.) and smooth vetches (Vicia glabrescens) can withstand temperatures of 0° F or lower.

Hoveland and Webster (1963) reported that vetch, 12 to 15 inches in height, cut to a 3 inch stubble yielded only 65% as much as if cut to a 6 inch height. The recovery was more rapid in 6 inch stubble cut treatment and resulted in one additional clipping in the growing season.

Winter field peas are primarily considered as soil improving crops rather than hay, pasture, or silage crops. Austrian Winter pea is the most winter hardy among different varieties of peas and is widely grown in the southern parts of the United States (Henson and Hallowell, 1960).

Gautam and Lenka (1968) mentioned that 43 pounds of seed per acre is the optimum rate for pea producing a better vegetative growth and higher dry matter content per plant. They recorded no significant difference in yield of dry matter per plant at different row spacing of 8, 12, and 14 inches.

Maurer et al (1968) reported that severe water stress after blossom reduced pea forage yield regardless of soil water conditions prior to that stage. However, severe water stress prior to blossom did not cause a decrease in pea forage yield if ample soil moisture was made available after blossom.

Pumphrey and Schwanke (1974) indicated that adequate moisture during all stages of growth resulted in better plant growth than to moisture stress during any stage in field pea.

Washko (1963) studied the effect of four levels of 0, 50, 100, and 200 pounds of N per acre on 'Piper' sudangrass. He reported that during the droughty period there was no significant difference in sudangrass yields due to three levels of 50, 100, and 200 pounds of N per acre.

Harmes and Tucker (1973) reported that the application of different levels of 0, 19, 38, 76, and 152 pounds of N per acre had no significant effect on forage yield of sudangrass at the first clipping, but higher N levels produced significantly more forage in subsequent harvests. He recorded 3883, 5677, 7392, 8436, and 7826 pounds of Piper sudangrass forage per acre at 0, 19, 38, 76, and 152 pounds of N application per acre. The Sweet sudan variety produced 4386, 4790, 5933, 5588, and 5764 pounds of forage per acre respectively at the same levels of N application.

Jung et al (1964) indicated that there were increases in yield of forage sudangrass by applying increasing rates of N. Broyles and Fribourg (1959) stated that the application of N increased the yield of sudangrass as well as the percentage of N in the harvested forage. They further indicated that cutting the crop at early bloom to a 4-inch stubble produced the highest yield in comparison to harvesting the crop at the other stages of growth.

CHAPTER III

MATERIALS AND METHODS

Location of Experimental Area

The Agronomy Research Station, Perkins, Oklahoma was the location of this study. The plots were located on a Teller loam (Udic Arguistolls) soil, underlain by a loam subsoil. Teller loam soils are moderate in permeability and internal drainage. Their water holding capacity in the upper 40 inches of the solum is 5 to 6 inches. This type of soil is well suited for legume and small grain production (Ford et al., 1976). The soil test from experimental plots showed a pH = 5.5, P 69 lb/A, K 280 lb/A, and No_3-N 78 lb/A.

Design and Treatments

The experimental design for the first part of the study (winter, 1977) was a randomized complete block in which every plot was split into three sections as splitplot design for the second part of the study in the summer, 1978. The winter treatments assigned to the main plots consisted of 'Meechi' arrowleaf clover (Trifolium vesiculosum Savi); 'Yuchi' arrowleaf clover (Trifolium vesiculosum Savi); hairy vetch (Vicia villosa Roth); 'Austrian Winter' field pea [Pisum sativum (L.) Poir.]; 'Okema' rye (Secale cereale L.); and a check (uncultivated winter fallow) plot. All the winter treatments were assigned to uniform 20 x 30 foot plots. Four replicates were used and treatments were randomized within each block.

All the winter treatments were sown on October 25, 1977. Legumes were inoculated and planted by hand in a broadcasting system. Inoculation was accomplished by adding 1.08 fluid oz of molasses and 0.4 oz of inoculant to one pound of seed. The mixture was stirred thoroughly and 7.95 oz of lime was then added. Stirring continued for a few minutes until the seed was evenly coated.

The clovers, vetch, and peas were sown at the rate of 15, 25, and 30 pounds of seed per acre respectively. Rye was planted by small grain drill at the rate of 100 pounds of seed per acre. All the treatments received their only irrigation to maintain surface moisture for germination on the day of planting.

Rye was first harvested on April 7, 1978. First harvest of legumes and second harvest of rye was May 30, 1978. Sudangrass produced its only harvest on August 24, 1978.

Sampling Procedure

Each main plot in the first part of the study was subdivided into three portions of 10 x 20 foot subplots which were ultimately assigned to the N fertility treatments in the second part. Six samples of 3 feet width and 20 feet long, two samples from each subplot, were taken for forage yield from each winter treatment. Samples harvested by Jary Mower were weighed as green yield per plot and then small samples of 10.5 - 17.5 oz were oven dried at 140^{o}F for dry matter calculation. Yields were calculated as pounds of oven dry matter per acre. All the main plots were harvested for hay and disced following the last sampling period on May 30, 1978.

The second part of the experiment was begun by seeding the entire plot area with sudangrass on June 25, 1978. Three levels of 0, 30, and 60 pounds of N per acre, selected as the subplot fertility treatments, were applied as ammonium nitrate to sudangrass on July 25, 1978.

Sudangrass yield samples consisted of 4 rows, 5 feet long, spaced 10 inches apart in each subplot. The entire sample was oven-dried and dry forage yield was reported in pounds per acre. The sudangrass harvest was taken by hand clipper because the softness of soil at the time of sampling prohibited the Jari Mower operation.

CHAPTER IV

RESULTS AND DISCUSSION

Temperature and Precipitation

The daily average maximum, average minimum, and mean temperatures from September, 1977 to August, 1978, the entire period of the study, is presented in Table 1. These values are from Stillwater, about 12 miles north of the research plots. The winter months of January and February were much colder than normal.

Monthly precipitation (Table 2) was often below normal. Only during February and May did the monthly precipitation exceed the long-term average. Precipitation for cool season crops, through May, was 4.68 inches below normal. Precipitation for the sudangrass growth, June to August, was 5.22 inches below normal with July and August being quite dry.

Cool Season Production

Yuchi and Meechi arrowleaf clovers had such a thin stand that weeds invaded and they were eliminated from the experiment. Vetch, peas, and rye seemed to have a better cold and drought tolerance than arrowleaf clovers with respect to stand establishment and yield.

Hairy vetch is the most winter hardy of the different species of vetches and has a better drought tolerance than other types of vetches (Henson and Schath, 1961).

Table I. Average of monthly maximum and minimum temperature (F) for period of study (September 1977 to August 1978)1/

Month	Year	Av. Daily Max.	Av. Daily Min.	Daily Mean	Long Term Mean
		F			
September	1977	86	65	76	73
October	1977	77	48	63	63
November	1977	63	41	52	50
December	1977	53	27	40	40
January	1978	34	15	26	37
February	1978	36	19	27	42
March	1978	59	34	46	49
April	1978	76	50	63	61
May	1978	77	57	67	69
June	1978	86	67	77	77
July	1978	98	72	85	82
August	1978	94	68	81	81

1/ Data from Stillwater, 12 miles north of experimental plots.

Table II. Monthly total, long term average, and deviation of precipitation at Perkins from September 1977 to August 1978.

Month	Year	Rainfall		
		Total	Long Term Av.	Deviation
		inches		
September	1977	1.77	3.81	-2.04
October	1977	1.26	3.21	-1.95
November	1977	1.55	1.90	-0.35
December	1977	0.38	1.42	-1.04
January	1978	0.92	1.53	-0.61
February	1978	2.63	1.46	+1.17
March	1978	1.46	2.20	-0.74
April	1978	1.85	3.16	-1.31
May	1978	7.28	5.09	+2.19
June	1978	4.59	4.58	+0.01
July	1978	0.90	3.45	-2.55
August	1978	0.53	3.19	-2.66
Total		24.12	35.00	-10.88

The oven dry forage yield in pounds per acre for rye, vetch, and peas is presented in Table 3. There was no significant difference between pea and vetch production. Rye produced significantly more forage per acre than legumes.

Table III. Mean forage yield (pounds per acre) of rye, vetch, and peas in the spring, 1978.

Winter Crop	Yield[1/]
rye	4690
vetch	2981
peas	2961

[1/] Significant difference among winter crops with LSD (P=0.05) = 355.

The field peas and hairy vetch are cool season crops and are fairly well adapted to the cold conditions. However, there should be a reasonable temperature fluctuation and a fairly abundant rainfall during the fall, winter, and early spring for them to approach their potential production. The unsuitable climatic conditions at the time of emergence and early growth stage, followed by invasion of weeds and high competition for the limited soil moisture available, led to a poor performance of legumes in spring production.

Choudhary (1961) indicated that the field peas emerged 7 to 24 percent more when sown in March than those planted in November, and he also noticed that the field pea planted in November suffered heavy winter injury in Stillwater.

Rye seemed to be adapted to the conditions more than legumes. Despite the drought conditions rye emerged well and covered the plots so completely that there was very little weed invasion. Compared to the other cereals adapted to the same area, winter rye generally is more winter hardy, earlier in maturing, and produces more in less fertile soils (Briggle, 1959).

The check (uncultivated winter fallow) plots were totally covered by low growing weeds during spring 1978. Weed yields were not harvested as check plot forage production; however, check plots were disced in after the weeds were harvested for hay, and were planted by sudangrass on June 25, 1978 for the second part of the study.

Summer Production

The mean yield of sudangrass at different levels of N is presented in Table 4. Neither the different preceding crops nor different N levels caused a significant difference in sudangrass yields.

The extreme drought conditions and high temperature undoubtedly had an effect on failure of sudangrass to respond to the treatments. June precipitation of 4.59 inches preceded the planting date of sudangrass and could be a favorable factor in establishment of it. But drought conditions during July and August in which sudangrass received only 0.90 and 0.53 inches of rainfall after N fertilization undoubtedly contributed to a low production and very little regrowth after the only harvest on August 24, 1978.

Table IV. Mean forage yield (pounds per acre) of sudangrass at different levels of N following different winter crops.

Preceding Crop	Dry wt. Forage Yield			
	N fertilization[1/]			
	0	30	60	Mean
		lbs/A		
rye	2557	2545	2419	2507
vetch	2200	2216	2321	2246
peas	3042	2659	2528	2743
check	2908	2241	2725	2625
Mean	2677	2415	2498	2530

1/ No significant difference due to preceding crop or N fertilization with coefficient of variation = 15%.

Since there was no significant difference in sudangrass yield due to preceding crop it seems that the sudangrass received no benefit from the preceding legumes in the system. Soil pH of 5.5 as well as high soil N content of 78 pounds of No_3-N per acre may also have been contributing factors.

In dry conditions legumes and grasses, used as green manure, hay or pasture, usually depress the yield of crops immediately following (Brown, 1964). This reduction is commonly associated with depleted soil moisture reserves. Brown further recorded that sweet clover used the soil moisture up to 9 feet in one year. He finally came to the conclusion that only in years where precipitation is high enough, the legumes could increase the yield of corn and small grain.

Accumulative Production

The yield of sudangrass and preceding crops is presented in Table 5. The rye system produced the highest yield and was followed in order by peas, vetch, and the check systems. The higher productivity of rye system was primarily due to the higher production of rye during the winter. There was no significant difference between the vetch and pea systems while they both produced significantly more forage than the check system.

The check plots were invaded by weeds during the spring period of the first part of the study which have been a factor in depleting the soil moisture reserves and subsequent sudangrass production.

Table V. Mean accumulative forage yield (pounds per acre) of the forage systems, winter forage plus sudangrass.

Winter Crop	Dry wt. Forage Yield			
	N fertilization			
	0	30	60	Mean
	lbs/A			
rye	7294	7261	7038	7197
vetch	5342	5221	5117	5227
peas	6030	5434	5648	5704
check	2908	2241	2725	2625
Mean	5394	5039	5132	5188

1/ Significant difference among forage system treatments, LSD (P=0.05) = 1042.

2/ No significant difference due to N fertilization, CV = 8.23%.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in 1977-1978 at the Agronomy Research Station at Perkins, Oklahoma, on a Teller loam soil.

The objectives of this study were (1) to evaluate winter forage production from five cool season species, (2) to evaluate sudangrass production at different N fertility levels following the cool season species, and (3) to evaluate total productivity of these different systems.

The experiment was conducted in two stages. The first stage, starting October, 1977, consisted of cool season legumes, hairy vetch, Austrian Winter field peas, Yuchi arrowleaf clover, Meechi arrowleaf clover, and Okema rye plus an uncultivated plot as check.

At the second stage of experiment beginning in June, 1978, sudangrass was planted in all plots following the harvest of the first crop to serve as a biological indicator of the N status of the soil following the previous crops. Three levels of N of 0, 30, and 60 pounds per acre were applied to all sudangrass plots as the soil fertility treatments.

The temperature and rainfall played a very important role in the establishment of the first part of the experiment as far as the legumes were concerned. Unfavorable climatic conditions resulted in a poor establishment of Yuchi and Meechi plots and they were removed from the experiment.

Rye produced significantly more forage than the vetch and peas in the first part of the study while there was no significant difference in the yield between these two legumes.

At the second part of the study, sudangrass yields showed no significant response due to either the preceding legumes or the levels of N fertilizer applied.

The accumulative forage production of cool season species and sudangrass was highest with the rye system followed in order by the peas, vetch, and check systems. No significant difference was obtained between peas and vetch systems while they both produced significantly more forage than the check system.

Under the unfavorable climatic conditions of this test, the high initial N level in the soil and the soil pH of 5.5, it could not be determined if N fixed by a preceding crop or applied as N fertilizer had an influence on sudangrass production.

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