A yield and day length requirement evaluation of single- and multi-cut sainfoin (Onobrychis viciaefolia Scop.)

by Ronald Howard Delaney

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agronomy
Montana State University

Abstract:
Seventeen sainfoin lines (Onobrychis viciaefolia Scop.), 'Eski' sainfoin (0. viciaefolia Soop.), 'Ladak' and 'Haymor' alfalfa (Medicago sativa L) were evaluated for their regrowth and forage yielding ability for two years at two locations. Two weeks follpwing the first harvest, the seventeen sainfoin lines were 9-12 inches high compared to the 4-6' inch height of Eski. Eski produced 78% of its total season yield the first harvest compared to a range of 57-70% for the regrowth lines at Bozeman, Montana. Under three-cut conditions at Huntley, Montana, Eski yielded 6l% the first harvest and the regrowth lines ranged from 43-57%= At Huntley, the second harvest year all regrowth lines produced a greater total season yield than the single-cut type Eski. The two alfalfa varieties also, yielded more than Eski at Huntleyc The regrowth sainfoin lines were similar to Eski in seasonal yield at Bozeman the second harvest year0 With one exception, all sainfoin entries yielded more than Ladak and Haymor alfalfa= The day length requirement for flowering of five sainfoin clones was studied= Artificial day lengths of 13 1/2 and 16 1/2 hrs under 65-45 F day-night temperatures were used. The effect of the growth chamber day length pretreatment was also evaluated when plants were transplanted to the field= The studies did not allow separation of the growth types depending on day lengths. The day length requirements for optimum flowering were not the same for all five clones.

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ABSTRACT

Seventeen sainfoin lines (Onobrychis viciaefolia Scop.), 'Eski' sainfoin (O. viciaefolia Scop.), 'Ladak' and 'Haymor' alfalfa (Medicago sativa L.) were evaluated for their regrowth and forage yielding ability for two years at two locations. Two weeks following the first harvest, the seventeen sainfoin lines were 9-12 inches high compared to the 4-6 inch height of Eski. Eski produced 78% of its total season yield the first harvest compared to a range of 57-70% for the regrowth lines at Bozeman, Montana. Under three-cut conditions at Huntley, Montana, Eski yielded 61% the first harvest and the regrowth lines ranged from 43-57%. At Huntley the second harvest year all regrowth lines produced a greater total season yield than the single-cut type Eski. The two alfalfa varieties also yielded more than Eski at Huntley. The regrowth sainfoin lines were similar to Eski in seasonal yield at Bozeman the second harvest year. With one exception, all sainfoin entries yielded more than Ladak and Haymor alfalfa.

The day length requirement for flowering of five sainfoin clones was studied. Artificial day lengths of 13½ and 16½-hrs under 65-45 F day-night temperatures were used. The effect of the growth chamber day length pretreatment was also evaluated when plants were transplanted to the field. The studies did not allow separation of the growth types depending on day lengths. The day length requirements for optimum flowering were not the same for all five clones.

INTRODUCTION

The interest in sainfoin (*Onobrychis spp.*) is rapidly expanding in the United States and Canada. The increased use of this legume is creating a demand for development of growth types which are adapted to various climates, soils and agronomic uses. The Montana developed 'Eski' sainfoin has shown alfalfa weevil resistance and fails to cause bloat. Eski yielded well on dryland and in areas where a large first cutting of hay is desired. It has not performed well under irrigation in areas where two and three cuttings of hay are normally harvested. The performance of Eski in irrigated pastures has also been impaired by inadequate distribution of forage yield throughout the season. Weed invasion has also been a serious problem in pure Eski stands.

Based on the current problems with sainfoin the need for differing growth types became apparent. A type which would produce upright growth following harvest and distribute its forage yield throughout the season would be desirable. A regrowth type of sainfoin would possibly have a yield advantage over the present single-cut type when grown in the longer growing season areas of Montana. The purpose of this study was to select and evaluate the yield potential of a multi-cut sainfoin type in Montana.

A logical source for sainfoin with a genetical potential to regrow following harvest was the vast number of *Onobrychis spp.* introductions growing at Bozeman, Montana. Of 144 introductions planted in 1965 the remaining 98 were evaluated for their ability to elongate following harvest in 1966.

Diverse degrees of regrowth ability were found in these introductions. It was observed that cutting dates only two weeks apart may determine if a particular type will regrow. This led to an investigation of the day length requirements for elongation of sainfoin.

LITERATURE REVIEW

Sainfoin, genus Onobrychis, is creating considerable interest in the United States and Canada. Sainfoin shows great potential in alfalfa weevil infested areas. Its non-bloating quality increases its desirability for hay and pasture. Most reports indicate sainfoin is best adapted to calcareous soils under dryland conditons. Jensen and Sharp (19) in Nevada reported that sainfoin will persist in highly saline soils. The annual precipitation minimum for sainfoin is approximately thirteen inches (12). Tests at Nevada indicate sainfoin is more tolerant to frost than alfalfa (19). At Creston, Montana 'Eski' (Onobrychis viciaefolia Scop.) produced unsatisfactory dryland hay yields on acid soils of forest origin (26). Eski exhibits good drought and winterhardiness in Montana (14).

The yield potential of sainfoin indicates that under one-cut conditions Eski will equal or out-yield alfalfa; however, where two or three cuttings are harvested alfalfa (Medicago sativa L.) is generally higher yielding if the alfalfa weevil is controlled. Hanna and Smoliak (17) reported that sainfoin will yield equal to alfalfa at the first cutting in Canada.

The nutritive value of sainfoin is similar to alfalfa. Holden (18) reported that sainfoin has a higher leaf to stem ratio than alfalfa and is lower in protein and crude fiber. He also found that sainfoin had a greater percentage of nitrogen free extract in comparison to other forage legumes. The protein quality of sainfoin seed is similar to soybean oil meal.

Sainfoin consists of many species with widely differing adaptation and growth characteristics. Recent studies by Badoux (2) indicate that Onobrychis viciaefolia Scop. is a general term for several species of sainfoin. Chapman and Yuan (11) in a cytological evaluation of twelve species were unable to distinguish between these species.

Andreev (1) has described the types of sainfoin grown in Russia as common, sandy and transcaucasian. Common or vetched-leaved Onobrychis viciaefolia Scop. has medium drought and winterhardiness. Characteristically, during the year of establishment, the common type develops slowly; however, in the second year early spring growth occurs. Shain (27) reports that common has slow recovery and is used as a one-cut forage in Russia. Sandy sainfoin, Onobrychis arenaria Kit., excells the other two types in winterhardiness (1). It also has good drought tolerance. The one-cut growth habit of sandy sainfoin resembles the common type. Transcaucasian sainfoin, Onobrychis transcaucasica Grosh., exceeds the common type in winter hardiness, drought tolerance, and yield. The yield of the transcaucasian type results from its two and often three cuts per year under irrigation. It is considered to be less long-lived than the common or sandy sainfoin.

Giant and common sainfoin are grown in England. Common is reported by Fyfe (15) to be a single-cut type as it lacks the ability to flower twice in one year. Thomson (30) found that the large first harvest of common sainfoin allowed it to yield more under hay and pasture conditions than giant. It was also able to withstand the pasture treatment better than the giant type. Baker (3) reported that giant sainfoin, Onobrychis sativa L., is a multi-cut type. The highest season yield was obtained when it was cut twice at full bloom.

A Persian type of sainfoin, Onobrychis viciaefolia, forma persiia, Shiryaev, is classed as a "many-cut sainfoin" by Kellner (20). Another source of potential regrowth material has been described by Bawolski (6) in Polish populations of sainfoin. Varga (32) in Romania has developed variety ICA_6 which is a high yielding multi-cut sainfoin type. This variety also provides a high seed yield the second cutting if the first cutting is harvested at the bud stage. Eski, the only registered variety in Montana, has been reported by Cooper and Roath (13) to be primarily a one-cut type.

Onobrychis viciaefolia Scop. or the single-cut type sainfoin generally fails to bloom the year of seeding. Bawolski (4) suspected that the inability to bloom the first year and to produce a second cutting in subsequent years may be correlated to a day length requirement. He subjected plants at four stages of growth (after sprouting, 10 days, 20 days, and 30 days after germination) to a twelve hour photoperiod representing a short day. All the plants which characteristically develop only a rosette the year of seeding elongated and bloomed after the application of short days. The increases in height resulting from these short day treatments for O. viciaefolia Scop. and the multi-cut O. transcaucasica Kit. are shown in Figures 1 and 2.

In a later experiment Bawolski (5) reported that under Polish growing conditions (latitude 51° 26' N) the two year developmental

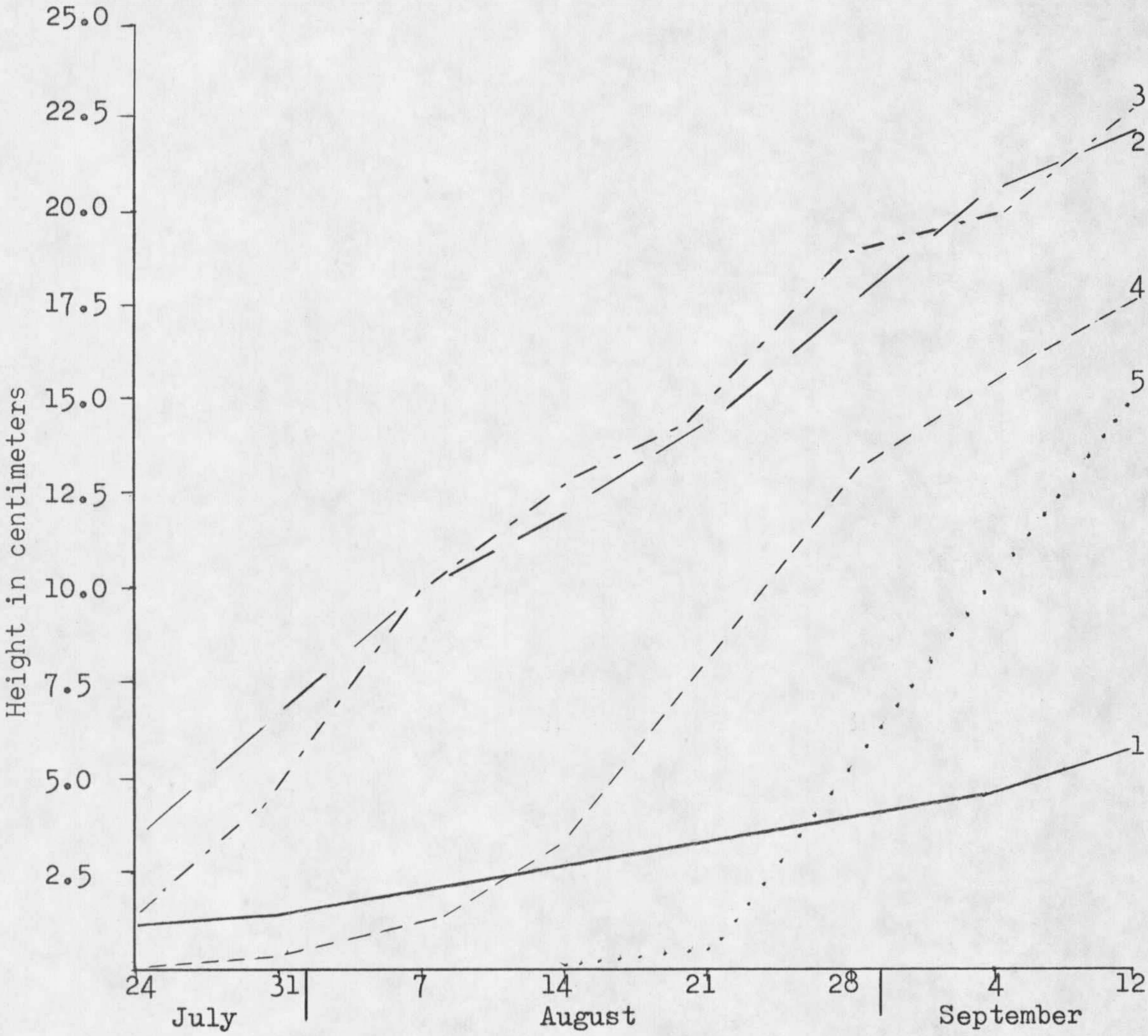

Fig. 1. The growth of plants of Onobrychis viciaefolia Scop., Bawolski (4).
1. Control combination [subjected to long days only]
2. The day shortened immediately after sprouting
3. The day shortened 10 days after sprouting
4. The day shortened 20 days after sprouting
5. The day shortened 30 days after sprouting

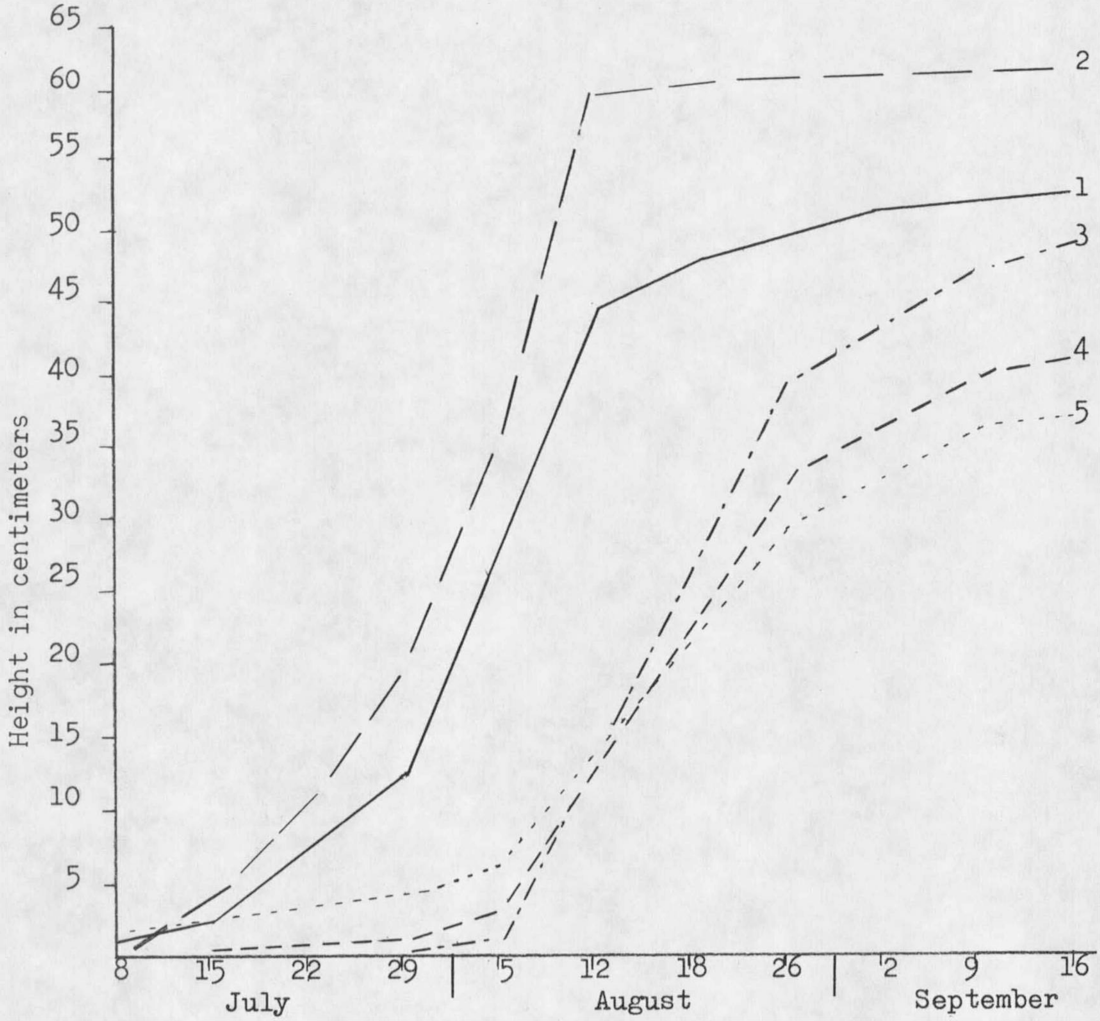

Fig. 2. The growth of plants of Onobrychis transcaucasica Grosh., Bawolski (4).

1. Control combination [subjected to long days only]
2. The day shortened immediately after sprouting
3. The day shortened 10 days after sprouting
4. The day shortened 20 days after sprouting
5. The day shortened 30 days after sprouting

requirement of the winter biotype depends on the diurnal variation throughout the seasons. Under greenhouse conditions sainfoin would not flower when subjected to consistently long or short days but required 20-40 short days followed by long days. Under natural conditions Bawolski suggests that the single-cut type sainfoin requires a long day, short day, long day (L-S-L) sequence. A S-L pattern stimulated flowering under controlled conditions. Bawolski subjected all day length treatments to varying night temperatures; however, he concluded that vernalization exerted no significant influence upon the generative development of sainfoin.

The influence of day length and vernalization on the growth habit of many forage plants has long been known. Oakley and Westover (24) have shown that northern (or early dormant types) and southern (or non-dormant type) alfalfa varieties can be separated by their day length requirements. When grown in the greenhouse under a seven-hour day for six weeks, seedlings of the southern varieties elongated more than the northern varieties. Shornhorst et al. (28) subjected seedlings of nine varieties of alfalfa to eight, twelve and sixteen-hour photoperiods for eight weeks. They also grew plants at each day length treatment at constant temperatures of 60, 70 and 80 F. Following the eight-week treatment, the plants were hardened at 35 F in a chamber for two weeks, clipped, and returned to their respective day length chambers. They found that the varieties could be separated into three basic fall growth types when using the 60 F and twelve-hour photoperiod.

Elongation was least for the early dormant types, intermediate for late dormant types, and greatest for southern or non-dormant types.

Nittler and Gibbs (23) used photoperiod, color of light and temperature to evaluate the dormancy types of northern and southern alfalfa varieties. They found that growth of northern types was limited more by low than high temperatures. The non-dormant southern types grew well at low temperatures. They concluded that elongation of the stem below the cotyledons was influenced by color of light, length of dark period, and light intensity.

SELECTION AND EVALUATION OF PLANT INTRODUCTIONS FOR REGROWTH

Materials and Methods

In 1966 ninety-eight sainfoin plant introductions consisting of nine species from fourteen countries were evaluated for regrowth following each of two cuttings made at full bloom. The Montana 'Eski' was used as a check. These accessions were planted in 20-ft rows with 1-ft row spacings in 1965 at the Agricultural Experiment Station at Bozeman, Montana by C. S. Cooper. Regrowth was measured three weeks after harvest. Harvest dates were June 21 and July 20, 1966. This evaluation resulted in the selection of seventeen introductions for their regrowth potential.

All selected accessions are classified as *Onobrychis viciaefolia* Scop. Fifteen were collected in Iran, one in Turkey and one in Armenia (Table I). Some of the Iranian introductions were collected from fields growing at elevations ranging from 500 to 8500 feet and latitudes from 26° 40' to 38° 15' N. Eski originated from plant introductions from Eskisehir, Turkey (39° 46'N).

The seventeen lines produced seed in 1966 on the regrowth following the second forage harvest. Seed was harvested from individual rows and used to establish a yield trial at two locations in 1967. The trial seeded at the Agricultural Experiment Station at Bozeman (elevation: 4,770 ft; latitude: 45° 40' N) on April 12 consisted of these seventeen sainfoin plant introductions, 'Eski', 'Ladak', and 'Haymor'

Table I. Origin, winterhardiness, and regrowth evaluation of 17 selected plant introductions and 'Eski'.

Entry 1/	P.I. no.	Origin	Elevation collected (ft)	North Latitude collected ° '	Regrowth 3 wks after harvest 2/ 1st cut (in)	2nd cut (in)	Winter-hardiness %survival 3/
1	227,375	Iran	500	32.03	20	15	90
2	212,241	Armenia	--	--	14	8	87
3	223,389	Iran	5,000	38.15	16	10	72
4	227,038	Iran	5,200	29.38	18	13	86
5	227,373	Iran	7,200	--	20	10	68
6	228,289	Iran	6,000	33.23	18	16	67
7	228,352	Iran	8,000	32.42	17	10	--
8	228,402	Iran	7,500	32.20	16	10	68
9	229,612	Iran	8,500	35.18	14	10	69
10	236,486	Turkey	--	--	10	11	61
11	239,957	Iran	--	--	20	16	60
12	239,958	Iran	6,000	33.23	18	16	69
13	239,959	Iran	3,600	26.49	19	14	77
14	239,960	Iran	4,900	35.44	20	18	78
15	243,226	Iran	4,950	38.05	14	12	81
16	243,227	Iran	4,950	38.05	14	12	85
17	250,024	Iran	500	32.30	19	16	80
Eski		Turkey	3,000	39.46	8	5	83

1/ These entry numbers will replace the P.I. numbers throughout this paper.

2/ Data collected at Bozeman, Montana (10).

3/ Data collected at Moccasin, Montana (12).

alfalfa.* The trial at the Huntley Branch Station at Huntley, Montana (elevation: 2,989 ft; latitude: 45° 54' N) was planted on April 13, 1967 with entry P. I. 228,352 deleted because of lack of seed.**

Since only small quantities of seed were available, single-row plots one meter long with 30 cm row spacings and five replications were used. Each sainfoin plot including Eski was seeded with an Eski row on each side. The alternate Eski rows provided the same competition for each entry and also allowed the use of the analysis of covariance where entry yields can be adjusted to the yield of the check rows (22). The alfalfa entries were buffered with two rows of alfalfa on each side. The plots were seeded with a single row cone seeder at a rate of 30 lb/A for sainfoin and 10 lb/A for alfalfa.

The trial was grown under irrigation at both locations. A soil probe was used to determine soil moisture conditions. The alfalfa weevil was not controlled; however, alfalfa entries were not noticeably damaged.

The complete trial was harvested when the sainfoin was at 100% bloom. This stage is considered optimum for yield and quality of sainfoin

* Ladak and Haymor alfalfa were entered in this trial for their characteristic growth habits within alfalfa. Ladak is comparable to the single-cut characteristic of Eski; Haymor represents a multi-cut type corresponding to the regrowth sainfoin lines (29).

** The Huntley location was selected because of its higher temperatures and long growing season which allows a multi-cut forage to express its potential.

forage (9). Alfalfa was at 10-50% bloom at this time. Eski was in full bloom the first harvest; however, at succeeding harvests was not at full bloom. Harvesting at Bozeman consisted of two hay cuttings both years. The trial at Huntley was harvested for hay twice during the year of seeding and three times in 1968. All harvesting was done with a hand sickle. Forage was weighed and recorded as grams of green matter per plot. Moisture samples were taken separately for alfalfa, Eski, and a composite of regrowth lines. These samples were oven-dried and used to convert the green weights to grams of dry matter per plot. Regrowth in inches was measured periodically following first and second cuttings.

Because of differences which occurred in plot lengths at Huntley all plots were measured in centimeters. An analysis of covariance was used to adjust the forage yield means for plot length. In order to evaluate total season yield distribution by cuttings, the individual cutting yields were converted to the percentage of total season yield. Differences between entries in their distribution of yield were determined by an analysis of variance of these percentages. All possible simple correlations were run between cuttings, years, and locations.

Results and Discussion

The design of the yield trials with buffer Eski rows provided a standard competitor between rows for all regrowth plots. It also allowed considerable yield data to be obtained when only a small amount of seed was available for planting. Melton and Finkner (22) have shown this planting design allows the use of the analysis of covariance to adjust treatment means to remove a portion of environmental variation. They found the use of "systematic controls" (buffer rows) in combination with the analysis of covariance increased efficiencies from 38 to 528%.

When the analysis of covariance was used for the first harvest in 1967 at Bozeman, a loss of 2% efficiency occurred. On the average the regression coefficient of the entry of the two Eski buffer rows was byx = -1.17, indicating that when the entry was low in yield the Eski buffer rows were high. This negative relationship occurred because the entry was low in yield when the Eski buffer rows were high due to competition. The negative relationship prevented the use of the analysis of covariance to reduce environmental error.

A negative spring growth rating of -.6 was obtained for Eski (Table III). The negative value occurred because the more nearly two plants are alike the greater is the competition for environmental factors. The design of the experiment was as follows:

E_1 R_1 E_2 E_3 E_4 R_2 E_5

E_1, E_2, E_4, E_5 = Eski buffer rows
E_3 = Eski yield row
R_1, R_2 = Regrowth entry yield rows

In the above planting design the Eski yield row (E_3) had less spring growth than the Eski buffer rows E_2 and E_4. It is thought that this occurs because Eski rows E_2 and E_4 are competing on one side with rows R_1 and R_2 which are regrowth types. Therefore, the single-cut type Eski apparently competes better with a multi-cut sainfoin than with itself.

The yields and height of regrowth for sixteen regrowth lines, Eski, Ladak and Haymor alfalfa grown at Huntley in 1967 and 1968 are shown in Tables II and III. In the year of seeding the second cutting yielded more than the first. The larger second harvest was due to increase in size and tillering of the plants. The two alfalfa entries out-yielded the regrowth lines the first cutting. In the second harvest seven regrowth lines out-yielded Eski demonstrating their multi-cut potential. The total season yield, the year of establishment, showed only Haymor alfalfa yielding significantly more than Eski. However, Eski was the lowest yielding entry for both the second harvest and the total season yield.

Three harvests were taken at Huntley in 1968 which allowed the regrowth lines to express their growth characteristic. Four lines yielded more than Eski with Ladak and Haymor yielding the least in the first cutting. One major reason that the fifteen lines out-yielded the alfalfa entries was the loss of alfalfa leaves. The alfalfa leaf loss was due to lodging and rotting of the leaves during the wet spring. The sainfoin did not lodge and suffered no leaf loss. Twelve regrowth lines yielded significantly more than the single-cut type Eski in the second harvest. Eski was significantly lower than all

Table II. Yield and height measurements of 16 sainfoin regrowth lines, Eski, and two alfalfa varieties the first harvest year at Huntley, Montana (1967). 1/

Entry 2/	First Cutting 7/26/67 (g)	Second Cutting 9/20/67 (g)	Total (g)	Regrowth 8/19/67 (in)	Regrowth 9/3/67 (in)
Haymor	132.7a	156.4a	287.7a	14.4*	17.6*
13	88.5c	158.4a	247.5ab	13.2*	16.6*
8	92.5bc	153.1abc	245.6ab	13.4*	18.0*
14	83.7c	155.7ab	243.2ab	13.4*	17.2*
Ladak	114.8ab	126.5abcd	240.8ab	13.0*	14.2*
6	83.6c	148.5abc	232.5b	12.4*	16.0*
5	80.8c	147.0abc	226.8b	13.0*	16.2*
10	80.7c	142.6abc	223.3b	11.8*	15.8*
16	80.2c	139.3abcd	220.8b	13.0*	16.0*
4	84.3c	134.8abcd	219.8b	12.4*	15.8*
11	74.2c	140.8abc	214.9b	11.8*	16.0*
15	79.4c	132.6abcd	213.2b	11.0*	12.4*
2	84.2c	126.3abcd	209.9b	10.4*	11.0
3	72.7c	131.0abcd	205.6b	11.0*	13.8*
12	69.7c	135.3abcd	204.5b	12.2*	15.6*
9	72.8c	126.9abcd	199.7b	10.8*	13.6*
1	73.2c	120.3bcd	193.8b	11.0*	13.0*
17	72.1c	118.9cd	190.4b	11.4*	14.2*
Eski	86.0c	103.4d	187.8b	8.6	8.8
$s\bar{y}$	8.50	10.50	17.37		
cv	22.20	17.07	17.42	10.60	13.72
LSD .05	23.6	29.4	48.6	1.3	2.5

1/ Values followed by the same letter are not significantly different at P=.05. The asterisk (*) indicates values significantly different from Eski at P=.05.

2/ Entries ranked according to 1967 total season yield.

Table III. Yield, height and spring growth measurements of 16 sainfoin regrowth lines, Eski, and two alfalfa varieties the second harvest year at Huntley, Montana (1968). 1/

Entry 2/	First Cutting 6/12/68	Second Cutting 7/31/68	Third Cutting 9/11/68	Total	Regrowth 6/29/68	Spring Growth 3/ 4/19/68
	(g)	(g)	(g)	(g)	(in)	
13	319.1ab	180.5abc	184.3a	684.0a	10.0*	1.9
14	316.8ab	179.8abc	173.1ab	669.8ab	10.6*	1.6
6	307.5abc	193.0ab	135.8bcdef	635.5abc	10.6*	1.4
11	294.3abcd	176.5abc	152.4abcde	623.2abc	10.2*	1.6
10	330.4a	149.0cde	122.9cdef	602.4abc	7.8*	1.6
8	249.7de	108.6ef	167.0abc	597.3abc	10.4*	1.6
Haymor	213.2e	213.5a	166.1abcd	592.6abc	8.2*	--
15	311.1ab	155.7bcd	120.0def	587.0abc	9.4*	.8
3	300.3abcd	164.1bcd	121.7cdef	586.1abc	8.4*	.8
16	307.6abc	145.0cde	132.2bcdef	584.9abc	9.2*	.6
4	293.2abcd	153.9bcd	128.3bcdef	575.5abc	9.0*	1.4
12	295.1abcd	133.2def	132.1bcdef	560.3abc	9.4*	2.0
5	274.0abcd	146.3cde	130.3bcdef	550.6bc	8.6*	.2
Ladak	215.7e	195.5ab	135.1bcdef	546.2bc	6.4*	--
17	268.7bcd	157.9bcd	118.4ef	545.0bc	9.6*	1.4
2	303.5abcd	123.4def	98.4f	525.2c	6.8*	.2
9	268.8bcd	133.7def	122.2cdef	524.8c	8.8*	1.2
1	275.4abcd	146.0cde	101.1f	522.6c	9.6*	1.2
Eski	253.8cde	103.8f	48.1g	405.5d	4.0	-.6
$s\bar{y}$	16.92	12.79	13.80	37.02		
cv	13.23	18.23	23.40	14.30	10.80	
LSD .05	47.3	35.7	38.6	103.5	1.2	

1/ Values followed by the same letter are not significantly different at P=.05. The asterisk (*) indicates values significantly different from Eski at P=.05.

2/ Entries ranked according to 1968 total season yield.

3/ 2=much superior to Eski buffer rows
1=superior to Eski buffer rows
0=same as Eski buffer rows
-1=inferior to Eski buffer rows

other entries in the third cutting and total season yield.

This yield trial may indicate one of the reasons for the poor performance of Eski sainfoin at Huntley (21). Eski ranked, out of 19 entries, 16th, 19th, and 19th, respectively, for the yields of the first, second, and third harvests. The dormancy of Eski is shown in the regrowth height measurement following the first harvests in 1967 and 1968 (Tables II and III). The elongation of all regrowth lines was significantly greater than the check variety Eski in both years.

The regrowth lines varied greatly in early spring growth; however, the top five lines for total season yield were among the best six lines rated for spring growth the second harvest year (Table III). The top six yielding lines included the best five lines evaluated for height of elongation seventeen days following the first harvest. The relationship between the early spring growth, regrowth in height, and forage yield may be of benefit to the plant breeder in selection of sainfoin regrowth lines. A measurement of spring growth and regrowth elongation would possibly allow a rapid method for screening a large volume of material for forage yield under three-cut conditions.

At Huntley the correlation coefficients between the first and second, second and third, and first and third harvests were -.099, .572* and .068, respectively. The low correlation between first harvest and succeeding cuttings indicated the lines did not perform similarly at all cuttings. The yields were significantly correlated between the second and third harvests suggesting that the lines with the best regrowth tended to retain their yield potential for both harvests. Two notable exceptions to this general trend were entries thirteen and fourteen which ranked among the highest three yielding regrowth lines for all three cuttings in 1968. Simple correlation coefficients for first, second and third cuttings with total season yields were .458*, .602** and .885**, respectively. Coefficients of determination (r^2) show that most of the variation in total season yield was due to variation in the third cutting (r_2 = .783).

Fourteen of the seventeen lines significantly out-yielded Eski in total season yield the seeding year at Bozeman (Table IV). Because of the late first harvest date (July 25), the early dormant Eski type failed to elongate and yielded less than 16 of the 17 multi-cut lines at the second harvest. The late killing frost and 7 F above normal September mean temperature increased the growth of regrowth types. The mean height for all entries three weeks after the first harvest was 18.5 inches; Eski was 10.0 inches high. Elongation measurements for all entries were significantly greater than Eski.

In the second harvest year (1968) growth was not sufficient to warrant a third harvest. Eski ranked ninth in total season yield the second year; however, it was not significantly lower yielding (Table V). The single-cut characteristic of Eski was expressed in its large first harvest yield. Eski ranked number one and significantly out-yielded six regrowth lines, Ladak and Haymor alfalfa. The alfalfa entries yielded significantly less than all sainfoin except line 6

Table IV. Yield and height measurements of 17 sainfoin regrowth lines, Eski, and two alfalfa varieties the first harvest year at Bozeman, Montana (1967). 1/

Entry 2/	First Cutting 7/25/67	Second Cutting 8/29/67	Total Season	Regrowth 8/19/67
	(g)	(g)	(g)	(in)
3	119.6a	162.8ab	282.4a	16.8*
14	104.4abcd	171.4a	275.8ab	21.0*
9	110.0abc	161.3ab	271.3abc	17.8*
4	110.0abc	160.7ab	270.7abcd	19.0*
11	107.0abc	163.0ab	270.0abcd	19.8*
12	104.4abcd	156.0abc	260.5abcde	21.4*
16	103.6abcd	156.4abc	260.0abcde	19.0*
15	102.9abcd	156.0abc	258.9abcde	18.2*
10	104.4abcd	151.1abc	255.5abcdef	19.2*
13	102.7abcd	150.3abc	253.0abcdef	20.4*
2	113.6ab	133.5bcd	247.1abcdefg	14.2*
1	99.7abcd	145.6abcd	245.3abcdefg	19.8*
6	95.7bcd	143.7abcd	239.4bcdefgh	20.0*
8	91.6bcd	146.1abcd	237.8cdefgh	20.0*
17	93.9bcd	139.6abcd	233.6defghi	20.4*
Ladak	97.5abcd	130.1bcde	227.6efghi	17.2*
5	82.8d	138.4abcd	221.2fghi	17.4*
7	88.4cd	124.4cde	212.8ghi	19.2*
Haymor	92.4bcd	112.3de	204.7hi	18.8*
Eski	101.0abcd	100.8e	201.8i	10.0
$s_{\bar{y}}$	6.78	10.23	11.12	
cv	14.96	15.76	14.26	7.8
LSD .05	19.0	28.8	44.0	1.8

1/ Values followed by the same letter are not significantly different at P=.05. The asterisk (*) indicates values significantly different from Eski at P=.05.

2/ Entries ranked according to 1967 total season yield.

Table V. Yield and height measurements of 17 sainfoin regrowth lines, Eski, and two alfalfa varieties the second harvest year at Bozeman, Montana (1968). 1/

Entry2/	First Cutting 7/2/68	Second Cutting 8/8/68	Total Season	Regrowth 7/19/68	Regrowth3/ 9/18/68
	(g)	(g)	(g)	(in)	(in)
16	383.2ab	165.2abc	548.4a	9.8*	7.2*
4	372.0abc	151.3abc	523.3ab	9.2*	7.6*
14	333.4abcde	189.3a	522.7ab	11.6*	8.8*
3	355.0abcd	161.9abc	516.9ab	7.8*	5.7*
2	372.1abc	144.9bcd	516.9ab	8.0*	5.0*
15	345.6abcde	165.8abc	511.4ab	10.8*	7.7*
13	328.6abcde	171.0ab	499.6ab	11.0*	8.9*
10	354.0abcd	144.9bcd	498.9ab	8.2*	5.8*
Eski	387.2a	108.6d	495.8abc	3.8	3.1
1	328.8abcde	155.4abc	484.1abcd	11.0*	7.7*
7	310.6abcde	169.7ab	480.3abcd	10.8*	8.7*
11	302.8bcde	165.8abc	468.6bcd	11.4*	7.9*
8	296.2cde	165.8abc	462.3bcd	10.8*	8.1*
17	300.8cde	155.3abc	456.1bcd	11.2*	7.6*
9	309.0abcde	143.6bcd	452.6bcd	9.0*	6.2*
12	287.8de	157.9abc	445.7bcd	11.4*	8.3*
6	268.6ef	151.3abc	420.0cde	10.6*	8.2*
5	287.6de	126.6cd	414.2def	10.4*	6.3*
Haymor	202.8f	148.7abc	351.5ef	11.0*	12.0*
Ladak	213.4f	133.6bcd	347.0f	5.6*	8.1*
$s\bar{y}$	24.13	12.28	23.51		
cv	17.02	17.84	15.79	14.48	3.4
LSD .05	67.9	34.6	93.6	1.8	1.6

1/ Values followed by the same letter are not significantly different at P=.05. The asterisk (*) indicates values significantly different from Eski at P=.05.

2/ Entries ranked according to 1968 total season yield.

3/ Aftermath at killing frost. Not included in total season yield.

for the first cutting. Eski yielded significantly less than 13 regrowth lines and Haymor alfalfa in the second harvest. The 1968 yield data at Bozeman indicates that the growing season was too short to allow the multi-cut regrowth types to demonstrate their full yield potential.

Regrowth measurements taken seventeen days after the first harvest in 1968 indicated that the four sainfoin entries with the poorest stem elongation (lines 2, 3, 10 and Eski) ranked in the top half for total season yield. In the first harvest, these three lines and Eski were among the highest six yielding entries; however, lines 2, 10 and Eski yielded among the bottom five sainfoin entries in the second harvest. Aftermath measurement taken after a killing frost indicated that these same four entries had the poorest elongation.

The simple correlation coefficients for first and second cutting with total season yield were .948** and .384, respectively. Coefficients of determination (r^2) show most of the variation in total season yield was due to variation in the first harvest ($r^2 = .90$). First and second harvest yields were not significantly correlated.

In order to examine the seasonal distribution of forage yield for individual entries, all yields were converted to percentages of the total season yield. Significant differences in percentages indicates a significant cutting x entry interaction. The interaction for yield distribution of cuttings x entries was highly significant for both locations and years. The mean percentage of the individual entries seasonal yield distribution for both years at both locations are given in Table VI. When two harvests were made in one year, only one cutting is shown because the yield percentage of one harvest is the complement of the other harvest since the total for two cuttings have been equated to 100%.

At Huntley, in the year of seeding, the ratio between the means of the first and second cutting was 38.0 to 62.0%, respectively. The first harvest yields of Ladak, Haymor and Eski, expressed as a percentage of total season yield, were higher than all regrowth lines; consequently, they were significantly lower in the second harvest.

In the second harvest year (1968) the first, second and third cuttings of all entries contributed 50.0, 27.6 and 22.4% of the total season yield, respectively. Eski demonstrated its single-cut characteristic by producing 70.0% of its yield the first harvest. The percentage of yield for the first harvest of Eski was significantly greater than all entries except regrowth line 2. Regrowth lines 2, 3, and 10 were among the four lines producing the greatest proportion of their yield in the first harvest at Huntley. These same lines elongated less than other regrowth entries at both locations. The two alfalfa varieties produced a greater percentage of their season yield in the second cutting than all other entries. No significant differences in yield distribution occurred between the sainfoin entries in the second harvest. In the third harvest Haymor yielded the largest percentage of total season yield (28.2%) and was significantly greater than 14 entries. The three highest yielding sainfoin lines were 8, 13 and 14 with yield distributions of 27.5, 26.8

Table VI. The percent of total season yield for individual cuttings at Bozeman and Huntley, Montana in 1967 and 1968. 1/

Huntley								Bozeman			
1967		1968						1967		1968	
Entry 2/	1st cut	Entry	1st cut	Entry	2nd cut	Entry	3rd cut	Entry	1st cut	Entry	1st cut
	%		%		%		%		%		%
L	46.97a	Eski	60.95a	H	35.62a	H	28.23a	Eski	50.10a	Eski	78.05a
H	45.59a	2	57.62ab	L	35.42a	8	27.48ab	2	46.14b	2	72.20b
Eski	44.96a	10	54.95bc	6	30.62b	13	26.81abc	H	45.13bc	10	71.27bc
2	39.82b	15	53.73bc	8	29.85b	14	25.24abc	L	42.83bcd	4	70.96bc
4	38.43b	3	53.23bc	17	29.13b	L	24.94abc	3	42.54bcd	16	70.57bc
1	37.97b	1	52.92bc	11	28.11b	11	24.10bc	7	41.84cd	5	69.08bc
15	37.95b	12	52.45bc	1	28.00b	12	23.69bc	13	40.98cd	9	68.52bc
17	37.90b	16	52.39bc	3	27.29b	5	23.55bc	10	40.91cd	3	68.30bc
8	37.41b	9	51.61c	5	26.93b	16	22.80c	4	40.76cd	1	68.13bc
16	36.87b	4	51.34c	14	26.65b	9	22.70c	1	40.70cd	15	67.27bc
9	36.07b	5	49.52c	4	26.46b	4	22.20c	9	40.57d	17	66.23c
10	35.89b	17	49.01c	15	26.37b	17	21.85c	17	40.38d	13	65.55c
13	35.70b	6	48.49c	13	26.16b	6	20.89c	12	40.06d	7	65.08c
6	35.61b	14	48.11c	Eski	25.73b	10	20.30c	6	40.05d	11	64.60c
14	35.41b	11	47.78c	9	25.69b	15	19.90c	16	39.89d	12	64.35c
5	35.36b	13	47.03cd	16	24.81b	3	19.47c	15	39.71d	14	63.90c
3	34.99b	8	42.67de	10	24.75b	1	19.08c	11	39.56d	6	63.80c
11	34.59b	L	39.64ef	12	23.85b	2	18.76c	8	38.71d	8	63.45c
12	34.29b	H	36.15f	2	23.62b	Eski	13.31d	14	37.83d	L	61.44cd
								5	37.49d	H	57.11d

1/ All values are expressed as % of total season yield. Values followed by the same letter are not significantly different at P=.05.

2/ Entry L=Ladak, H=Haymor.

and 25.2%, respectively. Eski yielded 13.3% of its total season yield in the third harvest which was significantly less than for all other entries.

The yield distribution analysis for the Huntley trial has shown that variation exists between the multi-cut lines. The yield distribution of Eski was significantly greater than all sainfoin entries in the first harvest for both years with one exception; there was no significant difference between Eski and line 2 in 1968. Eski also produced the smallest proportion of total season yield when compared to all sainfoin entries the last harvest each year. These data show the single-cut (early fall dormancy) characteristic of Eski.

The potential of regrowth sainfoin under irrigation in Montana's long-growing-season areas appears very promising. Eski, which is currently recommended for hay at Huntley because of its alfalfa weevil resistant characteristic, was the lowest yielding sainfoin entry at Huntley in 1968. Lines 10, 13, 14 and 15 yielded significantly more than Eski in all three harvests. Eski does not exhibit the one large hay cutting advantage at Huntley.

The yield distributions at Bozeman were similar to those received at Huntley. The variety Eski produced a significantly higher percentage of its total season yield the first harvest than all other entries. This reflects its first cutting potential and failure to regrow following harvest. Lines 2, 3 and both alfalfa entries also showed a large first harvest distribution the year of seeding. In the first harvest (1968), the yield ratios among cuttings were significantly less for Ladak and Haymor than all other entries.

The data from both locations indicates that the sainfoin entries could be categorized into single-cut (Eski), intermediate (entries 2, 3, and 10), and multi-cut types. Entries 2, 3 and 10 were generally intermediate to the Eski and other regrowth lines in spring growth, height of regrowth following first harvest, and yield percentages among harvests.

Even though the regrowth lines did not significantly out-yield Eski at Bozeman, this type of material may have a place in the Gallatin valley and other high elevation areas in Montana. There are some undesirable features of a large first cutting. One of the undesirable features of Eski sainfoin used as pasture has been the production of nearly 80% of the total season yield the first 40 days of the growing season. This distribution fails to produce pasture throughout the season. Regrowth lines 13 and 14 ranked higher than Eski in total season yield and produced less than 65% of their forage the first harvest at Bozeman. These regrowth lines may find an important place in Montana legume and legume-grass pastures.

Other undesirable features of the Eski yield distribution pattern can occur in hay production. The extremely large first harvest of the Eski type is difficult to cure. An additional advantage of the multi-cut sainfoin types is that a large percentage of the total hay yield will not be subject to damage by June rains. Another possible advantage of the regrowth type sainfoin over the Eski type is the potential to elongate rapidly after harvest providing better competition with weeds. This competition for light would also be advantageous to sainfoin when grown in a pasture mixture with a grass. Further pasture and weed competition studies are needed to fully evaluate the possible potentials of regrowth sainfoin.

DETERMINATION OF DAY LENGTH REQUIREMENTS OF FIVE SAINFOIN CLONES

Materials and Methods

In October 1967 five clones were selected for their single-cut or multi-cut characteristics (Table VII). Ten cuttings from each clone were established in 8-inch pots in the greenhouse. Two clones were selected from Eski, G-3 and G-4, and one clone from the collection at Hall, Montana, J-12, to represent single-cut types. Two introductions (P. I. 239,959), D-1, and (P. I. 227,377), D-2, were selected as multi-cut types.

All plants grew in the greenhouse under a natural photoperiod from October to January without exposure to artificial light. On January 1 all plants were clipped to a 1-inch height and placed in a growth chamber for 45 days. Chamber conditions consisted of an 8-hr day and a 16-hr night with a 65 F day and 40 F night temperature. Light intensities were approximately 2,400ft-c. Plants were periodically fertilized with 16-20-0. Nicotine bombs were used for insect control.

On February 15 all plants were clipped to 1-inch. Since the 45 day period served only to precondition all plants to a standard treatment, no measurements were taken. One half of the cuttings of each clone were placed in a growth chamber with a 16½-hr day and a 7½-hr night. This photoperiod represented the day length of June 15th at Bozeman. The remaining five cuttings of each clone were placed in a chamber with a 13½-hr day and a 10½-hr night. This represented the day length of September 1st at Bozeman, Montana. The temperature treatment in both chambers was a 65-40 F day-night regime. After

102 days all flower racemes were counted to determine the effect of long and short days on stimulation of elongation and flowering.

The plants were removed from the growth chambers and transplanted to the field on 4-ft centers at the Agricultural Experiment Station at Bozeman, Montana on May 29, 1968. The flower racemes were then counted on July 17, August 1 and September 4. An analysis of variance and interaction chi-square were used to determine the effect of short or long day growth chamber pretreatments on flowering. Three plants of each clone were clipped July 17 and August 1 to evaluate their ability to elongate under these natural day lengths in the field.

Table VII. Characteristics of five sainfoin clones selected for determination of their day length requirements at Bozeman, Montana (1967).[1/]

Clone	Plant type	Date first bloom	Seed yield Date	Seed yield Grams	% Cross-fertility	Regrowth Date	Regrowth Inches
D-1	Multi-cut	6/30	8/7	186	90.82	9/7	15
D-2	Multi-cut	6/30	8/11	3	2.34	9/7	18
G-3	Single-cut	6/26	8/11	372	48.63	9/4	8
G-4	Single-cut	6/28	8/11	223	25.32	9/4	7
J-12	Single-cut	6/10	8/1	108	43.40	9/7	5

1/ Unpublished data on sainfoin by Carleton (10).

Results and Discussion

The effect of day length on the five clones tested varied greatly among clones. When subjected to the long-day chamber, the two clones (D-1 and D-2), which were selected for their regrowth characteristic, flowered similarly (Table VIII). The five plants of Clone D-1 had a mean raceme number per plant of 13.0 under the long-day (LD, $16\frac{1}{2}$-hr) and 17.0 when subjected to the short day (SD, $13\frac{1}{2}$-hr) treatment. Clone D-2 flowered under the LD treatment; however, it was significantly inhibited under the SD with a mean of 2.2 racemes per plant. The two Eski cones (G-3 and G-4), selected for their single-cut characteristic, flowered in the LD chamber. The flowering of G-4 was inhibited ($\bar{x}$=.2) when subjected to SD's, while G-3 was not affected. Clone J-12, which has a single-cut growth characteristic, produced 3.2 racemes per plant under LD's and .8 under SD's. The racemes initiated in the LD chamber were all seed heads when counted indicating that J-12 would not initiate more racemes without a SD treatment.

Significant interactions (chi-squares: $P < .025$ and $P < .10$) occurred within the two growth types for response to day length. This prevented the separation of the growth types by their flowering response to day length. The growth chamber study did not allow the multi-cut types to be separated from the single-cut types. However, it was found that the various clones responded differently to differing day and night lengths. If flowering of sainfoin was required for greenhouse breeding studies, it would appear that the flowering of both types would be the greatest under SD's followed by LD's.

Table VIII. The effect of growth chamber day length on flowering of five sainfoin clones within the chambers and when transplanted to the field. 1/

	Mean no. of racemes per plant				
	Eski clones		Hall clone	Regrowth clones	
	G-3	G-4	J-12	D-1	D-2
Growth chamber2/					
LD $16\frac{1}{2}$-hr	17.6a	12.2a	3.2b	13.0a	11.6a
SD $13\frac{1}{2}$-hr	18.8a	.2b	.8b	17.0a	2.2b
Field 3/					
$16\frac{1}{2}$-hr pretreatment	98.0b	151.4a	.0f	78.0bc	63.0bcd
$13\frac{1}{2}$-hr pretreatment	40.8cde	156.6a	17.4ef	34.0def	47.4cde

1/ Values followed by the same letter are not significantly different at P=.05. The growth chamber and field experiments were analyzed separately.

2/ All plants were subjected to 45 eight hour days followed by 104 days in their respective growth chambers.

3/ Plants removed from growth chambers, clipped and transplanted to the field May 29. The flowers in the field were counted July 17.

The plants were moved from the growth chambers to the field on May 29. Various clipping dates were to be used to determine the effect of natural day lengths on regrowth and flowering. Because of the effect that the growth chamber day length had on behavior of the clones in the field, the clipping studies could not be completed.

The growth chamber pretreatment effects on flowering in the field are shown in Table VIII. Clones D-1, D-2 and G-3 bloomed profusely when pretreated with LD's. The SD pretreatment reduced the number of racemes approximately one half for these three clones. Following the LD pretreatment, G-4 produced approximately double the number of racemes in the field as compared to clones D-1, D-2 and G-3. With a SD pretreatment the flowering of G-4 was four times that of the above three clones. Clone J-12 had a mean of 17.4 racemes per plant when moved from the SD chamber to natural long day length. It produced no flowers in the field when pretreated with a LD.

The combination of the growth chamber and field studies allows a separation of these clones for day length requirements. Clones D-1 and G-3 will apparently bloom under both long and short days assuming that the long days are preceded by a short day treatment. Clone D-1 is a plant taken from Line 13, which was the best regrowth line in the yield trials. The regrowth ability of the line may be linked to its ability to elongate under SD's following second and third harvests. The flowering of D-2 was greatly inhibited under short days suggesting that it is a LD or SD-LD plant. Clone G-4 was inhibited under SD's; however, in relation to the other four clones its flowering was greatly increased when LD's were preceded by SD's. These data allow the photoinductive cycle of G-4 to be classed as SD-LD for greatest raceme initiation. The flowering of J-12 was nearly inhibited completely unless LD's were preceded by SD's. J-12, which is a semi-native to Montana, blooms very early in the spring when compared to the other four clones in the study (Table VII). This may indicate that fewer LD's are required for flowering than for the other clones. This clone also has less growth following seed harvest than all other clones. This may indicate that it will not initiate elongation under the SD lengths of August and September at Bozeman, Montana.

It is important to emphasize that a short day in these studies was $13\frac{1}{2}$ hours compared to the standard definition in the literature of a short day being 8-10 hours. The reason for selecting the $13\frac{1}{2}$ hour day was that under this natural day length the single-cut sainfoin fails to elongate following harvest. The regrowth type will elongate under the $13\frac{1}{2}$-hr natural day at Bozeman, Montana.

Plants are generally evaluated in day length studies as either flowering or not flowering for a specific length of day. However, in this study the effects of day length on the degree of flowering was evaluated. The degree of flowering would be very important when selecting sainfoin material for seed production in the first or second seasonal harvest. The degree or number of tillers elongating will also affect forage yield and quality.

Further study is needed to determine the effect of day length on sainfoin elongation and flowering. It is suggested that a larger number of clones of each growth type be used. The effect of temperature and temperature x day length interactions on flowering may also be important in the growth of the single- and multi-cut types.

SUMMARY

Sainfoin (Onobrychis viciaefolia Scop.) is rapidly increasing in use in the United States and Canada. This legume is drought and winter-hardy, alfalfa weevil resistant, non-bloating, and highly nutritional. The yield of the variety Eski has been similar to alfalfa on dryland and under irrigation in the mountain valleys of Montana. Eski is a single-cut type which fails to equal alfalfa in regrowth following the first and second harvests.

Seventeen lines were selected from 98 plant introductions for their regrowth characteristic. These lines were then tested for their yielding ability at Bozeman, Montana, which is a two cut area for alfalfa and Huntley, Montana, where three cuttings of forage are generally harvested. At Huntley all entries yielded significantly more than Eski in the third harvest and total season yield in 1968. Regrowth lines 13 and 14 yielded more than Eski in all cuttings the second harvest year. The r^2 or coefficient of determination showed that 78 percent of the variation in total season yield was due to variation in the third cutting.

The 61% total season yield distribution of Eski in the first harvest at Huntley was higher than all other entries. Eski produced 13% of its yield the third harvest which was lower than all other entries. The yield distributions received at Huntley indicate the regrowth lines are superior to Eski if one large first harvest is not desired. The proportion of yield distribution of Eski was greater than all regrowth lines the first harvest and less than all lines the second cutting in

1968 at Bozeman. Eski ranked ninth in total season yield; however, it was not significantly out-yielded.

An experiment was conducted to determine the day length requirements for flowering of single- and multi-cut sainfoin types. The two types could not be separated according to day length requirements; however, the five clones tested did show variation in requirements.

LITERATURE CITED

1. ANDREEV, N. G. 1963. (Publishing house for Agricultural Literature and Journals), Description of sainfoin in Agronomiya. p. 400-402 (translated by R. P. Knowles).

2. BADOUX, S. 1965. Etude des caracteres morphologiques, physiologiques et agronomiques de populations d'esparcette (Onobrychis spp.) [Morphological, physiological and agronomic characteristics of sainfoin populations (Onobrychis spp.)]. Schweiz. landw. Forsch. 4(2):111-190.

3. BAKER, C. J. L. 1952. Studies on the composition of sainfoin. Jour. Agr. Sci. 42:382-394.

4. BAWOLSKI, S. 1961. Wplyw krotkiego dnia na rozwoj esparcety. (The influence of short day on the development of sainfoin) Rocz. Nauk Rolniczych Ser. A. Roslinna 82(4):941-963.

5. __________. 1966. Badania nad rozwojem esparcety siewnej (Onobrychis viciaefolia Scop.). Investigations on the development of sainfoin Onobrychis viciaefolia Scop. Pamietnik Pulawski-Prace Iung. 23:97-134.

6. __________. 1966. Krotka charackterystyka krajowych populacji esparcety siewnej (Onobrychis viciaefolia Scop.) [Characterization of Polish populations of sainfoin, (Onobrychis viciaefolia Scop.)]. Pamietnik Pulawski-Prace Iung. 23:73-95.

7. CAPRIO, J. M. 1967. Weather data at agricultural experiment stations in Montana. p. 11.

8. CARLETON, A. E. 1967. Annual forage research committee report. Montana Agr. Exp. Sta. pp. 66-76.

9. CARLETON, E. E., COOPER, C. S., DELANEY, R. H., DUBBS, A. L., and ESLICK, R. F. 1968. Growth and forage quality comparisons of sainfoin(Onobrychis viciaefolia Scop.) and alfalfa (Medicago sativa L.). Agron. Jour. 60:630-632.

10. CARLETON, A. E. 1967. Unpublished data on sainfoin. Montana State University, Plant and Soils Science Dept.

11. CHAPMAN, S. R. and YUAN, M. 1969. Cytological and morphological variation in breeding stocks of Onobrychis. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

12. COOPER, C. S., CARLETON, A. E., ESLICK, R. F., and DELANEY, R. H. 1969. Evaluation of sainfoin (Onobryohis viciaefolia Scop.) for winterhardiness. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Bull. 627.

13. COOPER, C. S. and ROATH, C. W. 1965. Sainfoin for hay in Montana? Now. 1:3-5.

14. DUBBS, A. L. 1969. The performance of sainfoin and sainfoin-grass mixtures on dryland in Central Montana. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

15. FYFE, J. L. 1943. Sainfoin (a very useful crop). Jour. Ministry of Agr. 49:208-210.

16. HANNA, M.R. 1969. Sainfoin breeding in Canada. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

17. HANNA, M. R. and SMOLIAK, S. 1969. Sainfoin yield evaluations in Canada. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

18. HOLDEN, J. L. 1963. Agronomic potential of sainfoin (Onobrychis viciaefolia Scop.) for Montana. M.S. Thesis, Montana State Univ.

19. JENSEN, E. H. and SHARP, M. E. 1969. Agronomic evaluation of sainfoin in Nevada. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

20. KELLNER, E. 1939. The Persian form of esparcette (Onobryohis viciaefolia, forma persica, Shiryaev)(many-cut sainfoin). Amer. Bee Jour. 79(11):536-537.

21. KRALL, J. L. 1969. Preliminary report on grazing irrigated sainfoin with yearling steers. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

22. MELTON, B. A. and FINKNER, M. D. 1967. Relative efficiency of experimental designs with systematic control plots for alfalfa yield tests. Crop Sci. 7:305-307.

23. NITTLER, L. W. and GIBBS, G. H. 1959. The response of alfalfa varieties to photoperiod, color of light and temperature. Agron. Jour. 51:727-730.

24. OAKLEY, R. A. and WESTOVER, H. I. 1921. Effect of the length of day on seedlings of alfalfa varieties and the possibility of utilizing this as a practical means of identification. J. Agr. Res. 21:559-608.

25. Plant Inventory U. S. Horticultural Crops Research Branch. Plant Introductions Section. Nos. 162-166.

26. ROATH, C. W. 1969. Sainfoin for dryland hay in western Montana. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

27. SHAIN, S. S. 1959. Description of sainfoin in Agrotechniques of Perennial Forages. (Moscow, State Publishing house of Agricultural Literature). pp.51-54.

28. SHORNHORST, M. H., DAVIS, R. L. and CARTER, A. S. 1957. Response of alfalfa varieties to temperature and day lengths. Agron. J. 49: 142-143.

29. SPRAGUE, M. A. and FUELLEMAN, R. F. 1941. Measurements of recovery after cutting and fall dormancy of varieties and strains of alfalfa, Medicago sativa. Jour. Amer. Soc. Agron. 33:437-447.

30. THOMSON, J. R. 1951. Sainfoin in its first harvest year. J. Brit. Grassl. Soc. 6:107-117.

31. Times Atlas of the World (South-West Asia and Russia), The. Volume II. Mid-century Edition. London: The Times Publishing Co. LTD. 1959.

32. VARGA, P. 1969. Aims in sainfoin breeding in Romania. Sainfoin Symposium, Montana State Univ. Montana Agr. Exp. Sta. Bull. 627.

33. VARGA, P. and SLUSANSCHI, H. 1959-60. Influenta epocii de rocoltare aspura valifatii funului de sparceta si posibilitiatea producerii simintelor las coasa a II-a. (Effect of harvesting date on the quality of sainfoin hay and the possibility of obtaining seed from second cut) Anal. Inst. Cercetari Agron. Ser. B. 27:227-235.