Influence of Three Cutting Systems on the Yield, Water Use Efficiency, and Forage Quality of Sainfoin[1]

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ABSTRACT

Yield, water use efficiency, and forage quality of 'Eski' sainfoin (*Onobrychis viciaefolia* Scop.) were examined at the Central Great Plains Field Station, Akron, Colo. to determine its potential as a forage crop under dryland conditions. Despite below-average rainfall during both years of the experiment, average seasonal forage yields over all treatments were 3,494 and 2,383 kg/ha dry matter for 1969 and 1970, respectively. Most of the forage yield was produced by the first cutting. Water use efficiency was high for the first cutting, but was low for the second cutting due to the slow regrowth. A prolonged late-season drought stress occurred during both years and plants were dormant during this time. Roots extracted soil moisture from depths of 180 cm. Survival rate over the 2-year period was slightly lower for plants harvested consistently at the early bloom stage of maturity. Forage quality, in terms of leaf, protein, and mineral percentages, cell wall components, and *in vitro* dry matter digestibility decreased little from early to late-bloom maturity. This could be attributed to the high retention of leaves and rapid rate of maturation. Leaves had higher percentages of protein, *in vitro* digestibility, Ca, and Mg and had lower percentages of cellulose, hemicellulose, lignin, cellwall constituents, and K than stems.

Additional index words: **Evapotranspiration, Drought resistance, *In vitro* dry matter digestibility, *Onobrychis viciaefolia* Scop.**

FEW perennial legumes are well adapted to the environmental conditions in the Central Great Plains region of the United States. Briggs and Shantz (4) and Shantz and Piemeisel (10) pointed out that legumes required substantially more water and also were less efficient in water use than grain crops, native and introduced grasses, and certain weeds. Cooper and Roath (6) in Montana and Murray and Slinkard (9) in Idaho reported that sainfoin (*Onobrychis viciaefolia* Scop.) consistently outyielded alfalfa (*Medicago sativa* L.) in areas where production was limited to one cutting. In areas where alfalfa is well adapted, Hanna and Smoliak (8) did not find sainfoin to be superior. Carleton et al. (5) state that this species is currently recommended for pasture in Montana dryland areas that receive 33 cm or more annual precipitation. In addition, they pointed out that sainfoin hay supplies adequate protein to meet the needs of beef animals and also contains total available energy equal or superior to that of alfalfa.

Since sainfoin is considered a nonbloating, fairly drought-tolerant forage species, its potential under dryland conditions of eastern Colorado was evaluated. This paper reports the yield, water use efficiency, and forage quality of sainfoin grown under climatic conditions that are typically semi-arid and characterized by erratic rainfall, extremes in temperature, high average wind velocity, and high evaporation rates.

MATERIALS AND METHODS

Sainfoin, var. 'Eski,' was established in 1968 at the Central Great Plains Field Station near Akron, Colo. The study was conducted on a Weld silt loam typical of the "hard-land" soils occurring in this area. Soil analysis of the surface 15 cm showed 0.70% organic matter and 18.3 ppm of available P. The previous crop was wheat (*Triticum aestivum* L.), which was followed by one year of fallow. A randomized complete block design with four replications was used. Each plot consisted of 12 rows, 38 cm apart. and 6.8 m long. Three harvesting practices were used: (i) an early harvest prior to flowering; (ii) a medium harvest when flowers started to appear; and (iii) a late harvest when plants were in full bloom. For the first cutting of the 1st harvest year, 1969, all plots were cut uniformly at the late-harvest stage, but all subsequent harvests were made at the early, medium, and late stages of growth, leaving a stubble height of 5 cm. Regrowth characteristics limited the harvests to two a year. Forage was oven-dried at 70 C, ground in a Wiley mill to pass a 40-mesh screen, and stored for chemical analyses.

Soil moisture measurements were made with a neutron probe and scaler using access tubes located in the harvest areas. Measurements were taken at 30-cm intervals down to 180 cm in the soil profile. Water use efficiency was calculated as the ratio of dry forage weight to the amount of water used. A 15-bar estimate of the permanent wilting point was determined to be 9.48%. A volume percentage of 12.51 was obtained by using a determined soil bulk density of 1.32 and, for purposes of calculation, available soil moisture was considered to be the amount of water in excess of the 15-bar percentage.

Samples from four replications of each maturity and cutting were analyzed in duplicate for N, Ca, P, K, Mg, *in vitro* dry matter digestibility (IVDMD), cell wall constituents, and lignin. Nitrogen percentages were determined by the micro-Kjeldahl technique. Following a wet digeestion using nitric, sulphuric, and perchloric acids, P was determined using the method outlined by Barton (3). Ca and Mg were determined on a Perkin-Elmer atomic absorption spectrophotometer as outlined by David (7) and Allan (1). Potassium determinations were made using a Coleman flame photometer as described by Toth et al. (13).

IVDMD's were determined according to a modified Tilley-Terry procedure (12) in which the acid-pepsin incubation was replaced by a neutral detergent digest as suggested by Van Soest et al. (15). Rumen liquor was taken from a fistulated steer on a constant diet. One-half gram oven-dried samples of all treatments for a given year were incubated with the same batch of rumen inoculum. Two standard samples were included in each fermentation.

Acid detergent fiber analyses were according to Van Soest (14). Cellulose was determined with 72% sulfuric acid treatment of acid detergent fiber. Lignin was measured by the loss in weight upon ashing at 500 C.

RESULTS AND DISCUSSION

Growth Pattern

Growth was rapid as there was little competition from weeds the spring following establishment. Stems were coarse and represented a major portion of the dry matter at the first harvest in 1969. Very little leaf loss occurred prior to and during the first harvest. Leaf percentage (Table 1) varied with forage yields.

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Table 1. Effect of plant maturity on forage yield and leaf percentage for sainfoin at two cuttings, 1969-1970.

Year	Bloom stage	Harvest date		Forage yield			Leaf percentage	
		Cutting						
		1	2	1	2	Total	1	2
				kg/ha				
1969	Early		July 14		612 a			64.4 a
	Medium		July 23		685 a			64.0 a
	Late	June 9	July 31	2,835	682 a	3,517	36.2	61.6 a
1970	Early	May 28	June 30	1,410 a*	618 a	2,028 a	51.2 a	67.1 a
	Medium	June 4	July 9	1,765 a	679 a	2,444 a	51.4 a	66.1 a
	Late	June 10	July 11	2,003 a	675 a	2,678 a	53.2 a	68.2 a

* Values in the same column and year followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

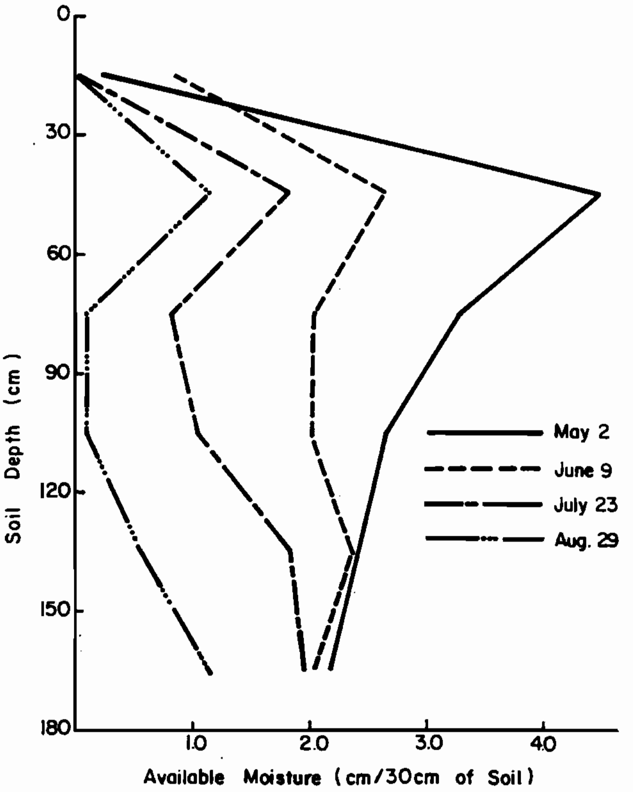

Fig. 1. Soil moisture distribution on May 2, during the first cutting June 9, during the second cutting July 23, and on August 29, 1969.

The first cutting was taken at late bloom in 1969, at which time no new growth had appeared. Once new shoots were produced, however, growth and maturation were rapid.

Root growth and activity are shown by examining soil moisture extraction patterns (Fig. 1 and 2). In 1969 there was considerable soil moisture at the beginning of the growing season. Most available water was in the upper 20 to 30 cm of the profile, but there was a supply of moisture down to 180 cm. While the roots extracted water, mainly from the upper profile with the first cutting (May 2-June 9), they had apparently penetrated deeper and removed moisture from the 30- to 50-cm depths of the profile during the regrowth period (June 9 - July 23). Roots had evidently been active in removing water from the entire 180-cm profile during the growing season. A few soil moisture measurements were taken down to 210 cm and, in general, there was little available moisture at this depth. However, in cases where there was available moisture, it was later utilized.

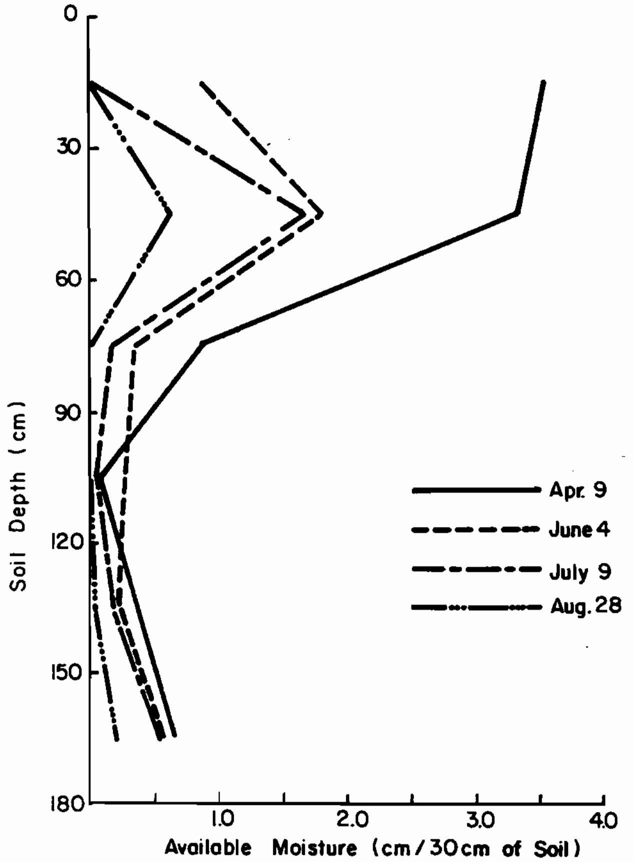

Fig. 2. Soil moisture distribution on April 9, during the first cutting June 9, during the second cutting July 9, and on August 28, 1970.

The lower profile was not recharged and most soil moisture was limited to the upper regions of the profile in 1970 (Fig. 2) because of below-average rainfall in the winter and spring of 1969-70.

Forage Yield

First-cutting and seasonal yields were highest with late-bloom harvest; however, the differences were not significant (Table 1). Yield differences were nonsignificant both years for the three maturities at the second cutting. The second cutting produced about 25% as much forage as the first-cutting harvest did.

First-cutting yields in 1970 were considerably lower than in 1969 and reflected the limited moisture supply during the early part of the season. A lower seasonal yield resulted, even though rainfall was more abundant following the first cutting in 1970.

Water Use and Water Use Efficiency

Water use and water use efficiency (WUE) were not significantly different among cutting treatments during either year. Table 2 shows similar water use for both cuttings both years when averaged over time of harvest treatments. WUE, therefore, was dependent on forage yields rather than time of harvest. Since yields were low both years under the second cutting, WUE of the second cutting was low.

WUE was only slightly lower during the 2nd year under the first cutting, despite the fact that only half the total amount of available water was present. Although environmental differences from year to year would presumably influence WUE, these data would indicate that sainfoin would produce high early season forage yields during years of average or above-average winter and spring rainfall.

Drought Resistance

In terms of effective rainfall, a rather prolonged drought occurred in 1969. Except for the 3.07 cm received on July 5, all other amounts during July, August, and September were 0.89 cm or less. High daytime temperatures (37 to 39 C) were associated with the low moisture supply during August.

After the second cutting, regrowth was very slow and prostrate. The new leaflets remained small and relatively unexpanded and tended to remain folded during the day. There did not appear to be any loss of leaves or change in the morphology of the leaves during this period. Even though there was appreciable water in excess of the 15-bar percentage at the second cutting (July 23) in 1969 (Fig. 1), growth, based on water used, was limited almost exclusively to the roots at 150- to 180-cm depths. For the most part, water at tensions greater than 15 bars was not utilized.

Rainfall in 1970 was more evenly distributed but less in total amount than in 1969. In terms of soil moisture, a drought stress comparable to 1969 was experienced during July and August. Pan evaporation was higher throughout the 1970 season.

Table 2. Water availability and use by sainfoin at two cuttings irrespective of three harvest treatments, 1969-1970.

Year	Cutting	Stored soil moisture	Rain-fall*	Total water available	Water use†	Water use efficiency
		cm	cm	cm	cm	kg/ha-cm
1969	First	16.89	10.52	27.41	14.61	205
	Second	12.94	6.92	19.86	13.19	64
1970	First	8.29	5.11	13.40	9.51	186
	Second	3.88	8.64	12.52	10.03	65

* Rainfall obtained during growing season May to August. † Evapotranspiration.

Table 3. Stand counts and survival of Eski sainfoin, 1969-1970.

Date	Maturity*	Plants /m	% survival†	Date	Maturity*	Plants /m	% survival†
May 2, 1969	E	16		April 9, 1970	E	14	91
	M	15			M	14	96
	L	16			L	15	95
Oct. 9, 1969	E	15	96	Sept. 21, 1970	E	14	89
	M	15	98		M	14	94
	L	15	96		L	15	93

* Plots were cut repeatedly at either early-, medium-, or late-bloom stage of maturity.
† Based on May 2, 1969, stand count.

Stand counts were taken from each individual plot during the spring and fall each year of the experiment (Table 3). Very little loss occurred within any of the harvest treatments during the 2-year period. This would indicate that sainfoin has good drought resistance as the rate of loss was negligible under rather severe moisture stresses that occurred during the summers of 1969 and 1970. In addition, time of harvest had no significant effect on stand survival.

Forage Quality Evaluation

Leaf percentage. Time of harvest had no significant effect on leaf percentage (Table 1). Approximately one-third of the dry matter of the first cutting in 1969 was composed of leaves, while leaves made up nearly two-thirds of the dry weight with the second cutting. In 1970 about one-half of the first-cutting dry matter was leaves, while the second-cutting composition was similar to that of 1969.

Protein Percentage. Whole plant, leaf, and stem protein percentages (Table 4) decreased with an increase in maturity, but the decreases were not significant. The first and second cuttings at the late-bloom harvest stage were not significantly different in 1969; in 1970, however, the second cutting contained a higher percentage of protein. The relatively small decrease in whole-plant protein concentration and nearly constant leaf protein is consistent with the findings of Baker et al. (2). Protein levels were higher than those reported by Carleton et al. (5) at similar maturities.

In Vitro Dry Matter Digestibility. In general, a decrease in cell wall constituents (CWC) or an increase in the percentage of CWC digested increased IVDMD (Table 4). IVDMD for the late-harvest forage of the second cutting in 1969 was higher than for the same stage of harvest with the first cutting. There are two reasons for this result: (i) there was a substantially higher proportion of leaves with the second cutting, and therefore, less CWC; and (ii) stems were higher in digestibility with the second cutting. IVDMD was not significantly different for the three harvest treatments with the regrowth forage in 1969.

In 1970 there was a highly significant interaction between maturities and cuttings. IVDMD decreased with maturity in the first cutting, but increased in the late-harvest treatment of the second cutting. The decrease in the first cutting was the result of an increase

Table 4. Cutting and time of harvest effects on several quality factors of sainfoin with respect to the whole plant, leaf, and stem components of the forage.

			Whole plant				Leaves				Stems			
Year	Cutting	Bloom stage	Crude protein	IVDMD	CWC	% of CWC digested	Crude protein	IVDMD	CWC	% of CWC digested	Crude protein	IVDMD	CWC	% of CWC digested
			%											
1969	First	Late	16.9 a*	72.1 b	39.3 a	37.6 a	22.2	82.3	25.6	36.7	12.1	61.1	57.8	30.3
	Second	Early	17.5 a	75.4 a	37.7 ab	38.1 a	20.7	81.0	29.9	41.0	14.2	66.9	47.7	32.8
		Medium	16.0 a	74.1 a	38.4 ab	37.1 a	19.0	80.5	30.8	41.2	12.5	66.4	48.0	32.1
		Late	15.9 a	76.0 a	33.8 b	35.9 a	19.1	79.7	29.2	40.1	12.0	70.2	42.1	32.0
1970	First	Early	15.7 ab	80.3 b	31.1 b	40.8 a	19.0	84.1	24.6	41.9	11.8	71.1	41.8	33.7
		Medium	14.4 b	80.6 b	30.8 b	42.0 a	18.6	83.9	22.0	43.3	10.5	67.8	47.4	34.4
		Late	14.6 b	77.6 c	33.4 a	36.6 c	18.9	83.3	21.8	40.1	10.4	68.1	47.7	33.3
	Mean		14.9 b	79.5	31.8	39.8 ab								
	Second	Early	17.1 a	81.2 b	30.7 b	39.6 ab	19.9	85.4	22.8	42.8	12.7	71.1	40.8	32.2
		Medium	16.0 a	79.8 b	31.1 b	37.4 bc	19.0	84.2	21.8	40.5	11.4	68.3	44.8	31.6
		Late	16.2 a	82.9 a	28.1 c	35.3 c	20.4	85.5	19.5	38.3	11.6	69.4	43.5	32.2
	Mean		16.4 a	81.3	30.0	37.4 bc								

* Values in the same column and year not followed by the same letter are significantly different at the 5% level as determined by Duncan's Multiple Range Test.

in CWC with delayed time of harvest and a decrease in digestibility of CWC, as might be expected. The increase in IVDMD with the second cutting was accompanied by a decrease in CWC with the late-maturity harvest, which could have resulted from the reduced time of regrowth following late-bloom harvest (Table 1).

Leaves were considerably higher than stems in digestibility and this was consistent over cuttings and time of harvest for both years. Changes in stem IVDMD accounted for most of the change in whole-plant IVDMD. There was little difference in cell wall digestibility of stems over cuttings and harvest times.

There is a major disparity between the results of this study and those reported by Terry and Tilley (11) in the relative digestibility of leaves and stems. They found leaves and stems to be similar in digestibility. This study showed that leaves at all harvest times were considerably higher than stems in digestibility.

Fiber Analysis. Stems, in many cases, contained twice the concentration of CWC as leaves (Table 4) and were responsible for the increase in CWC with respect to the whole plant.

Cellulose comprised the largest portion of CWC, and lignin was second in abundance (Table 5). Hemicellulose, the least prevalent component, was present in amounts from one-fourth to one-third that of cellulose. Cellulose percentage closely followed the trend of CWC with delayed harvest time. Forage hemicellulose percentages were not significantly different for either year, cuttings, or time of harvest. Lignin concentration, within the range of maturities studied, did not vary significantly.

Mineral Concentrations. Table 6 summarizes the harvest time and cuttings effects on mineral percentages. Calcium percentages increased with delayed harvest time and were highest with the second cutting. Calcium percentages were considerably higher in the leaves than in the stems.

Whole-plant Mg percentage did not differ significantly with time of harvest at the second cutting in 1969. Magnesium concentrations decreased with the first but increased with second cutting in 1970. Leaves, in every case, contained higher Mg percentages than stems.

Phosphorus, in contrast to Ca and Mg, was higher in the stem fraction of the forage; differences between leaf and stem concentrations, however, were less pronounced. Whole-plant P decreased with maturity with all cuttings. In general, P values were higher in 1969 than in 1970 and may indicate that P was more limiting in 1970, since no fertilizer was applied. However, no visual P deficiency symptoms appeared.

Potassium percentages generally decreased with delayed harvesting but showed no consistent pattern with cuttings. Potassium percentage was higher in the stems than in the leaves.

Table 5. Effect of harvest practice on three cell wall components of sainfoin with respect to the whole plant, leaf, and stem fractions of the forage.

			Whole plant			Leaves			Stems		
Year	Cutting	Bloom stage	Cellulose	Hemicellulose	Lignin	Cellulose	Hemicellulose	Lignin	Cellulose	Hemicellulose	Lignin
			% dry weight								
1969	First	Late	21.8 a*	6.8 a	10.7 a	13.7	4.0	9.9	30.7	16.5	10.6
	Second	Early	23.2 ab	5.4 a	9.1 b	16.3	4.6	9.0	24.9	12.7	10.1
		Med.	19.9 ab	7.2 a	9.6 b	16.4	5.3	9.1	25.9	12.4	9.7
		Late	18.3 b	6.0 a	9.5 b	15.5	4.3	9.4	22.7	10.7	9.7
1970	First	Early	20.3 ab	4.3 a	7.5 a	15.7	3.1	5.8	26.5	8.0	7.3
		Med.	19.8 ab	4.2 a	7.8 a	13.5	3.3	5.2	28.6	10.9	7.9
		Late	21.5 a	5.2 a	7.7 a	12.6	3.4	6.2	25.9	10.5	8.3
	Second	Early	19.0 b	5.2 a	7.5 a	14.4	2.9	6.0	25.9	7.7	8.2
		Med.	20.1 ab	4.7 a	7.3 a	12.6	3.0	6.4	26.9	9.4	8.5
		Late	16.0 c	5.6 a	7.5 a	10.7	2.8	6.5	26.1	9.0	8.4

* Values in the same column and year not followed by the same letter are significantly different at the 5% level as determined by Duncan's Multiple Range Test.

CONCLUSIONS

Since most rainfall generally occurs in the spring and early summer in the Central Great Plains Region, first-cutting yields of sainfoin would be high due to its efficient use of water. Eski sainfoin has an inherently poor regrowth potential that limits seasonal yield and fails to efficiently utilize midseason moisture supplies. However, the slow regrowth may be a contributing factor to the excellent drought resistance displayed. Plants were dormant during the long periods of drought stress and roots were active in absorbing water to a depth of 180 cm in the soil profile. Consistent cutting at early compared to late-bloom had no significant effect on regrowth and survival rate after 2 years.

Little quality was sacrificed by leaving the forage until late bloom. Leaves were maintained well with maturity. Lignification occurred before blooming and the lignin percentage remained nearly constant thereafter. Stems were high in digestibility despite being coarse in appearance. Low fiber concentrations were responsible for high digestibility.

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Table 6. Cutting and time of harvest effects on mineral percentages of sainfoin with respect to the whole plant, leaf, and stem components of the forage.

			Whole plant				Leaves				Stems			
Year	Cutting	Stage	Ca	Mg	P	K	Ca	Mg	P	K	Ca	Mg	P	K
			% dry weight											
1969	First	Late	1.07 b*	.29 b	.27 a	2.29 a	1.68	.39	.18	2.23	0.58	.17	.27	2.37
	Second	Early	1.23 a	.33 ab	.27 a	2.19 ab	1.40	.36	.23	2.07	0.68	.24	.30	2.24
		Medium	1.31 a	.35 ab	.24 b	2.19 ab	1.46	.37	.19	1.93	0.77	.22	.31	2.23
		Late	1.40 a	.38 a	.23 b	1.99 b	1.54	.39	.20	1.90	0.78	.24	.27	2.18
1970	First	Early	1.00 b	.34 b	.17 c	2.39 a	1.15	.38	.15	2.37	0.56	.22	.20	2.65
		Medium	1.00 b	.31 c	.16 cd	2.16 c	1.13	.37	.15	2.09	0.51	.20	.18	2.41
		Late	1.07 b	.30 c	.15 d	2.19 c	1.31	.36	.14	2.12	0.60	.19	.17	2.47
	Second	Early	1.06 b	.30 c	.22 a	2.44 a	1.34	.33	.21	2.26	0.64	.24	.23	2.59
		Medium	1.15 a	.32 bc	.19 b	2.38 ab	1.43	.34	.18	2.32	0.64	.25	.21	2.43
		Late	1.22 a	.37 a	.16 cd	2.31 b	1.48	.38	.15	1.97	0.63	.29	.18	2.41

* Values in the same column and year not followed by the same letter are significantly different at the 5% level as determined by Duncan's Multiple Range Test.

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Burning vs Incorporation of Rice Crop Residues[1]

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ABSTRACT

The effect of burning and incorporating rice (*Oryza sativa*) straw on grain production and the N economy of the crop was evaluated over a 5-year period in a field planted annually to 'Colusa' rice. An additional variable was vetch (*Vicia benghalensis*) planted in the previous autumn for green manure. The rice crop was fertilized annually at rates of 0, 45, 90, 135 kg/ha N.

The amounts of straw produced ranged from 33 to 85 ql/ha (dry), and the N concentration varied from 0.42 to 0.59%, depending on the N and vetch treatments. Amounts of N incorporated in the straw or presumably volatilized by burning the straw ranged from 13 to 50 kg/ha, and N uptake measured in the grain-plus-straw ranged from 38 to 115 kg/ha, but burning caused no measurable decrease in the uptake of N. Highest yields were obtained from 135 N or 90 N plus vetch. Vetch had a positive effect on yield equivalent to about 45 kg/ha of fertilizer N.

Five-year averages of yields of grain show no measurable difference between burning and incorporation at any level of fertilizer or vetch N.

Additional index words: **Straw management, Vetch green manure, Nitrogen uptake.**

THE disposal of rice (*Oryza sativa*) crop residues has received increasing attention for a number of years from both agricultural and nonagricultural segments of our population. To the agriculturists the residues present a growing management problem as grain yields, enhanced by improved technology, are accompanied by increasing straw yields. The traditional method of disposal in California, burning, is faced with more and more opposition and regulation as air pollutant levels from many sources increase and controls are established at state and local levels.

The experiment described here was initiated to compare incorporation and burning of rice straw where rice was grown every year at various fertility levels resulting from chemical N applications and growing vetch as a green manure.

METHODS

Straw management treatments were begun prior to the 1964 cropping season in a field planted annually to 'Colusa' rice at the Rice Experiment Station, Biggs, Calif., on Stockton clay. Straw from the previous crop was incorporated by plowing or was burned. An added variable was purple vetch (*Vicia benghalensis*) planted in the previous autumn, with a control, in combination with the straw treatments. The rice crop was fertilized annually at rates of 0, 45, 90, 135 kg/ha N as ammonium sulfate drilled in. All treatments were repeated on the same plots for 5 successive years in six replications using a split block design with the N rate treatments crossing over the straw and vetch treatments, resulting in two sets of main plot treatments. A 12.6- × 2.6-m strip was harvested out of each 15.3- × 7.0-m subplot for grain yield. One or two 1.22-m^2 quadrats were cut per subplot for determination of straw-grain ratio and subsampled for Kjeldahl N analysis of grain and straw. Because of a heavy watergrass infestation in two replications in the 1st year, data were used from only the four relatively clean replications, but in succeeding years watergrass was controlled chemically and all replications were used. Grain yields are corrected to 14% moisture, and all other data are on a dry-weight basis.

RESULTS AND DISCUSSION

The yield of grain averaged over 5 crop years showed no difference between burning and incorporation of the residues at any of the fertilizer N levels in either the presence or absence of vetch green manure (Table 1). There was a highly significant effect of N application up to the maximum applied of 135 kg/ha without vetch. Peak yields at about the same yield level, 62 to 64 ql/ha, were obtained at the 90 kg/ha rate of fertilizer N applied with vetch. The vetch green manure had an effect on yield equivalent to about 45 kg/ha of fertilizer N. It has been shown previously that organic sources of N such as vetch are used very effectively by the flooded rice crop (6, 7), with even as much as 100% recovery being attained (8). However, vetch grown as a winter green manure crop grew poorly in this experiment and supplied only about 25% of the N needs of the crop. There was no

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