YIELDS, ROOT DEVELOPMENT, CARBOHYDRATE RESERVES AND In Vitro DRY MATTER DISAPPEARANCE OF SPRING-SEEDED ALFALFA (MEDICAGO SATIVA L.) TREATED WITH HERBICIDES AND HARVESTED IN THE YEAR OF SEEDING

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Yields, root development, carbohydrate reserves and *In Vitro* dry matter disappearence of spring seeded alfalfa (*Medicago sativa* L.) treated with herbicides and harvested in the year of seeding

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ABSTRACT

YIELDS, ROOT DEVELOPMENT, CARBOHYDRATE RESERVES AND *In Vitro* DRY MATTER DISAPPEARANCE OF SPRING-SEEDED ALFALFA (*MEDICAGO SATIVA* L.) TREATED WITH HERBICIDES AND HARVESTED IN THE YEAR OF SEEDING

By

Seppo K. Pulli

The effects of early and late spring-seeding on two varieties of alfalfa treated with a herbicide and seeded at seven rates and given two cutting systems were evaluated in seeding-year yields, population density, root development, total nonstructural carbohydrates in roots, *in vitro* dry matter disappearance of forage, and incidence of *Phytophthora megasperma* Drechs root rot in experiments in 1971 and 1972 at East Lansing, Michigan. Yields in the year after seeding were used to compare the yield levels and *in vitro* dry matter disappearance of spring seedings with summer seedings in the year after seeding.

Yields of alfalfa in the seeding year were reduced when spring seeding was delayed from the earliest possible date in the spring until 3 to 4 weeks later. The highest yield in both experiments was obtained from early-seeded alfalfa cut three times during the seeding year. Levels of total nonstructural carbohydrates in

the fall of the seeding year and similar yields the next year indicated no differential effect of the cutting systems.

Irrigation decreased seeding-year yields when compared to nonirrigation in a year of above-normal rainfall, primarily because of a marked incidence of *Phytophthora* root rot, especially in the late-seeded alfalfa cut three times.

Saranac yielded more than the Vernal variety in the year of seeding when seeded early. Yields of both varieties in the seeding year increased up to a seeding rate of 9.0 kg/ha when the seeding was early and weed control was satisfactory but a rate of 13.5 kg/ha was necessary for maximum yields in the seeding year when weed control was unsatisfactory and the time of seeding was delayed.

Yields in the year after seeding from spring-seeded, herbicide-treated alfalfa were similar to early- and medium-dates of summer seeding. Required seeding rates for maximum yield in the year after seeding were 9.0 kg/ha in both spring and summer seedings.

Plant population in the fall of the first and second year after seeding was significantly higher in the early seeding than in the late seeding. Cutting either variety two or three times had no significant effects on the number of plants/m^2 in the fall of the cutting year or in the second year. The number of plants/m^2 at the 9.0 kg/ha seeding rate which produced the maximum yield was 268 over all treatments of cutting date and seeding date in 1971 and 211 at the optimum rate of 13.5 kg/ha in 1972. Higher seeding rates of 18.0 or 36.0 kg/ha produced lower survival of seedlings with the late seeding or with Saranac in contrast to late seeding or the Vernal variety.

Weight per root and total root yields at the end of the seeding year were influenced more by population density than seeding time. Over three-fourths of the weight per root in the spring of the year after seeding were in the top 30 cm; 14.6% were in the 30- to 60-cm zone and 6.6% were in the 60- to 90-cm zone. Cutting alfalfa two or three times in the seeding year had no differential effect on weight per root or root yield in the fall of the first and second year. Root yield was constant and paralleled top growth for any seeding rate beyond that necessary to produce maximum forage yield.

Seeding-year levels of total nonstructural carbohydrates were very similar or showed only a slight decrease in both varieties, cutting systems, and seeding dates as seeding rates increased from 1.1 to 36.0 kg/ha. Percentages of total nonstructural carbohydrates in roots of seedlings increased gradually in successive cuttings during the seeding year.

Irrigation, variety, and seeding rate had no effect on dry matter disappearance of the seeding year forage of alfalfa. The 3-cutting system produced higher in vitro dry matter disappearance values and in vitro digestible dry matter yields than the 2-cutting system in the seeding year. The decrease in dry matter disappearance per day in July was 0.5% in the early seeding and 0.28% in the late seeding. Summer seedings and spring seedings produced similar percentages of in vitro dry matter disappearance in the year after seeding except for the late-summer seeding which had higher values in the first and second cuttings.

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Irrigation increased the incidence of *Phytophthora* root rot in alfalfa roots when the natural precipitation between April 1 and October 31 was 56 cm, 4.5 cm above normal. Both varieties were generally similar in susceptibility to *Phytophthora* root rot except that Saranac under irrigation showed somewhat greater susceptibility. Alfalfa seeded at the lower seeding rates of 2.2 and 4.5 kg/ha and irrigated was significantly less diseased than at the higher seeding rates. Maximum *Phytophthora* root rot was induced by a combination of stress factors including high moisture levels in the soil, frequent cutting, high seeding rates producing smaller plants, and a susceptible variety.

YIELDS, ROOT DEVELOPMENT, CARBOHYDRATE RESERVES AND *In Vitro* DRY MATTER DISAPPEARANCE OF SPRING-SEEDED ALFALFA (*MEDICAGO SATIVA* L.) TREATED WITH HERBICIDES AND HARVESTED IN THE YEAR OF SEEDING

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INTRODUCTION

Alfalfa (*Medicago sativa* L) has long been accepted as the premier forage crop for ruminant animals in areas where it can be successfully grown. Fortunately, this range of adaptability is wide with relatively few areas in the United States where alfalfa cannot be grown.

There has been a continuous increase in the use of alfalfa in both the North Central and Northeastern areas, but the expansion of the acreage from the Western States into the North Central area has been one of the dramatic changes in forage use, Smith (36).

At the end of the 19th century very little alfalfa was grown in the North Central area excpet in Kansas and Nebraska. Most of the crop was grown in the Western States. The acreage cut for hay in the North Central area increased to 39% of the total acreage cut for hay in the United States in 1909 and to 44% in 1919, Ahlgren (1). With the increase of the culture of alfalfa in the whole area, the acreage cut for hay increased to 48% of the total acreage in the United States in 1929, to 54% in 1939, to 59% in 1949, to 64% in 1959 and to 67% in 1969, Paulling (28).

Over two-thirds of the alfalfa seedings made today in the North Central States are seeded in early spring, usually with oats as a companion crop, Tesar and Jackobs (42). These authors listed some advantages for companion crops:

1. They provide some income from grain or forage for pasture, hay and silage.

2. They help to reduce soil erosion.

3. They help to control annual weeds.

Summer and fall seedings have usually been seeded without a companion crop. Summer seedings have recently replaced a portion of spring seedings in oats and nearly all of the spring seedings in the winter wheat in the North Central and Northwestern Regions. Legumes seeded in the fall after September 1 in the northern one-half of the North Central states do not have sufficient time to be well established before winter.

Spring seeding without a companion crop using herbicides to control broad-leaved weeds is an alternative to seeding with a small grain companion crop. This method is rather new, having been used since about 1960. The new seeding method, sometimes called "clear seeding," becomes an attractive alternative to seeding with a companion crop, generally oats, if the livestockman has little use for the straw for or if stands of alfalfa are total or partial failures due to competition. The herbicides 2,4-DB applied postemergence and EPTC applied preplanting are used most frequently to control the annual broadleaves weeds. Alfalfa is harvested during the year of seeding and provides income in the year of seeding.

There are several economic reasons why alfalfa seeded alone and harvested in the year of seeding may be preferred to with a companion crop according to Anderson (3):

1. One-year delay in alfalfa production with companion crop.
2. Low value placed on oats by many farmers.
3. High potential yield of alfalfa in the seeding year.

Tesar and Jackobs (42) emphasize that the price of hay in many Northeastern States, e.g., $50 per ton in New York compared to $25 in Michigan, indicates that seeding without a companion crop may become more popular in the Northeastern than in the Northcentral states.

Establishing a good stand is essential in getting high yields of alfalfa. The seeding rate is one of the factors which is important in the stand establishment. Other factors are seedbed preparation, seeding techniques, time of seeding, competition from weeds, soil fertility, soil pH, drainage, insects, and management during the seeding year.

The objectives of this investigation were to determine (1) how many plants per unit area are necessary for maximum yield in the year of seeding and the next harvesting year; (2) what is the effect of date of seeding and frequency of harvest during the seeding year on the next year's yield; (3) how do spring seedings with herbicides compare in yield the next year with summer seedings which are a recommended practice; and (4) what is the effect of seeding rates on digestibility of forage and incidence of *Phytophthora megasperma* root rot disease.

Seeding rate studies were related to different management practices including seeding dates, irrigation practices, cutting frequencies, and two varieties. Included in this investigation were determinations on *in vitro* dry matter disappearance, root carbohydrate reserves, and comparisons between summer seedings and the second-year yields of spring-seeded alfalfa. The investigations were conducted in 1971 and 1972.

LITERATURE REVIEW

Seeding rate requirements and yields

Limited research on seeding rate of alfalfa harvested in the year of seeding has been reported. Research results and seeding rate recommendations vary considerably.

The recommended seeding rates per hectare based on limited research are: Michigan, 9 kg, Tesar (43); Illinois, 13.5 kg, Graffis (18); New York, 19 kg, Pardee (27); Maine, 11-13.5 kg, Brown and Stafford (6).

Tesar (43) compared seeding rates 4.5, 9, 13.5, 18 and 26.5 kg/ha in 1969. No difference in first-year yields were obtained above seeding rates of 4.5 kg/ha. Seedings at higher rates were slightly better in the second year but yield differences were not significant. The date of Graffis (18) in Illinois agree very closely with those obtained in Michigan. Pardee (27) in New York obtained an average increase of 0.47 tons per hectare in the seeding year for the 20 over the 13.5 kg rate. This advantage continued in the second year. Sund (40) from Wisconsin recommends 13.5 kg/ha as the optimum seeding rate for good seedbeds and 18 kg/ha on poorer seedbeds. Brown and Stafford (6) in limited tests in Maine increased seeding-year yields 1.16 tons per hectare by increasing seed rates from 9 to 18 kg/ha. Moline and Robinson (24) in Nebraska obtained no increase in yields during the first two years by increasing seed rates from 10 to 16.5 kg/ha.

Average seeding-year yields from several tests in various states range from 4.0 tons per hectare in Minnesota to 5.8 tons per hectare in Maine in the northern part of the United States and 6.9 tons in the central part of the Corn Belt, (42). Reports of hay yields in tons per hectare from at least two trials per state are: Missouri, 5.1 (29); Wisconsin, 3.1 (32); Nebraska, 3.7 (24); Minnesota, 4.0 (3); Michigan, 5.7 (43); and Illinois, 7.2 (19).

Seeding-year yields of alfalfa treated with herbicides are approximately 40 to 60% of maximum yields produced by well-established stands (42). Under less favorable moisture conditions, first-year yields are about 20 to 30% of maximum reported yields. In New York, Seaney (35) reports that plots yielding 9 to 11 tons per hectare in the seeding year yielded 14.5 to 16.8 tons per hectare in the next year. In Illinois, Graffis (18) reported second-year yields were about 14.1 tons per hectare compared to the first-year yields of 7.8 tons per hectare.

Very little information is available in regard to cutting frequency in the year of seeding. Graffis (17) in Illinois reported a 30- to 35-day interval to be optimum. In another study, Graffis (18) found no difference between two-and three-cutting treatments. Saranac yielded about 10% more than Vernal when cutting frequency was either 30, 35, or 40 days in New York (35).

Summer seedings have been made successfully in late July or August in the Great Lakes States and in the Northeast region. Seeding alfalfa after small grain harvest, especially after wheat, has become popular in the Corn Belt States and New York, Tesar and Jackobs (42).

In states where summer seeding is recommended, alfalfa, in the year after seeding, generally yields as well as when spring seeded in oats. Michigan yields in the year after seeding were 15.7 tons per acre when spring seeded in oats compared to 13.9 tons for early-August seedings, Tesar (43).

Recommended seeding rates of alfalfa harvested in the year after establishment are 4.5 to 9 kg per hectare in arid areas of the United States, Bolton (5), 9 to 13.5 kg in the humid North Central and Northeastern regions, and 16.5 to 33 kg per hectare in the southern and western areas of the United States, Tesar and Jackobs (42).

Population and root studies

Numerous factors such as temperature, available moisture, age, and osmotic concentration of the media surrounding the seeds are known to influence germination of alfalfa seed, Bula and Massengale (7). Temperature, light, available soil moisture and nutrients, seed size, and environmental conditions under which seeds matured affect seedling vigor, Pritchett and Nelson (30). Available soil moisture greatly influences growth of alfalfa seedlings. A readily available moisture supply during the seedling stage is important, but excessive moisture reduces soil aeration and may result in a shallow root system and plants with small crowns. In addition, excessive soil moisture may induce seedling damage or loss by increasing pathogens, Bula and Massengale (7). Short photoperiods, antinauxin applications, and decreasing stand density were found to enhance stem production of alfalfa, Cowett and Sprague (11). Competition between plants becomes more prevalent as stand density increases, Clements, Weaver, and

Hanson (10). The percentage of total sunlight penetrating through plant canopy has no significant effect on crown development and stem production; stem production per plant was not always closely associated with yield, Cowett and Sprague (11).

The amount and distribution of rainfall are among the most important factors in determining the optimum seeding rates, Tesar and Jackobs (42). Other important factors are method of seeding, seedbed preparation, soil type and tilth and purpose of seeding. Brown and Stafford (6) in Maine considered 60% emergence as excellent, 40% as fair, and 20% as poor. As a result of competition, disease, insects, winter injury, and other causes, the number of seedlings surviving the first year is generally in the range of 40 to 50% of the seed sown. Thirty to 35 seedlings from 50 seeds is considered good emergence. Of this number, 20 to 25 would survive the first winter. This number was high enough for maximum yield in the first harvest year after establishment, Jackobs and Miller (21).

Only limited information pertaining to development of alfalfa roots under natural conditions is available. Lamba, Ahlgren and Muckenhirn (23) observed in field studies that root weight increased steadily during the year of seeding, decreased as the soil became more course-textured, and decreased with increasing depth. More than one-half of the weight was in the surface 20 cm layer. The length of root per unit of dry matter increased considerably in each successive 20 cm layer.

In Wisconsin, Sund (40) varied seed rates of Vernal and Saranac alfalfa from 4.5 to 36 kg per hectare. Mortality of the plants during the first winter after seeding was high at rates above 20 pounds per acre because roots were small.

Total nonstructural carbohydrates

Very little information is available in regard to the trends of total nonstructural carbohydrates (TNC) in the year of seeding. There is no published information on TNC levels in roots of alfalfa spring seeded and treated with herbicides and cut during the seeding year. Several investigators have indicated that carbohydrate root reserves in well-established alfalfa decline during regrowth as new topgrowth is produced and that the decline continues 2 to 3 weeks under field conditions before reaccumulation occurs, Grandfield (20). The importance of carbohydrates in relation to cold tolerance was examined more than 40 years ago, Steinmetz (39). Garber, *et al*. (16) reported that alfalfa was more susceptible to winter injury when its roots contained low concentrations of carbohydrate reserves.

In vitro dry matter disappearance studies

Although no reports of *in vitro* dry matter disappearance (digestability) of alfalfa in the seeding year were found, a considerable amount is available on alfalfa in the year following seeding, Barnes and Gordon (4). Allinson, Tesar and Thomas (2) using a 6-hour *in vitro* dry matter disappearance (IVDMD) technique, found that the overall values of five forages cut one, two, three or four times per season were 13.0, 21.6, 24.9 and 25.4, respectively.

Reid et al. (31) in New York found that IVDMD of alfalfa declined about ½% per day after May 1. Mowatt et al. (25) stated that the digestibility of leaves of alfalfa decreased only slightly as the season progressed. However, the IVDMD of the stems declined rapidly early in the season. Unlike the grasses, the stems of alfalfa never attained as high a digestibility as the leaves at the early growth stage.

Phytophthora root rot studies

Phytophthora root rot (Phytophthora megasperma Drechs) was first observed in California in 1952, Ervin (12). The disease was observed in Illinois in 1957 (8), in Ohio, Mississippi and Canada in 1964 (34, 22, 9), in Minnesota in 1967 (13), and in Wisconsin, Iowa, Nebraska and South Dakota during 1971 (14). Phytophthora root rot was reported in Michigan in 1972 (44).

The disease is always reported to be associated with heavy, poorly drained soils and heavy rainfall and/or irrigation, Frosheiser (14). It becomes severe when the topsoil remains excessively wet during periods of heavy and continuous rainfall. Rotting of the tap-root may occur to a depth of about 50 cm, Frosheiser (14). If the wet conditions persist, the rot continues until the plants die. The plants are wilted or stunted with yellowed leaves. Identification of Phytophora disease in alfalfa was described by Frosheiser (14).

MATERIALS AND METHODS

Field Studies

A. Experiment I, seeded in 1971

Experiment I was established on the Michigan State University farm in East Lansing in 1971. The soil was a productive, well-drained Hillsdale loam soil with pH 6.8. The seedbed was well prepared prior to seeding. Fertilizer was broadcast and incorporated with the soil by disking. Germination was 93% for Saranac and 87% for Vernal. Seeding rates were adjusted to 100% germination according to germination and seed weight.

Experiment I was composed of two general seeding times--spring and summer. The spring seedings were harvested in 1971 and in 1972. The summer seedings were harvested first in 1972 when yields of the spring and summer seedings were compared.

Spring seedings, 1971

The specific experimental plan and variables were as follows:

1. Field plan

Plot design	:	split-split-split plot, 4 replications
Plot size	:	0.9 x 7.8 m
Rows	:	5 rows per plot, 15 cm apart
Drill	:	nursery planter
Fertilization	:	0-26-26, 600 kg/ha before seeding
Harvest area	:	.9 x 6.8 m

2. Variables

Seeding times	: early seeding - April 10, 1971
	: late seeding - May 9, 1971
	1971
Cutting frequencies	: early seeding, 2 cuttings (July 20, Oct. 1)
	: late seeding, 2 cuttings (Aug. 3, Oct. 1)
	: early seeding, 3 cuttings (July 9, Aug. 20, Oct. 27)
	: late seeding, 3 cuttings (July 20, Aug. 27, Oct. 27)
	1972
	: 4 cuttings on June 3, July 20, Aug. 21, Oct. 26
Varieties	: Saranac--vigorous, moderately winter-hardy, wilt resistant
	: Vernal--less vigorous, winterhardy, wilt resistant
Seeding rates, kg/ha	: 1.1 - 54 seeds per m^2
	: 2.2 - 108 seeds per m^2
	: 4.5 - 216 seeds per m^2
	: 9.0 - 432 seeds per m^2
	: 18.0 - 864 seeds per m^2
	: 36.0 - 1724 seeds per m^2

The early seeding was sprayed with 1.1 kg/ha of 2.4-DB and 1.1 kg/ha dalapon on May 22 when the seedlings were at the 2-trifoliate leaf stage in order to control weeds. A similar treatment was applied to the late seeding on June 12. Because of imperfect control of annual weeds, the late seeding was hand-weeded July 5. Stands were treated with an insecticide to control leafhoppers on August 11 and 25 and September 10.

The harvested area was 6.1 m^2 per plot. Fresh weight yields were converted to dry matter yields of pure alfalfa. A 1000 g fresh weight sample per plot was oven-dried with forced air for 36 hours at 70 C for percentage dry matter. The weed separation sample size was 1000 grams per plot. All yields of alfalfa and weeds are expressed on a weed-free, dry matter basis based on hand separation of all samples.

Roots were counted and root dry weight determination in the top 15 cm of soil was made in the first cutting in each seeding method and cutting frequency. Root samples were taken on 60 cm per row in a total of three directed sampling areas per plot in four replicates. Roots were counted, dry weight determined, and saved for total non-structural carbohydrate (TNC) analysis after the last harvest on October 2 in the 2-cutting and on October 27 in the 3-cutting treatments. Samples of 15 to 20 roots for late fall determinations of TNC were dug on November 26 for all treatments. Roots were washed in tap water after digging, top growth removed at the junction of the stem and root, trimmed to a length of 15 cm, and dried for one hour in a forced air drier at 100 C to stop enzymatic action. Drying was completed at 70^{o} C for 23 hours and samples ground to pass a 0.6 m sieve, and redried at 70^{o} C before analysis.

In order to determine dry matter distribution of roots in the soil, roots were sampled in the top 90 cm of soil on April 10, 1972, the year after seeding. A tractor-powered hydraulic soil sampler with a 10-cm diameter tube 152 cm long was used to obtain three 30-cm root sections. Samples consisted of two cores per plot for each of three replicates. All roots were washed and dried for 24 hours at 70^{o} C. Root weights were reported as dry matter.

Summer seedings, 1971

Summer seedings were made in three of the four replicates described in the spring seedings. Seeding establishment was similar in all respects to spring seedings except for the following differences:

Seeding dates	early - July 31, 1971
	medium - August 13, 1971
	late - August 27, 1971
Variety	Saranac only

Broadleaved weeds were controlled with 1.1 kg/ha of 2,4-DB one month after seeding. No harvests were made in 1971 on these seedings in contrast to 1971 spring seedings which were harvested in 1971. The year after seeding was the first harvest year. Yields are reported on a weed-free, dry matter basis.

Determinations in 1972 on 1971 seedings

In the spring of 1972, in the year after seeding, plots were fertilized with 700 kg/ha 0-14-42. Four cuttings were made on June 3, July 20, August 21 and October 26. Insects were controlled with insecticide on June 4, June 20, July 10, July 24, and August 25. Roots were counted and dry weights determined on October 28 in the spring-seeded plots only. The sample size was the same as in the seeding year. Dry matter yields, percent weeds, and dry weights of roots were determined as in the seeding year.

B. Experiment II spring seeded in 1972

Experiment II was established in 1972 about 0.5 km west of experiment I on a well-drained, fertile Conover loam soil with pH 6.8, (Figure 1). Four hundred kg/ha of 0-14-42 fertilizer were band-seeded with the alfalfa. The germination of seed of both varieties was adjusted to

100% germination and seeding rates were adjusted as described in Experiment I. The early seeding date was delayed until April 27 due to rainy weather. The split-plot design included seeding dates in the main plot, irrigation treatments in subplots, varieties in sub-subplots, cutting treatments in the next split, and seven seeding rates, completely randomized, in final plots. The seeding rate of 1.1 kg/ha included in Experiment I was omitted but seeding rates of 13.5 and 22.5 kg/ha were added. Irrigated blocks were sprinkler irrigated with 5 cm water on July 28 and August 15.

Herbicides were applied to the early seeding on May 27 and to the late seeding on June 16. Stands were sprayed to control leafhoppers on June 20, July 10, August 10 and 25. Dry matter yields, percent weeds, and dry weight of roots were determined and are reported as in 1971. Roots were sampled in each cutting for determinations of TNC during the seeding year. The sample size was 20 roots per plot. Numbers of roots and dry weights of roots in the top 15 cm of soil were sampled in the last cutting in the fall. The sample size as 0.325 m^2, a total of two 90-cm lengths of row in two areas per plot in four replicates. Roots used for dry weight determinations were also used for *Phytophthora* root rot studies.

The specific experimental plan and variables were as follows:

1. Field plan

Plot design	:	split-split-split-split plot with four replicates
Randomization	:	complete
Plot size	:	1.58 x 6.6 m
Rows	:	9 rows per plot, 17.5 cm apart
Drill	:	fertilizer-grain drill with legume band seeder

Figure 1. Herbicide-treated spring seedings in 1972 (Exp. II).

Fertilization : 400 kg/ha, 0-14-42 at seeding
Harvest area : 0,9 x 5.7 m (5 middle rows)

2. Variables

Seeding times : early seeding - April 27, 1972
late seeding - May 19, 1972

Irrigation treatments : irrigated, 5 cm each on July 28 and August 15
: nonirrigated. Rainfall was 56 cm between April 1 and October 31

Varieties : Saranac
: Vernal

Cutting treatments : early seeding, 2 cuttings (Aug. 1, Oct. 10)
: late seeding, 2 cuttings (Aug. 4, Oct. 10)
: early seeding, 3 cuttings (July 18, Aug. 31, Oct. 20)
: late seeding, 3 cuttings (July 26, Sept. 6, Oct. 20)

Seeding rates, kg/ha : 2.2 - 108 seeds per m^2
: 4.5 - 216 seeds per m^2
: 9.0 - 432 seeds per m^2
: 13.5 - 648 seeds per m^2
: 18.0 - 864 seeds per m^2
: 22.5 - 1080 seeds per m^2
: 36.0 - 1724 seeds per m^2

Disease symptoms observed in September on roots of 1972 spring-seeded alfalfa were caused by Phytophthora megasperma Drechs. Positive identification was made by the Department of Pathology at Michigan State University. Roots were sampled in October, 1972. Samples of 0.325 m^2 per plot from each of three replicates were obtained on all combinations of the following: early and late seeding, irrigation and nonirrigation, Vernal and Saranac varieties, two and three cuttings in 1972, and seven seeding rates--2.2, 4.5., 9.0, 13.5, 18.0, 22.5 and 36.0 kg/ha. After washing, the roots were classified into four cetegories, Figure 2, as follows based on a classification reported by

Figure 2. Phytophthora root rot symptoms in four classes: (1) healthy plants, (2) slight to moderate lesions anywhere on the root, (3) severe lesions early in the year with new adventitious roots appearing, (4) severe lesions, with remainder of roots 2.5 to 5.0 cm long.


3


4

Barnes et al. in the 1972 North Central area alfalfa test reports (Minnesota):

1. No lesions.

2. Slight to moderate lesions, blackish, anywhere on root.

3. (a) Severe lesions, many earlier in year and new adventitious roots appearing or above dead area.

   (b) Roots may be severed.

   (c) Very likely will live over winter.

4. (a) Severe lesions, roots severed by lesions.

   (b) Roots mostly 1-2 inches long after severing, some 2-3 inches long.

   (c) Probably will not survive winter.

Classification 5 used in the Minnesota study was dead plants which were not classified in this study since an initial number of plants per unit area was not determined.

A disease value representing all four studied disease classifications was calculated as follows:

$$\bar{y} = \frac{\Sigma\ fi\ Yi}{\Sigma\ fi}$$

where $\bar{y}$ - disease value representing all four categories

fi - number of roots in each of four categories

Yi - categories one to four

Σ fi - total number of plants in four disease categories

Laboratory Studies

A. Total nonstructural carbohydrates (TNC)

Samples prepared as described earlier were obtained from two replications. Total nonstructural carbohydrates were determined as follows by using a modified Weinman method as described by Smith (37): A 100-mg dry matter sample was weighed into 125 ml Erlenmeyer flask. About 15 ml distilled water was added followed by 1 to 2 minutes boiling to gelatinize starches. After cooling to room temperature, 10 ml of buffer solution containing three volumes 0.2 N acetic acid solution, two volumes acetic acid solution, and 10 ml 0.5% takadiatase enzyme solution were added to the flasks. The flasks were stoppered and incubated for 44 hours at 38 C. After incubation, the solution was filtered through Whatman No. 1 filter paper and diluted to a volume of 250 ml.

The Nelson-Somogyi photometric method (26, 38) was used for determination of reducing sugars. A 1-ml aliquot was pipetted into a test tube followed by 1 ml copper-carbonate-tartrate reagent described by Somogyi (38). Solutions were mixed thoroughly and the test tubes were covered by marbles and boiled for 20 minutes in a waterbath. After cooling to room temperature, 1 ml arsenomolybdate color reagent was added, Nelson (26). When the reaction was complete, the solution was diluted with distilled water to 25 ml and colorimetric measurements made with a Bausch and Lomb colorimeter by using a wavelength of 500 mu.

A reagent blank, enzyme blank, and two sugar standards adjusted to the dilution factor were included in the sugar determination.

Calculation formulas used were:

$$\text{TNC mg/ml} = \frac{y - b}{a} = X$$

$$a = \frac{\dfrac{(\text{sugar std 1 OD}}{\text{std1 mg/ml}} + \dfrac{\text{sugar std 2 OD})}{\text{std 2 mg/ml}}}{2}$$

$$\%\ TNC = \frac{X \times \text{dil. factor}}{\text{sample weight}} \times 100$$

where y = optical density (OD) of sample

b = optical density of enzyme blank

a = conversion factor, OD per mg sugar in ml of solution.

B. In vitro dry matter dry disappearance (IVDMD)

A two stage *in vitro* rumen fermentation technique was used to determine the dry matter disappearance (digestability) in alfalfa. Determinations were made on (1) 1971 spring and summer seedings harvested in 1972 and (2) 1972 spring seedings harvested two or three times in 1972.

Representative samples of each treatment were obtained in each of the cuttings in two replicates. After drying at 70 C for 24 hours, samples were ground to pass through a 0.6 mm sieve. The partially opened bottled samples were dried for six hours at 70 C prior to analysis.

A modified Tilly and Terry (46) *in vitro* fermentation technique was used. Duplicate samples each about 250 mg in size were weighed into 50-ml centrifuge tubes followed by the addition of two 7.5-ml portions of buffer solution. Between adding the buffer, the contents were mixed to saturate the substrate. The sides of the tube were washed down with the second portion of the buffer. The tubes were incubated at 39 C for 30 minutes before 10 ml of a mixture of equal parts of buffer solution and rumen fluid were added. The tubes were flushed with CO_2, stoppered immediately with a rubber stopper containing a bunsen valve, and incubated at 39 C for 48 hours. The tubes were gently rotated 2, 4, 20, and 28 hours after initiation of incubation to disperse the forage particles.

After 48 hours incubation, all samples were acified by adding 1 ml 6 N HCL to each tube, mixed, and 0.5 ml pepsin solution containing 20 g pepsin (1:10000) in 100 ml H_2O was added. Samples were incubated at 39 C for 48 hours without stoppers. After 48 hours incubation, the contents were filtered through previously dry-weighed Whatman No. 54 filter paper, oven dried for 24 hours, and the dry matter residue was determined.

Incubated blanks and a known standard were included in the fermentation process. In vitro dry matter disappearance (IVDMD) was calculated as follows:

$$\text{IVDMD\%} = \frac{100 \times \text{sample wt DM} - (\text{residual DM} - \text{incubated blank DM})}{\text{sample weight DM}}$$

The reagents used were a buffer-nutrient solution (Kansas State Buffer) made from part A, which consists of 10.0 g KH_2PO_4 + 0.5 g $MgSO_4$ 7 H_2O + 0.5 g NaCl + 0.1 g $CaCl_2 \cdot 2\ H_2O$ + 0.5 g Urea dissolved in 1 liter distilled water and part B including 15.0 g Na_2CO_3 + 1.0 g $Na_2S \cdot 9\ H_2O$ dissolved in 100 ml distilled water. Just prior to use, 20 ml of solution B was added to 1 liter of prewarmed solution A to obtain pH 6.8. If needed, necessary pH adjustments were made.

RESULTS AND DISCUSSION

I. Yields, Population and Root Studies

A. Seeding Year Yields

Experiment I

Yields of Individual Cuttings

Seeding-year yields of spring-seeded alfalfa are presented in Table 1. Weather conditions favoring early-spring seeding were excellent and the seeding was made early permitting an excellent comparison between early- (April 10) and late- (May 9) seeding dates. Weather and soil conditions were favorable during the summer for high yields.

The first cut of the 3-cutting system of alfalfa seeded early on April 10 was harvested on July 9. Yields increased gradually with increasing seeding rates. Saranac yields increased up to the 18-kg/ha rate whereas Vernal yields increased up to the 36-kg rate but the yield increase above 4.5 kg/ha with Vernal and 9.0 kg/ha with Saranac was minor. Saranac yielded 0.19 mt/ha more than Vernal.

The first cutting of the 3-cutting system of the late seeding yielded 1.37 mt/ha less than with the early seeding. Yields increased up to the 36-kg/ha seeding rate for Saranac and 18-kg/rate for Vernal. Saranac and Vernal produced similar yields.

Table 1. Seeding-year weed-free yields in metric tons per hectare of early- and late-seeded, herbicide-treated Vernal and Saranac alfalfa seeded at six rates and cut two or three times in 1971 (Exp. I).

Variety	Seeding rate, kg/ha	3-Cutting				2-Cutting			Avg. cuts
		Cut 1	Cut 2	Cut 3	Total	Cut 1	Cut 2	Total	
				Early Seeding					
Saranac	1.1	2.22	2.24	1.28	5.74a	1.60	1.85	3.45a	4.60a
	2.2	2.60	2.30	1.20	6.09a	3.17	1.90	5.07b	5.58b
	4.5	3.76	3.24	1.45	8.45b	3.97	2.40	6.37c	7.41c
	9.0	3.93	3.33	1.45	8.71b	4.82	2.35	7.16c	7.93c
	18.0	4.46	3.11	1.48	9.05b	4.58	1.85	6.43c	7.74c
	36.0	4.43	3.09	1.36	8.88b	4.55	1.84	6.39c	7.64c
	Avg.	3.58	2.88	1.37	7.82	3.78	2.03	5.81	6.82
Vernal	1.1	1.99	1.76	1.05	4.80a	2.03	1.59	3.62a	4.21a
	2.2	2.83	2.29	1.14	6.26b	3.12	1.92	5.04b	5.65b
	4.5	3.14	2.42	1.15	6.70bc	3.35	1.96	5.31b	6.01b
	9.0	3.97	2.67	1.17	7.81cd	4.64	2.05	6.69c	7.25c
	18.0	4.10	2.75	1.15	7.99d	4.89	1.95	6.84c	7.42c
	36.0	4.33	2.62	1.04	7.99d	4.68	1.94	6.82c	7.40c
	Avg.	3.39	2.42	1.11	6.92	3.82	1.50	5.62	6.32
Average, early		3.48	2.65	1.24	7.37	3.80	1.97	5.77	6.57
				Late Seeding					
Saranac	1.1	1.19	1.73	1.15	4.07a	1.93	1.56	3.49a	3.78a
	2.2	1.60	2.27	1.50	5.37b	2.39	1.86	4.25ab	4.81b
	4.5	1.78	2.50	1.61	5.89b	2.66	1.80	4.46ab	5.18b
	9.0	2.48	2.70	1.68	6.86c	3.19	2.04	5.23bc	6.04c
	18.0	2.57	2.54	1.64	6.75c	3.54	2.09	5.63c	6.19c
	36.0	2.86	2.37	1.51	6.75c	3.72	1.90	5.62c	6.18c
	Avg.	2.08	2.35	1.51	5.95	2.91	1.88	4.78	5.36
Vernal	1.1	.92	1.81	1.16	3.89a	2.05	1.59	3.63a	3.76a
	2.2	1.50	2.13	1.36	4.99a	2.15	1.91	4.06ab	4.52a
	4.5	2.25	2.65	1.52	6.42b	3.02	1.80	4.82bc	5.62b
	9.0	2.52	2.67	1.47	6.66b	3.39	1.87	5.26c	5.96b
	18.0	2.80	2.64	1.43	6.86b	3.57	1.98	5.55c	6.21b
	36.0	2.83	2.57	1.42	6.82b	3.64	1.78	5.42c	6.12b
	Avg.	2.14	2.41	1.39	5.85	2.97	1.82	4.79	5.37
Average, late		2.11	2.38	1.45	5.94	2.94	1.85	4.79	5.35
Average, dates		2.79	2.52	1.35	6.65	3.36	1.91	5.28	5.96

LSD .05, Differences between total yields: 0.66 = cutting treatments; 0.94 = cutting at the same level of date; 0.34 = varieties at the same level of date.

Means within columns for a given variety and for a given seeding date with the same letter are not significantly different.

The first cutting of the 2-cut system of the early seeding was harvested on July 20, eleven days later than the first cut of the 3-cutting system. This extra growing time yielded only 0.2 tons more than was obtained eleven days earlier. Leaf loss of the older leaves was observed during the period in the 2-cutting system similar to results reported by Fuess and Tesar (15). Saranac increased in yield up to the seeding rate of 9 kg/ha while Vernal showed a slight increase up to 18 kg/ha. Vernal and Saranac yields were similar.

Late-seeded Saranac and Vernal in the 2-cutting system cut for the first-time on August 4 had a growing period 11 days shorter than when seeded early. The average yield of all seeding rates of both varieties was 0.86 tons less than with early seeding. Yields increased up to the seeding rate of 36 kg/ha with both varieties which had similar yields.

The greatest differences in yield between seeding rates occurred in the first cutting with both seeding dates as shown above. Small differences were noted between low and high seed rates in the second cutting of the 3-cut system. In the last cutting of the 2- or 3-cut systems, there was practically no difference between seeding rates above the 2.2-kg/ha rate since the few existing plants at this seed rate were large enough to utilize the soil moisture and radiation to a maximum. Plants from the lowest seed rate, however, were not dense enough to equal yields of the alfalfa in the more densely populated plots.

Total Seeding Year Yields

Combined variety results of seeding year yields, Figure 3, show that alfalfa harvested three times was higher yielding at every seeding rate than when cut twice. Yields of early-seeded alfalfa cut three times during the seeding year, Figure 3, were higher than late seedings at all seed rates. A seeding rate of 9 kg/ha was adequate for the maximum yield in both early and late seedings with either cutting system.

Seeding-year yields averaged 1.22 mt/ha (6.57 vs 5.35) more in the early than in the late seeding, Table 1. The three-cut system yielded relatively more than the two-cut system in the early than in the late seeding, probably because the more frequent cuttings had longer cutting intervals with early-seeded alfalfa. Varieties reacted similarly to the two cutting systems. Late seeded alfalfa cut three times yielded 26.2% more than when cut twice. Yield differences between 3- and 2-cut systems were similar for the early and late seedings, ranging between 24 and 27% increases favoring the 3-cut system.

Saranac seeded early and cut three times yielded more than any other treatment, indicating that maximum yield under this relatively new system of alfalfa establishment can be achieved when a combination of management factors--highest yielding variety, early establishment, and an intensive 3-cut system--are utilized. When seeded late or cut two times, the two varieties yielded the same, again indicating that the maximum yield of the potentially highest yielding variety will not be expressed unless management factors of early seeding and intensive cutting are also incorporated into the management program.

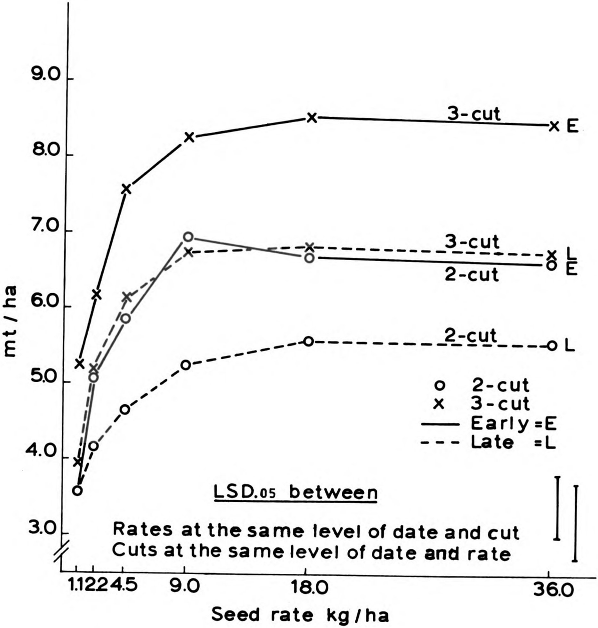


Figure 3. Average seeding year yields of early- and late-seeded alfalfa seeded at six rates and cut two or three times in 1971 (Exp. I).

Saranac yielded 13% more than Vernal alfalfa for the average of all seeding rates which is consistent with its 10% greater yield in Michigan, (42). Saranac and Vernal in the early seeding under the 2-cutting system reached the maximum yield level at seed rates of 4.5 and 9.0 kg/ha, respectively. Late-seeded Saranac and Vernal harvested two or three times increased in yields up to a seeding rate of 9 kg/ha.

Experiment II

Yields of Individual Cuttings

A late spring and weed competition attributable to poor weed control characterized spring seedings in 1972, Table 2, with the result that yield levels were considerably lower than in 1971, Tables 1 and 2. The first cut of alfalfa, seeded as early in the spring of 1972 as weather conditions permitted (April 27), and harvested two or three times in the seeding years yielded 0.84 and 0.90 mt/ha less, respectively, than in 1971 seedings. First-cut yields of late- and early-seeded alfalfa were 0.17 and 0.98 lower, respectively, in the two-cut system in 1972 than in 1971.

Yields in the first cut of early-seeded alfalfa in the 3-cut system increased up to 13.5 to 18.0 kg/ha. Saranac had 53% weeds in the first cutting while Vernal had 42%. When seeded late, the 3-cut treatment increased up to the 13.5-kg/ha seed rate with either variety. There was an indication of a slight yield increase of 0.2 mt/ha as the rate increased to 18 kg/ha but the increase was not significant.

Table 2. Seeding-year yields in weed-free metric tons per hectare of early- and late-seeded, herbicide-treated Vernal and Saranac alfalfa seeded at seven rates, irrigated or nonirrigated and cut two or three times in 1972 (Exp. II).

Variety	Seeding Rate kg/ha	Early Seeding 3-Cutting Cut 1	Cut 2	Cut 3	Total	Early Seeding 2-Cutting Cut 1	Cut 2	Total	Late Seeding 3-Cutting Cut 1	Cut 2	Cut 3	Total	Late Seeding 2-Cutting Cut 1	Cut 2	Total	Totals, Avg. Cuts Seeding Early	Late	Avg.
									Irrigated (I)									
Saranac	2.2	.77	.98	.72	2.47a	1.02	1.72	2.74a	.67	1.02	.52	2.21a	.56	1.47	2.03a	2.61a	2.12a	2.37a
	4.5	.95	1.13	.84	2.92a	1.11	2.29	3.40a	.71	1.22	.71	2.64a	1.27	1.85	3.12b	3.16a	2.89b	3.03b
	9.0	1.55	1.74	.99	4.28b	1.34	2.33	3.67a	1.34	1.64	.78	3.76b	1.32	1.88	3.20b	3.98b	3.48bd	3.73c
	13.5	2.03	2.34	1.18	5.55c	2.72	2.74	5.46b	1.82	1.74	.81	4.37b	1.91	2.06	3.97b	5.51c	4.17c	4.84d
	18.0	2.21	2.36	1.19	5.76c	2.86	2.55	5.41b	1.56	1.59	.77	3.92b	1.87	2.17	4.04b	5.59c	3.98cd	4.78d
	22.5	2.02	2.48	1.24	5.74	3.08	2.46	5.54b	1.39	1.70	.74	3.83b	1.92	2.05	3.97b	5.65c	3.90cd	4.77d
	36.0	2.17	2.33	1.10	5.60c	2.95	2.50	5.45b	1.28	1.84	.70	3.82b	2.11	1.91	4.02b	5.53c	3.91cd	4.72d
	Avg.	1.67	1.91	1.04	4.62	2.15	2.37	4.53	1.25	1.53	.72	3.50	1.56	1.91	3.48	4.58	3.49	4.03
Vernal	2.2	1.23	1.17	.51	2.91a	1.01	1.54	2.55a	1.05	.98	.44	2.47a	.76	1.37	2.13a	2.73a	2.30a	2.52a
	4.5	1.44	1.24	.58	3.26a	1.69	1.78	3.47ab	1.61	1.55	.55	3.71b	1.39	1.79	3.18b	3.36a	3.44b	3.40b
	9.0	2.34	1.84	.73	4.91b	2.58	1.78	4.36b	1.68	1.62	.55	3.85b	2.03	1.90	3.93bc	4.63b	3.90b	4.26c
	13.5	2.76	2.15	.85	5.76bc	3.48	1.97	5.45c	2.48	1.90	.53	5.01c	2.23	1.94	4.17bc	5.61c	4.59bc	5.10d
	18.0	3.06	2.23	.79	6.08c	3.63	2.00	5.63c	2.36	2.14	.74	5.24c	2.86	1.80	4.66c	5.86c	4.95c	5.40d
	22.5	2.92	2.26	.84	6.02c	3.74	1.92	5.66c	2.42	2.33	.76	5.51c	2.65	1.93	4.58c	5.84c	5.05c	5.44d
	36.0	2.75	2.23	.86	5.84c	3.86	1.90	5.76c	2.37	2.21	.72	5.30c	2.74	1.95	4.69c	5.80c	4.99c	5.40d
	Avg.	2.36	1.87	.74	4.97	2.85	1.84	4.70	2.00	1.82	.63	4.44	2.09	1.81	3.90	4.83	4.17	4.50
Average, I		2.02	1.89	.89	4.80	2.50	2.11	4.62	1.63	1.68	.68	3.99	1.83	1.86	3.69	4.71	3.83	4.27
									Nonirrigated (NI)									
Saranac	2.2	.43	1.00	.91	2.34a	1.03	1.80	2.83a	.67	1.10	.79	2.56a	.90	1.87	2.77a	2.59a	2.67a	2.62a
	4.5	1.46	2.17	1.28	4.91b	1.21	2.02	3.23a	1.00	1.51	1.11	3.62b	.96	2.17	3.13a	4.07b	3.37a	3.73b
	9.0	1.46	2.51	1.52	5.49bc	1.46	2.10	3.56a	1.89	1.91	1.27	5.07c	1.95	2.45	4.40b	4.52b	4.74b	4.63c
	13.5	1.62	2.88	1.56	6.06c	2.43	2.36	4.79b	1.88	2.13	1.86	5.17c	2.65	2.45	5.11b	5.43c	5.15b	5.29d
	18.0	1.62	2.92	1.54	6.08c	2.44	2.46	4.90b	1.83	2.22	1.30	5.35c	2.66	2.46	5.12b	5.49c	5.24b	5.36d
	22.5	1.53	2.88	1.55	5.96c	2.47	2.38	4.85b	1.97	2.13	1.25	5.35c	2.90	2.44	5.34b	5.40c	5.34b	5.37d
	36.0	1.72	2.88	1.54	6.14c	2.55	2.27	4.82b	2.09	2.10	1.23	5.42c	2.69	2.42	5.11b	5.48c	5.27b	5.37d
	Avg.	1.40	2.46	1.42	5.28	1.94	2.19	4.14	1.62	1.87	1.16	4.65	2.10	2.32	4.43	4.71	4.54	4.63
Vernal	2.2	.36	.98	.61	1.95a	.68	1.20	1.88a	.66	1.43	.51	2.60a	1.25	1.42	2.67a	1.92a	2.63a	2.28a
	4.5	1.85	1.81	1.01	4.67b	1.61	1.68	3.29b	.75	1.54	.73	3.02a	1.24	1.57	2.81a	3.97b	2.91a	3.45b
	9.0	2.31	2.44	1.16	5.91c	2.67	2.04	4.71c	1.35	1.93	.86	4.14b	1.77	1.79	3.56ab	5.31c	3.84b	4.58c
	13.5	2.68	2.72	1.15	6.55c	3.10	2.05	5.15c	2.15	2.03	1.04	5.22c	2.15	1.83	3.98b	5.85c	4.59c	5.22d
	18.0	2.52	2.80	1.33	6.65c	3.28	2.01	5.29c	2.40	2.47	1.04	5.91c	3.10	2.21	5.31b	5.97c	5.61c	5.79d
	22.5	2.43	2.74	1.25	6.47c	3.33	2.01	5.34c	2.46	2.26	.96	5.68c	2.59	1.79	4.38b	5.71c	5.03c	5.46d
	36.0	2.37	2.72	1.16	6.25c	3.30	1.79	5.09c	2.58	2.13	.93	5.64c	2.51	1.74	4.25b	5.67b	4.95c	5.31d
	Avg.	2.08	2.31	1.09	5.49	2.57	1.82	4.40	1.76	1.97	.87	4.59	2.09	1.76	3.85	4.94	4.22	4.58
Average, NI		1.74	2.39	1.26	5.39	2.26	2.01	4.27	1.69	1.92	1.02	4.62	2.10	2.04	4.14	4.83	4.38	4.61
Average, I and NI		1.88	2.14	1.08	5.10	2.38	2.06	4.44	1.66	1.80	.85	4.31	1.97	1.95	3.92	4.77	4.11	4.44

LSD differences between total yields: Dates, NS; Irrigation treatments, NS; Varieties, NS; Cuts=0.33 (Significant at 1% level); Cuts at the same level of date = 0.47 (Significant at 5% level); Cuts at the same level of irrigation = 0.47 (Significant at 5% level).
Means within columns for a given variety and for a given seeding date with the same letter are not significantly different.

In the first harvest of the 2-cut system in both early and late seedings, the 13.5-kg seed rate appeared to be adequate for maximum yield, although a slight increase in yields beyond this seed rate was observed. Since all treatments were irrigated for the first time on July 28, the irrigation had little or no influence on the yield from the first cuts. In the second cut of the 3-cut system, early-seeded nonirrigated plots produced 0.5 mt/ha more yield than irrigated plots. In late-seeded plots, the yield difference was 0.24 ton in favor of no irrigation. This result can probably be explained by Phytophthora root rot which was severe under irrigation (Part IV).

Seeding rates for maximum yield in the second cut averaged 13.5 kg/ha in the early-seeded systems. With late seedings of Saranac, the rates were 9 and 13.5 kg/ha for irrigated and nonirrigated, respectively, while 18 kg/ha produced the maximum yield under both conditions with Vernal.

In the last cut of the 2-cutting systems, Saranac yielded slightly more than Vernal with no difference between seeding dates. The second irrigation made on August 15 had no positive effect on yield results because of above normal rainfall in the growing season.

The final cut in the 3-cutting system produced a greater yield of 0.40 tons without irrigation for the early seeding and 0.34 tons more for late seeding with no difference between varieties. Early seeding yielded slighly more than late seeding. Seed rates for maximum yield were 9.0 to 13.5 kg/ha.

Total seeding year yield

Seeding year total yields, Table 2, produced no statistically significant difference between early and late seeding since the experimental split-plot design is not precise in measuring differences in the first split which is "dates of seeding." However, the yield difference of 0.66 mt/ha for early over late seeding was large enough to indicate the superiority of early seeding as in Experiment I. Irrigated yielded 0.34 tons less than nonirrigated treatments which will be related to the greater incidence of disease (Part IV).

The yield difference favoring three over two cuttings was 0.73 tons for early seeding and 0.52 tons for late seeding, again similar to Experiment I. The average yield of alfalfa cut three times was 13 percent greater than when cut twice, significant at the 1% level.

Alfalfa seeded early or late, cut three times or twice, under irrigated or nonirrigated conditions increased in yield up to a rate of 13.5 kg/ha with a few exceptions where the maximum yield was at the 9 kg rate.

Combined variety results, Figure 4, illustrate the main conclusions clearly. Irrigated treatments resulted in lower yields than with no irrigation when the alfalfa was cut three times, a condition which is probably related to greater incidence of *Phytophthora* root rot which is prevalent under wet soil according to Frosheiser (14). Under irrigation, yields increased up to 13.5 kg/ha of seed with all treatments. Three cuttings produced only slightly greater yields than two cuttings. Early seeding produced higher yields than late seeding at rates of 13.5 kg/ha or more. When not irrigated, three cuttings

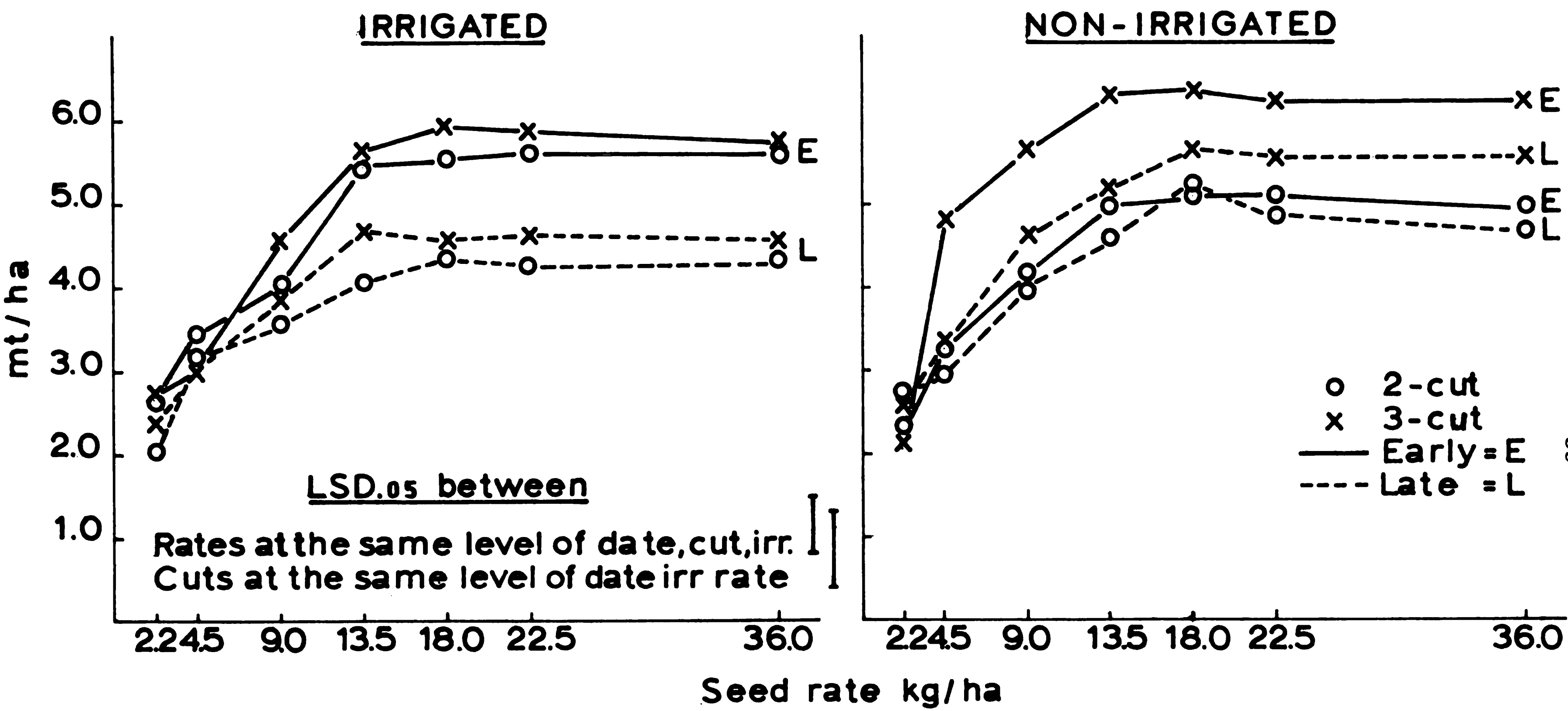


Figure 4. Seeding year yields in metric tons per hectare of early- and late-seeded alfalfa seeded at seven rates and cut two or three times in 1972 (Exp. II).

produced considerably more than two cuttings under both early and late dates of seeding. Yields in most instances increased up to the 13.5 kg/ha-seed rate for both dates of seeding and frequencies of cutting and then showed no further increase.

Seeding Year Yields in Experiments I and II

The seeding year of 1971 was characterized by an early, favorable spring, while the spring of 1972 was late, rainy and cool. A 17-day delay in the early seeding in 1972 compared to the early seeding date in 1971 produced a lower total average yield of 1.81 mt/ha in 1972. In the late seeding, a 10-day delay from the late-seeding date in 1971 resulted in 1.25 tons less yield in 1972 than in 1971. Saranac's yield reduction due to weed and disease problems was 1.77 mt/ha compared to a 1.30 ton reduction in Vernal.

Weeds played an important role in the first cuttings in both years but were extremely competitive in early seedings in 1972 because of poor weed control. In the first experiment in 1971, weeds comprised 24% of the total yield in Saranac in the first cutting. Early-seeded alfalfa had 20% weeds in the first cut of three cuttings and 31% in the first cut of the 2-cut system made later. For the 1972 year, early seedings had 50% weeds in the first cut compared to 36% in late seedings. In Experiment II, both cutting systems had the same amount of weeds--42%. In both experiments Saranac had more weeds than Vernal, 47 versus 38%.

The amount of seed required for maximum yield in Experiment I was less than in Experiment II, Tables 1 and 2, primarily because of better seedling emergences and better weed control, earlier seeding favoring alfalfa more than broad-leaved weeds, and no detected *Phytophthora* root rot which was prevalent in the second experiment.

Since there was little difference in the varieties relative to seed rates in Table 1 and 2, an average of the varieties will be used for comparing seeding rates in the two years. In the first experiment, Figure 3, yields increased up to the 9-kg/ha rate and then generally levelled off. Some increase was noted up to the 18-kg rate in two cases. In contrast, yields in the second experiment, Figure 4, increased up to the 18-kg rate with or without irrigation. Yields were higher without irrigation in all comparisons in the second experiment.

B. Yields in the Year after Seeding, Experiment I

Yields in the year after seedings established in regular spring seedings made with oats as a companion crop or seeded alone in summer generally yield equally well the next year, Tesar and Jackobs (42). Yields of summer seedings were compared to spring seedings with herbicides to determine relative yields in the year after seeding.

Yields of the spring seedings in Experiment I were obtained in four standard cuttings in the next year. Results are reported in Table 3 and Figure 5. Yields in the year after seeding showed that there was a significantly greater yield of 0.36 mt/ha after early seeding on April 10 compared to seeding late on May 9, Table 3. Most of the difference favoring the early seeding was in the first cutting

Table 3. Second-year (1972) yields in mt/ha of 1971 spring-seeded herbicide-treated Saranac and Vernal alfalfa seeded at six rates, two seeding dates, cut two or three times in the seeding year and four times in 1972 (Exp. I).

Variety	Seeding Rate kg/ha	Dry Matter, mt/ha										Avg. Cuts
		2-Cuttings					3-Cuttings					
		Cut 1	Cut 2	Cut 3	Cut 4	Total	Cut 1	Cut 2	Cut 3	Cut 4	Total	
						Early Seeding						
Saranac	1.1	3.74	4.41	2.35	2.04	12.55a	3.56	4.36	2.44	2.09	12.44a	12.49a
	2.2	3.77	4.78	2.47	2.07	13.09b	4.04	4.96	2.42	2.20	13.62ab	13.35b
	4.5	4.20	5.49	2.98	2.41	15.08c	4.25	5.57	2.91	2.35	15.08c	15.08c
	9.0	4.43	5.56	2.92	2.62	15.54c	4.73	5.34	3.09	2.69	15.85c	15.69c
	18.0	4.41	5.43	2.96	2.65	15.45c	4.48	5.09	2.93	2.53	15.03c	15.24c
	36.0	4.07	5.35	2.90	2.68	15.00c	4.19	4.95	3.04	2.51	14.68bc	14.84c
	Avg.	4.11	5.17	2.76	2.41	14.45	4.20	5.04	2.80	2.39	14.45	14.45
Vernal	1.1	3.51	4.22	2.50	1.29	11.52a	3.63	4.46	2.23	1.72	12.03a	11.78a
	2.2	3.93	4.63	2.38	1.55	12.50ab	4.09	4.50	2.51	1.88	12.97ab	12.74b
	4.5	4.31	4.78	2.37	1.71	13.17bc	4.13	4.97	2.96	1.93	14.00b	13.59c
	9.0	4.42	4.83	2.70	1.97	13.92c	4.40	4.95	2.88	1.94	14.17b	14.05c
	18.0	4.68	4.59	2.60	1.84	13.70bc	4.38	4.69	2.89	1.92	13.88b	13.80c
	36.0	4.24	4.59	2.56	1.80	13.20bc	4.39	4.40	2.91	1.72	13.42b	13.31bc
	Avg.	4.18	4.60	2.52	1.70	13.01	4.17	4.66	2.73	1.85	13.41	13.21
						Late Seeding						
Saranac	1.1	3.01	4.16	2.10	1.95	11.21a	3.20	4.81	2.11	1.89	12.02a	11.62a
	2.2	3.29	4.74	2.23	1.98	12.23ab	3.39	4.88	2.40	2.21	12.87ab	12.55b
	4.5	3.34	4.97	2.40	2.24	12.94b	3.51	5.20	2.80	2.34	13.86b	13.40b
	9.0	4.12	5.39	2.85	2.41	14.77c	4.40	5.36	3.17	2.48	15.42c	15.10c
	18.0	4.09	5.40	3.03	2.74	15.27c	4.44	5.44	3.15	2.61	15.64c	15.46c
	36.0	3.89	4.96	3.08	2.55	14.48c	4.31	5.42	3.14	2.59	15.46c	14.98c
	Avg.	3.62	4.94	2.62	2.31	13.48	3.88	5.18	2.80	2.35	14.21	13.85
Vernal	1.1	3.84	4.10	1.89	1.33	10.08a	3.57	4.34	2.03	1.73	11.68	10.88a
	2.2	3.72	4.39	2.20	1.79	12.09b	3.74	4.66	2.35	1.77	12.52ab	12.31b
	4.5	3.87	4.68	2.60	1.83	12.98bc	4.13	5.01	2.57	2.02	12.73ab	13.36c
	9.0	3.92	4.93	2.62	1.95	13.42c	4.21	4.81	2.65	2.15	13.82bc	13.62cd
	18.0	3.94	4.94	2.71	2.01	13.61c	4.45	5.37	2.76	2.28	14.86c	14.24d
	36.0	3.80	4.76	2.62	1.83	13.00bc	4.14	4.80	2.52	2.23	13.69bc	13.35cd
	Avg.	3.69	4.61	2.44	1.79	12.53	4.04	4.83	2.49	2.03	13.58	12.96
						Average, Dates, Varieties						
All	1.1	3.28	4.20	2.21	1.66	11.34a	3.49	4.49	2.20	1.86	12.04a	11.69a
	2.2	3.68	4.63	2.32	1.85	12.48b	3.81	4.75	2.42	2.02	12.99b	12.74b
	4.5	3.93	4.98	2.59	2.05	13.54c	4.01	5.19	2.81	2.16	14.17c	13.86c
	9.0	4.22	5.18	2.78	2.24	14.42d	4.44	5.12	2.95	2.31	14.82d	14.62d
	18.0	4.28	5.09	2.82	2.31	14.51d	4.44	5.15	2.93	2.33	14.86d	14.68d
	36.0	4.00	4.92	2.79	2.22	13.92d	4.26	4.98	2.90	2.26	14.31cd	14.12d
	Avg.	3.90	4.83	2.58	2.05	13.37	4.07	4.93	2.70	2.16	13.87	13.62

LSD .05 between total yields: dates, 0.28; cuts, 0.52; varieties, 0.25. Varieties at the same level of date and cut 0.49.

Means within columns for a given variety and for a given seeding date with the same letter are not significantly different.

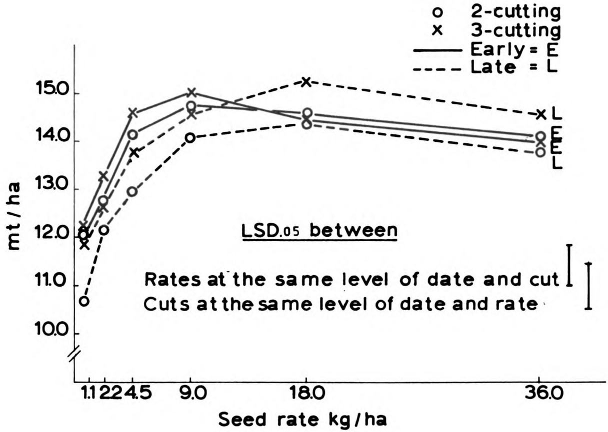


Figure 5. Second-year yields of 1971 early and late spring-seeded alfalfa seeded at six rates and cut two or three times in 1971 and four times in the year after seeding in 1972 (Exp. I).

which was significantly higher in yield than late-seeded alfalfa. Yields in the last three cuttings were similar.

Yields in the year after seeding were similar when cut twice or three times in the previous year, Table 3 and Figure 5. A slight increase of 0.1 ton in each of the four cuts of the 3-cut over the 2-cut system indicated no harmful effect of the three cutting system.

For the average of all treatments of varieties, seeding dates, and frequency of cutting in the first year, yields in the next year increased up to a seed rate of 9 kg/ha and then levelled off, Table 3 and Figure 5. There was an indication that late seedings were increasing in yield up to a seed rate of 18 kg/ha but the increase was not significant, Figure 5.

Saranac and Vernal reacted similarly in these residual yields to early and late seeding and two or three cuttings in the seeding year. Saranac yielded 1.07 tons more than Vernal.

Early, medium, and late summer seedings established in 1971 were cut four times in 1972. Late seedings yielded 1.3 tons less than early or medium seedings which had nearly identical yields, Table 4. The main advantage in yield of the earlier summer seedings was expressed in the greater yield of the first two cuttings. Late in the year, late-seeded alfalfa equalled early seedings in yield. Total yields increased up to the 9 kg/ha rate, Table 4 and Figure 6, and then levelled off.

Spring seeding with herbicides and summer seedings established at the recommened times in early to mid-August, (39), yielded similarly in the next year, Figure 6, indicating that alfalfa

Table 4. Yields in the year after seeding of Saranac alfalfa, summer-seeded in 1971 at three different dates and six seeding rates and harvested four times in 1972 (Exp. 1).

Seeding Rate kg/ha	DM, mt/ha				
	Cut 1	Cut 2	Cut 3	Cut 4	Total
			Early Seeding (July 31)		
1.1	2.09	3.21	1.73	1.23	8.26a
2.2	2.57	3.60	2.29	1.60	10.06a
4.5	3.57	4.88	2.63	2.15	13.24b
9.0	4.13	5.13	2.90	2.48	14.64bc
18.0	5.08	4.94	2.99	2.47	15.49c
36.0	4.61	5.15	3.13	2.34	15.23c
Avg.	3.67	4.86	2.61	2.05	12.83
			Medium Seeding (Aug. 13)		
1.1	1.96	3.63	2.23	1.63	9.47a
2.2	2.49	3.98	2.29	1.80	10.57a
4.5	3.36	4.96	2.57	2.25	13.13b
9.0	3.51	5.10	2.80	2.45	13.86bc
18.0	4.14	5.30	3.12	2.34	14.19bc
36.0	4.22	5.34	3.23	2.57	15.37c
Avg.	3.28	4.72	2.70	2.17	12.88
			Late Seeding (Aug. 27)		
1.1	1.49	2.78	1.92	1.61	7.81a
2.2	2.32	3.78	2.37	2.04	10.51b
4.5	2.43	4.12	2.62	2.18	11.34b
9.0	3.61	4.58	2.63	2.46	13.28c
18.0	3.38	4.52	2.64	2.59	13.13c
36.0	2.88	4.67	2.90	2.67	13.14c
Avg.	2.68	4.08	2.51	2.26	11.54
			Average, Seeding Dates		
1.1	1.85	3.21	1.97	1.49	8.51a
2.2	2.46	3.79	2.32	1.82	10.38b
4.5	3.12	4.65	2.61	2.19	12.57c
9.0	3.75	4.94	2.78	2.46	13.93d
18.0	4.20	4.92	2.92	2.47	14.51d
36.0	3.90	5.06	3.09	2.53	14.58d
Avg.	3.21	4.43	2.62	2.16	12.41

LSD .05 between totals: dates NS.

Means within column for a given variety and for a given seeding date with the same letter are not significantly different.

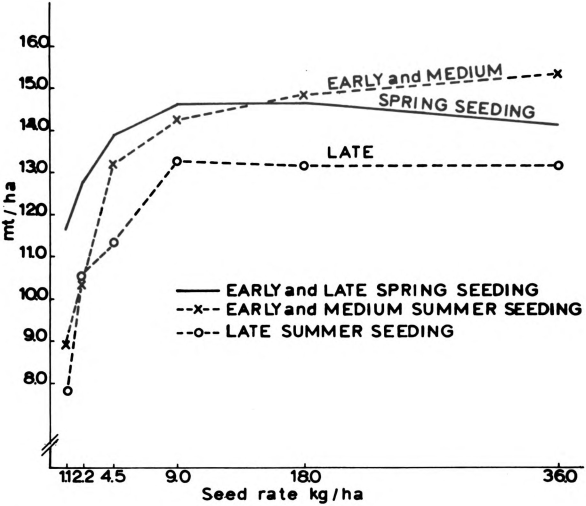


Figure 6. Average yields of early and late spring-seeded early and medium summer-seeded and late summer-seeded alfalfa at six seeding rates when harvested four times the year after seeding in 1972.

established by the new system of treating spring seedings with herbicides with no companion crop is not injured appreciably by cutting in the seeding year. Furthermore, cutting three times in the seeding year is not appreciably more severe on the alfalfa than cutting twice. The maximum production in the year after seeding was obtained at the 9-kg/ha rate for both spring and summer seedings.

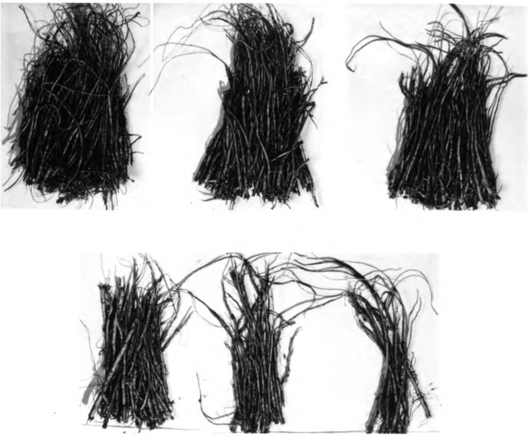


Figure 7. Alfalfa roots of five seeding rates from 1.1 to 36.0 kg/ha representing unit area of 0.278 m^2 in the first cut on July 20 in 1971 (Exp. I).

C. Population and Root Studies

Experiment I

Plants per unit area in the seeding year

Studies were conducted in the fall of 1971 to observe the above-below ground relationships of alfalfa in the seeding year and in the year after seeding. Results are presented in Table 5 and Figure 8.

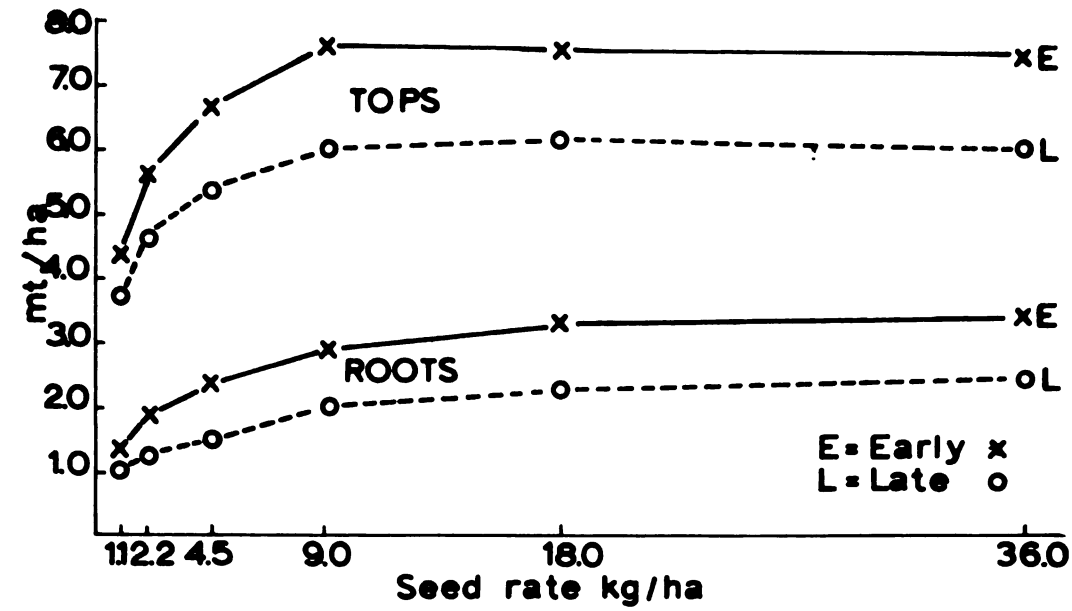
Cutting two or three times had no significant effect on the number of alfalfa plants/m^2 in the fall of the cuttings. There was a significant difference, however, between the early seeding with an average of 351 plants/m^2 and the late seeding (216 plants). This difference was likely due to a better seedling emergence and a higher percent of establishment with the early seedings. Vernal had more plants in the fall but this may have been due, again, to a higher percent of establishment since the number of viable seeds planted per unit area as the same within any seed rate.

A significant interaction showed that Saranac with higher seeding rates of 18 or 36 kg/ha had a lower survival of seedlings between first cutting and fall sampling than Vernal. A similar interaction was found between seeding dates and rates, i.e., higher seeding rates of 18 or 36 kg/ha produced a lower survival of seedlings in the late seeding than in the early seeding. This detrimental effect was not evident with lower seeding rates.

Table 5. Plants per square meter of spring-seeding alfalfa in fall in the year of seeding and in the fall of the year after seeding (Exp. 1).

Variety	Seeding Rate kg/ha	Cuttings per Year: 3-Cut Fall 1971	3-Cut Fall 1972	2-Cut Fall 1971	2-Cut Fall 1972	Average Fall 1971	Average Fall 1972	Average % 72/71
				Early Seeding				
Saranac	1.1	40	40	39	39	40	40	100
	2.2	88	80	82	70	85	75	88
	4.5	174	168	151	93	163	131	80
	9.0	362	253	285	178	324	216	67
	18.0	595	217	557	273	576	245	42
	36.0	790	325	872	312	831	319	38
	Avg.	342	181	331	161	337	171	50.7
Vernal	1.1	44	31	52	35	48	33	69
	2.2	85	80	98	98	95	84	88
	4.5	172	142	159	134	172	138	80
	9.0	335	239	318	201	327	220	67
	18.0	531	285	608	269	570	277	48
	36.0	979	295	996	406	988	351	35
	Avg.	358	179	372	191	365	185	50.6
Average, early		350	180	352	176	351	178	51
				Late Seeding				
Saranac	1.1	30	27	36	32	33	30	61
	2.2	47	31	67	40	57	35	61
	4.5	89	92	114	92	102	92	90
	9.0	219	113	177	120	198	117	59
	18.0	418	235	324	225	371	230	61
	36.0	452	240	423	238	438	239	54
	Avg.	209	123	190	125	200	124	62.0
Vernal	1.1	31	27	26	26	29	27	93
	2.2	53	50	50	47	52	46	74
	4.5	99	92	133	114	116	103	89
	9.0	205	159	243	212	224	186	83
	18.0	307	234	398	221	353	228	64
	36.0	610	297	596	248	603	273	45
	Avg.	220	142	240	145	231	143	61.9
Average, late		215	131	216	135	216	133	62
Average, dates		283	156	284	156	284	156	54

LSD between:	1971	1972
Dates	116.5*	38.7**
Cuts	NS	NS
Varieties	26.7*	18.5*



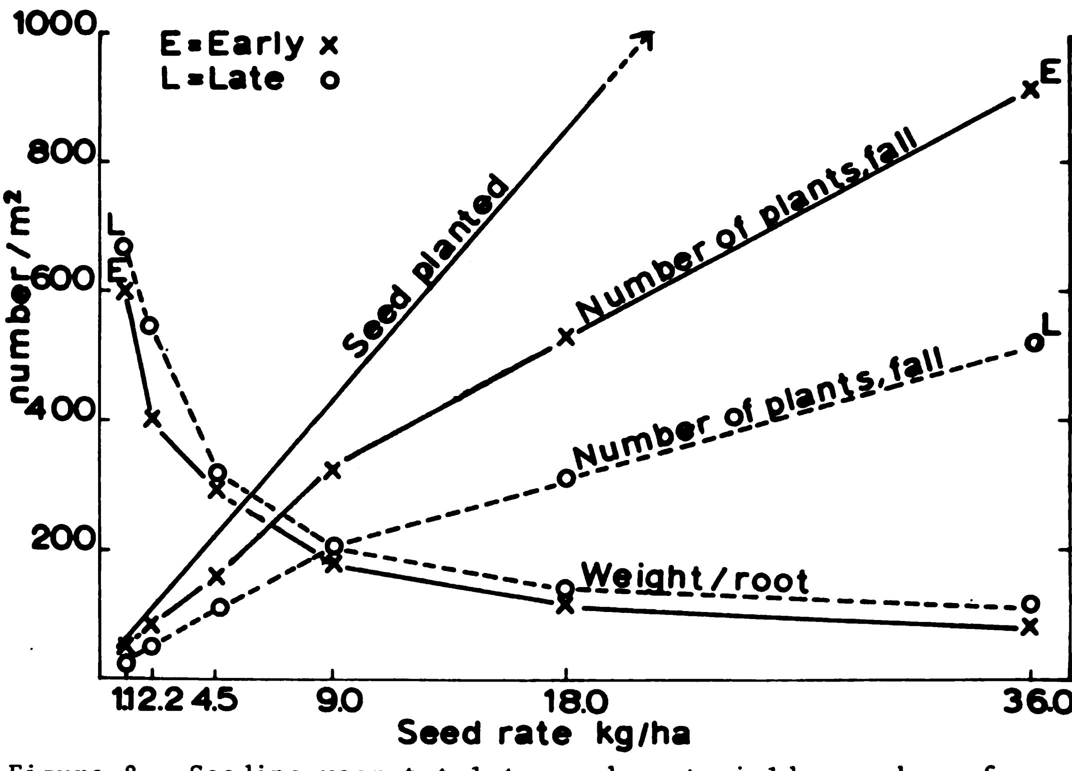


Figure 8. Seeding year total top and root yields, number of plants/m^2 and root weight, g/root, of early and late spring-seeded alfalfa at six seeding rates harvested in 1971 (Exp. I).

The number of plants/m^2 increased as the seed rate increased linearly up to the 9 kg/ha rate and then linearly to the 36-kg/ha rate, Figure 8. As an average of early and late seedings, there were about 40 plants at the 1.1-kg/ha rate with increasing numbers to 877 plants/m^2 at the 36-kg/ha rate, Figure 7. The number of plants/m^2 at the 9 kg/ha seeding rate which produced the maximum forage yield was 268 over all treatments of cutting and seeding date, Figure 8. This number was adequate for maximum yield in the seeding year with both early and late seedings. Accurate correlations of numbers of plants of early and late seedings with yields is not possible since the length of the growing period favored the early seeding which, in fact, was significantly higher in yield than late seedings as shown earlier in Table 1.

The reduction in root number between the earliest sampling in the first cutting in July and the end of the season after the last cutting was similar for early and late seedings, Table 8 and Figure 8. Early seedings had 89% and late seedings had 78% as many seedings in late October as in the first cutting, Table 8. Decreases in root number were 7% at the 1.1 kg seeding rate for all treatments and 18% at the 36-kg rate.

Weight per root in the seeding year

The weight in grams/root is presented in Table 6 and Figure 8. As the number of plants per unit area increased with increasing seed rates, weight per root dropped in both sampling dates. Early seeding resulted in greater emergence than late seeding but the weight per root in the late seeding was equal or higher to that in the early seeding,

Table 6. Weight per root in grams (15 cm) of alfalfa spring seeded in 1971 and sampled in the fall of the seeding year and in the fall the year after seeding (Exp. I).

Variety	Seeding Rate kg/ha	Cuttings per Year: 3-Cutting Fall 1971	3-Cutting Fall 1972	2-Cutting Fall 1971	2-Cutting Fall 1972	Average Cuts Fall 1971	Average Cuts Fall 1972
		Oct. 26		Oct. 26			
				Early Seeding			
Saranac	1.1	3.95	6.50	2.56	6.57	3.26	6.54
	2.2	2.53	4.83	1.80	5.41	2.17	5.12
	4.5	1.58	3.15	1.66	3.37	1.62	3.26
	9.0	.87	1.72	.98	2.24	.93	1.98
	18.0	.60	2.04	.57	1.62	.59	1.83
	36.0	.41	1.34	.39	1.56	.40	1.45
	Avg.	1.66	3.26	1.33	3.46	1.50	3.36
Vernal	1.1	3.01	7.64	3.13	6.87	3.07	7.26
	2.2	2.27	4.08	2.02	4.03	2.24	4.21
	4.5	1.29	2.75	1.40	2.50	1.35	2.63
	9.0	.84	1.70	.95	1.65	.90	1.68
	18.0	.57	1.67	.59	1.38	.58	1.53
	36.0	.38	1.27	.37	1.07	.38	1.17
	Avg.	1.39	3.19	1.41	2.92	1.42	3.08
Average, early		1.53	3.22	1.37	3.19	1.46	3.20
				Late Seeding			
Saranac	1.1	3.64	6.41	3.08	7.89	3.36	7.15
	2.2	2.53	6.93	2.41	4.86	2.47	5.90
	4.5	1.63	3.74	1.52	4.25	1.58	4.00
	9.0	.98	3.07	1.00	3.10	.99	3.09
	18.0	.70	2.06	.70	2.14	.70	2.10
	36.0	.65	2.05	.54	1.71	.60	1.88
	Avg.	1.69	4.04	1.54	3.99	1.62	4.02
Vernal	1.1	3.80	6.38	2.92	5.76	3.05	6.07
	2.2	2.86	6.25	2.98	6.12	2.92	6.19
	4.5	1.69	4.19	1.62	3.91	1.66	4.05
	9.0	1.39	2.70	1.01	2.06	1.20	2.38
	18.0	.84	1.75	.69	1.95	.77	1.85
	36.0	.54	1.39	.51	1.62	.53	1.51
	Avg.	1.85	3.78	1.62	3.57	1.69	3.68
Average, late		1.77	3.91	1.58	3.78	1.66	3.85
Average, dates		1.65	3.58	1.48	3.49	1.56	3.54

LSD between:	1971	1972
Dates	NS	.54*
Cuts	.17*	NS
Varieties	NS	NS

Figure 8, probably because of less competition for moisture and nutrients.

A comparison of the average weight per root at the time of the first cutting in July or early August over all levels of cutting, varieties, and cutting frequency with the fall weight shows a three-fold increase from 0.50 to 1.56 grams per root, Table 8. In a similar comparison of seeding rates, roots from low seed rates increased four-fold in weights whereas the increase was only doubled at the highest seed rate indicating increasing competition with higher seed rates.

Root yields in the seeding year

Root yields per unit area are presented in Table 7. The root yields were influenced more by the number of plants per unit area than by the weight per root, which was similar for all treatments except seeding rates. Accordingly, early seeding produced significantly higher root yields than did the late seeding primarily because of larger populations. No significant difference in root yields between Vernal and Saranac was observed. Fewer plants in late seedings at the higher seeding rates of 18 and 36 kg/ha, Table 7, resulted in less total root production. Root yields in the 2- and 3-cutting systems were the same. Total root weights doubled between mid-summer and fall at the 36-kg rate but showed a four-fold increase at the 1.1 kg rate, Table 8.

Table 7. Dry matter yields of roots (15 cm) in metric tons per hectare of spring-seeded alfalfa when sampled in the fall of the seeding year and in the fall year after seeding (Exp. I).

Variety	Seeding Rate kg/ha	Cuttings per Year					
		3-Cutting		2-Cutting		Average Cuts	
		Fall 1971	Fall 1972	Fall 1971	Fall 1972	Fall 1971	Fall 1972
				Early Seeding			
Saranac	1.1	1.60	2.74	.96	2.57	1.28	2.66
	2.2	2.11	3.77	1.81	3.81	1.50	3.85
	4.5	2.72	3.86	2.39	3.20	2.56	3.53
	9.0	3.08	4.32	2.79	3.70	2.94	4.01
	18.0	3.51	4.03	3.03	4.41	3.27	4.22
	36.0	3.11	4.32	3.20	4.53	3.16	4.43
	Avg.	2.69	3.84	2.31	3.71	2.50	3.77
Vernal	1.1	1.35	2.42	1.60	2.43	1.48	2.43
	2.2	1.94	3.26	1.98	3.90	1.96	3.58
	4.5	2.20	3.53	2.13	3.10	2.17	3.32
	9.0	2.80	3.81	2.84	3.06	2.82	3.44
	18.0	3.00	3.98	3.04	3.65	3.02	3.81
	36.0	3.70	3.98	3.62	4.06	3.66	4.02
	Avg.	2.50	3.50	2.62	3.40	2.56	3.45
Average, early		2.60	3.67	2.47	3.56	2.53	3.61
				Late Seeding			
Saranac	1.1	1.07	1.75	1.05	2.50	1.06	2.13
	2.2	1.18	2.03	1.39	3.04	1.29	2.54
	4.5	1.68	2.94	1.56	3.74	1.62	3.34
	9.0	2.08	3.15	1.63	3.45	1.86	3.30
	18.0	2.60	4.71	1.92	4.46	2.26	4.59
	36.0	2.52	4.91	2.08	4.02	2.30	4.47
	Avg.	1.78	3.81	1.61	3.53	1.70	3.40
Vernal	1.1	1.24	2.60	.72	2.27	.98	2.44
	2.2	1.27	3.20	1.28	2.82	1.27	3.01
	4.5	1.50	3.74	1.75	3.64	1.63	3.69
	9.0	2.02	3.87	2.41	4.32	2.22	4.10
	18.0	2.46	3.87	2.35	4.15	2.41	4.01
	36.0	2.48	3.98	2.72	3.97	2.60	3.98
	Avg.	1.83	3.54	1.87	3.53	1.85	3.54
Average, late		1.81	3.68	1.74	3.53	1.78	3.62
Average, dates		2.21	3.68	2.11	3.54	2.16	3.62

LSD between:	1971	1972
Dates	.69**	NS
Cuts	.16*	NS
Varieties	NS	NS

Table 8. Relative percentage of plants/m^2, g/root, and dry matter (DM) of roots at the first cutting in July or early August and in the fall of the year of seeding and in the fall of the following year, average of early and late seedings cut two or three times in 1971 (Exp. I).

Seeding Rate kg/ha	Plants/m^2			g/root			DM roots		
	Cut 1 1971	Fall 1971	Fall 1972	Cut 1 1971	Fall 1971	Fall 1972	Cut 1 1971	Fall 1971	Fall 1972
					Saranac				
1.1	100	90	88	100	404	834	100	337	774
2.2	100	93	72	100	314	744	100	287	589
4.5	100	82	70	100	291	660	100	275	453
9.0	100	96	61	100	253	668	100	247	377
18.0	100	88	44	100	237	726	100	240	383
36.0	100	78	34	100	250	830	100	186	305
					Vernal				
1.1	100	96	77	100	364	793	100	473	938
2.2	100	97	88	100	374	754	100	245	500
4.5	100	94	78	100	278	619	100	243	449
9.0	100	86	64	100	269	521	100	233	349
18.0	100	85	46	100	212	528	100	182	262
36.0	100	85	33	100	242	705	100	193	247
					Average				
1.1	100	93	82	100	383	813	100	429	864
2.2	100	96	83	100	340	744	100	263	540
4.5	100	88	74	100	287	644	100	260	451
9.0	100	91	62	100	263	600	100	241	364
18.0	100	86	45	100	220	607	100	208	314
36.0	100	82	34	100	240	750	100	190	274
Avg.	100	85	46	100	312	708	100	236	389

Root distribution after first year

Alfalfa roots were sampled with a hydraulically operated tractor mounted soil core sampler (10-cm diameter) in the spring following the seeding year to determine the distribution of roots in various seeding-year treatments. Data are presented in Table 9.

The main observation was that roots were concentrated mostly in the upper 30 cm which contained 79% of the total dry matter of the roots. Fifteen percent were in the 30- to 60-cm zone, and 7% in the 60- to 90-cm zone. The vertical distribution of roots was more evenly distributed in early than in late seedings. This was probably result of the more advanced growth stage and the better-developed root system of the early seedings. The same trend was found in a variety comparison which showed that Vernal had more evenly distributed yields of roots all the way down to 90 cm in both early and late seeding. This observation can be due partly to the denser population of Vernal. There was no difference in root distribution between 2- and 3-cutting systems.

Lower seeding rates had a more uniform root distribution in the upper 90 cm of soil than higher seeding rates in which the main part of the root dry matter was in the top 30 cm. For example, the average root distribution at the 1.1-kg/ha rate were 73, 18 and 9% in the 0- to 30-, 31- to 60-, and 61- to 90-cm zones, and 82, 13 and 4%, respectively, at the 36-kg rate. This indicates that alfalfa seeded at lower seed rates may have deeper roots than at higher seed rates but this was not confirmed except that every few roots were found below the 90-cm zone one year after establishment in any treatment.

Year after seeding density
and root studies

Root density results in the fall of the year after seeding are presented in Tables 5 and 8. Roots were sampled in the fall of the second year to observe the residual effects of the seeding year treatments and the development of roots during the second year when the plants were harvested four times.

The main observation in these plant density studies was that 3-cuttings did not hurt the plants during the seeding year since the number of the surviving plants in the fall of the second year was similar between 2 and 3 cuttings. The trend between seeding dates, observed in the fall of the seeding year, continued in the fall of the second harvest year since the number of plants in early seedings was significantly higher than in late seedings. Early seedings had 51% and late seedings had 62% as many plants as at the time of the first cutting in the previous year, Table 5.

Reduction in plant density was greatest at the highest seeding rates and was lowest at lowest seeding rates during the first winter and second growing season. This is shown by comparing plant numbers in the first cutting of the previous year where seedings at the 1.1-kg/ha rate had 81% as many plants as at the 36-kg rate which had only 46% as many plants as in the fall of the second year, Table 8.

Results on weight per root in the year after seeding are presented in Tables 6 and 8. As a result of a lower plant density in the seeding year, roots in the late seeding (3.68 g/root) were significantly larger than roots in the early seeding (3.08 g/root) in the

Table 9. Percentage distribution of roots in the top 90 cm in the spring following the seeding year of two varieties seeded at six rates, and two seeding dates and harvested two or three times in the seeding year (Exp. I).

Variety	Seeding Rate kg/ha	3-Cut 0-30	3-Cut 31-60	3-Cut 61-90	2-Cut 0-30	2-Cut 31-60	2-Cut 61-90	Avg. Cuttings 0-30	Avg. Cuttings 31-60	Avg. Cuttings 61-90
		cm below root crown								
					Early Seeding					
Saranac	1.1	73.7	14.7	11.6	79.4	14.2	6.4	76.6	14.5	9.0
	2.2	75.3	12.9	11.8	79.0	14.3	6.7	77.2	13.6	9.3
	4.5	76.6	13.3	10.1	78.2	12.2	9.6	77.4	12.8	9.8
	9.0	82.9	13.4	3.7	78.5	12.7	8.8	80.7	13.1	6.5
	18.0	82.7	13.8	3.5	78.7	13.7	7.6	80.7	13.8	5.6
	36.0	83.9	12.6	3.5	79.4	14.8	5.8	81.7	13.7	4.7
	Avg.	79.2	13.5	7.3	78.9	13.7	7.4	79.1	13.6	7.3
Vernal	1.1	69.7	22.1	8.2	70.9	18.9	10.2	70.3	20.5	9.2
	2.2	71.1	21.1	7.8	70.6	18.4	11.0	70.9	19.8	9.3
	4.5	76.5	17.2	6.3	75.1	18.1	6.8	75.8	17.7	6.6
	9.0	78.4	16.0	5.6	77.0	16.3	6.7	77.7	16.2	6.2
	18.0	79.6	15.0	5.4	78.3	16.0	5.7	79.0	15.5	5.6
	36.0	80.2	14.5	5.3	79.9	15.7	4.4	80.1	15.1	4.9
	Avg.	75.9	17.7	6.4	75.3	17.2	7.5	75.6	17.5	6.9
					Late Seeding					
Saranac	1.1	76.0	13.1	10.9	70.4	20.9	8.7	73.2	17.0	9.8
	2.2	82.3	10.6	7.1	81.7	11.2	7.1	82.0	10.9	7.1
	4.5	82.0	12.2	5.8	82.0	12.4	5.6	82.0	12.3	5.7
	9.0	82.0	12.4	5.7	82.0	12.9	5.1	82.0	12.6	5.4
	18.0	83.1	12.9	4.0	83.1	12.5	4.4	83.1	12.7	4.2
	36.0	84.6	13.7	1.6	83.9	11.7	4.4	84.3	12.7	3.0
	Avg.	81.7	12.5	5.9	80.5	13.6	5.9	81.1	13.0	5.9
Vernal	1.1	76.2	17.2	6.6	69.9	20.7	9.4	73.1	19.0	8.0
	2.2	78.8	14.6	6.6	76.8	13.7	9.5	77.8	14.2	8.0
	4.5	80.3	15.0	4.7	78.1	12.3	9.6	79.2	13.7	7.1
	9.0	82.0	13.6	4.4	79.1	13.4	7.5	80.6	13.5	5.9
	18.0	82.6	13.2	4.2	81.6	12.4	6.0	82.1	12.8	5.1
	36.0	83.8	12.5	3.7	83.3	16.8	4.9	83.6	12.2	4.3
	Avg.	80.6	14.4	5.0	78.1	14.1	7.8	79.4	14.2	6.4
		Average, seeding dates and varieties						Avg., date, cut, variety		
Average	1.1	73.9	16.8	9.3	72.7	18.7	8.6	73.2	17.8	9.0
	2.2	76.9	14.8	8.3	77.0	14.4	8.6	77.0	14.6	8.4
	4.5	78.9	14.4	6.7	78.4	13.8	7.9	78.6	14.1	7.3
	9.0	81.3	13.9	4.8	79.2	13.8	7.0	80.3	13.9	6.0
	18.0	82.0	13.7	4.3	80.4	13.7	5.9	81.2	13.7	5.1
	36.0	83.1	13.3	3.6	81.6	13.5	4.9	82.4	13.4	4.2
	Avg.	79.4	14.5	6.1	78.2	14.7	7.1	78.8	14.6	6.6

fall of the second year. Neither varieties nor different cutting systems in the seeding year produced any differences in the weight per root in the second year. In seeding rate comparisons, Table 8, the lower seeding rates doubled the root size during the second growing season and, at the higher seeding rates, the increase was three times that observed in the first fall. The decrease in weight per root with fewer numbers of roots and increasing seeding rates is shown by the 1.1-kg/ha seeding rate which had roots four times as heavy as at the 36-kg rate.

Yields of roots in the fall of the second year are presented in Tables 7 and 8. There were no significant differences between varieties, seeding dates, or cutting frequencies in the seeding year on root yields in the following year. The root yields followed the trend found with top yields, both showing marked increases in production up to the 9-kg/ha rate and then levelling off. Root yields, however, increased gradually up to the maximum seeding rate of 36 kg/ha while forage yields in the first year increased only to the 9-kg rate.

Experiment II

Plant density data determined in the fall of the seeding year 1972 in Experiment II are presented in Table 10. As a result of a late spring, a growing season with above normal rainfall, and heavy weed competition, the reduction in plant density during the seeding year was considerably higher than in 1971.

Table 10. Plants/m^2 of alfalfa spring-seeded in 1972 and sampled in the fall of the seeding year (Exp. II).

Variety	Seeding Rate kg/ha	Irrigated 3-Cut	Irrigated 2-Cut	Nonirrigated 3-Cut	Nonirrigated 2-Cut	Ave. Cutt-ings
			Early Seeding			
Saranac	2.2	38	46	25	27	34
	4.5	54	92	81	58	71
	9.0	125	102	119	119	116
	13.5	132	200	182	189	175
	18.0	222	233	227	274	240
	22.5	314	320	338	321	324
	36.0	455	405	517	490	467
	Avg.	192	200	212	211	203
Vernal	2.2	39	41	35	36	38
	4.5	109	93	73	81	89
	9.0	130	138	135	163	142
	13.5	201	213	208	229	213
	18.0	311	314	304	301	307
	22.5	415	341	313	422	373
	36.0	506	624	544	478	538
	Avg.	245	252	231	244	243
Average, early		219	226	222	228	223
			Late Seeding			
Saranac	2.2	39	39	26	48	38
	4.5	70	61	74	88	73
	9.0	163	135	158	171	157
	13.5	212	175	223	232	210
	18.0	193	242	265	283	246
	22.5	298	253	401	350	325
	36.0	363	485	396	502	436
	Avg.	191	199	220	239	212
Vernal	2.2	43	36	35	32	37
	4.5	92	78	83	102	89
	9.0	172	155	159	209	174
	13.5	203	185	255	340	246
	18.0	324	317	328	388	339
	22.5	314	413	335	438	375
	36.0	382	474	603	534	489
	Avg.	219	237	257	292	251
Average, late		205	218	239	266	232
Average, dates		212	222	231	247	228

LSD between: Dates = NS; Irrigations = NS; Varieties, 27.9***; Cuttings = 15.4*.

The stand density in early- and late-seeded stands was similar. The reduction in stand density of Saranac was significantly higher than with Vernal when compared to the amount of seed planted. This was more evident when Saranac was irrigated and heavily infested with Phytophthora root rot.

As in Experiment I, there was no difference in the effect of cutting systems on plant population in the fall of the year, Table 10. The reduction in plant density was slightly higher when the early-seeded stand was irrigated and significantly higher when the late seeding was irrigated.

Plant density was much higher at the higher seeding rates, Table 10, especially in the late seeding. Irrigated treatments with high seeding rates were significantly lower at the 5% level than in nonirrigated plots. All these diffierences can be partly related to the disease problem to be discussed later.

Weights per root of spring seedings in Experiment II are presented in Table 11. Seeding dates and irrigation treatments did not produce any significant differences in weight of individual roots. Saranac had heavier roots than Vernal which was likely the result of fewer plants per unit area.

Roots were heavier at the 1% level in the 2- than in the 3-cut system. This can be partly a result of Phytophthora disease, but probably mostly the result of later planting dates in 1972 resulting in harvest periods shorter than necessary for three cuttings.

Weights per root decreased markedly from low to high seed rates with a five-fold decrease between seed rates of 2.2 and 3.6

Table 11. Weight per root in grams (15 cm) of alfalfa, spring-seeded in 1972 and sampled in the fall of the seeding year (Exp. II).

Variety	Seeding Rate kg/ha	Irrigated 3-Cut	Irrigated 2-Cut	Nonirrigated 3-Cut	Nonirrigated 2-Cut	Average Cuttings
			Early Seeding			
Saranac	2.2	1.49	1.79	2.03	2.29	1.90
	4.5	1.31	1.16	1.36	1.81	1.41
	9.0	.83	1.07	.85	1.15	.98
	13.5	.71	.74	.65	.96	.77
	18.0	.51	.58	.61	.62	.58
	22.5	.48	.56	.46	.52	.51
	36.0	.31	.40	.38	.40	.37
	Avg.	.81	.90	.91	1.11	.93
Vernal	2.2	1.28	1.48	1.63	2.06	1.61
	4.5	.90	1.06	1.08	1.57	1.18
	9.0	.98	.82	.90	1.06	.94
	13.5	.52	.95	.58	.81	.72
	18.0	.47	.57	.45	.58	.52
	22.5	.36	.55	.42	.42	.44
	36.0	.27	.38	.32	.37	.34
	Avg.	.68	.83	.79	.98	.82
Average, early		.74	.87	.85	1.04	.88
			Late Seeding			
Saranac	2.2	1.26	2.21	2.17	2.47	2.03
	4.5	.96	1.68	1.19	1.88	1.43
	9.0	.64	.98	.77	.97	.84
	13.5	.50	.94	.54	.76	.69
	18.0	.47	.81	.52	.72	.63
	22.5	.44	.63	.40	.59	.52
	36.0	.31	.37	.43	.40	.38
	Avg.	.65	1.09	.86	1.11	.93
Vernal	2.2	1.32	2.17	1.08	2.13	1.67
	4.5	.82	1.27	1.03	1.28	1.10
	9.0	.62	1.04	.58	.70	.73
	13.5	.56	.76	.51	.74	.64
	18.0	.43	.60	.45	.47	.49
	22.5	.51	.52	.37	.46	.47
	36.0	.36	.38	.25	.33	.33
	Avg.	.66	.96	.61	.87	.77
Average, late		.66	1.03	.74	.99	.85
Average, dates		.70	.95	.79	1.02	.87

LSD between: Dates = NS; Irrigations = NS; Varieties = .13***; Cuttings = .13***.

kg/ha. When irrigated, roots of plants in the lowest seeding rates were considerably smaller than when not irrigated.

The total yields of roots in the fall of the year are presented in Table 12. Total yields were similar between early or late seedings, varieties, or irrigation levels. Because seedings were made about two to three weeks later than normal, the 2-cutting system produced significantly higher yields than 3 cuttings. In the seeding rate comparison, root yields increased up to the seeding rate of 13.5 kg/ha, and then leveled off, paralleling yields of top growth which reached a maximum at the same rate, Table 2.

Comparisons between Experiment I and Experiment II

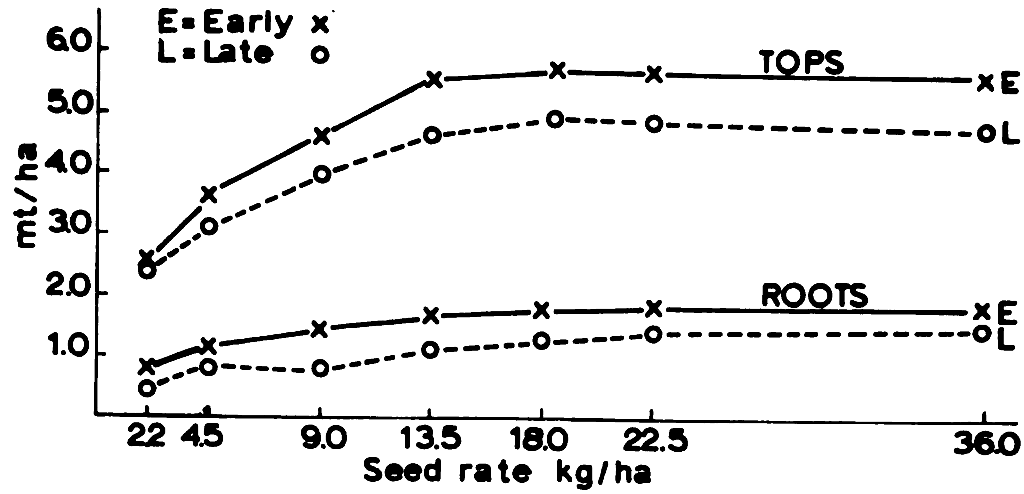
Combined variety and cutting frequency results obtained in the year of seeding in 1971, Figure 8, and in 1972, Figure 9, showed the forage yields and the root yields closely paralleled each other. Both increased up to a seed rate of 9 kg/ha in Experiment I and 13.5 kg in Experiment II which had poorer weed control, and, therefore, required more alfalfa plants to produce the maximum yield. Root weight and top growth did not increase above these rates indicating that the number of roots multiplied by root weight is constant for any rate of seeding beyond the maximum yield level. The ratio of top to roots was 164:100 in the first experiment and 338:100 in 1972.

In Figure 8, combined variety and cutting frequency results show in Experiment I that the number of plants in the fall was considerably higher in the early than late seeding which coincides with higher forage yields from early seeding. In both experiments, plant

Table 12. Dry matter yields of roots (15 cm) in metric tons per hectare of spring-seeded alfalfa when sampled in the fall in the seeding year in 1972 (Exp. II).

Variety	Seeding Rate kg/ha	Irrigated 3-Cut	Irrigated 2-Cut	Nonirrigated 3-Cut	Nonirrigated 2-Cut	Average Cutt-ings
			Early Seeding			
Saranac	2.2	.50	.82	.50	.60	.60
	4.5	.70	1.06	1.08	.97	.95
	9.0	1.04	1.09	1.00	1.38	1.13
	13.5	.93	1.47	1.18	1.65	1.31
	18.0	1.14	1.27	1.39	1.70	1.37
	22.5	1.41	1.77	1.45	1.65	1.57
	36.0	1.44	1.61	1.85	1.84	1.69
	Avg.	1.02	1.30	1.20	1.40	1.23
Vernal	2.2	.47	.75	.55	.80	.64
	4.5	1.00	.99	.85	1.27	1.03
	9.0	1.13	1.14	1.21	1.70	1.29
	13.5	1.04	1.56	1.19	1.78	1.39
	18.0	1.43	1.65	1.52	1.92	1.63
	22.5	1.49	1.81	1.29	1.73	1.58
	36.0	1.36	2.33	1.73	1.73	1.79
	Avg.	1.13	1.46	1.19	1.56	1.34
Average, early		1.08	1.38	1.20	1.48	1.28
			Late Seeding			
Saranac	2.2	.48	.84	.49	1.22	.76
	4.5	.66	1.00	.86	1.65	1.04
	9.0	1.02	1.35	1.20	1.77	1.34
	13.5	1.06	1.63	1.21	1.80	1.42
	18.0	.91	1.94	1.35	2.01	1.56
	22.5	1.30	1.58	1.58	2.04	1.63
	36.0	1.20	1.77	1.53	2.00	1.62
	Avg.	.95	1.44	1.17	1.79	1.34
Vernal	2.2	.55	.91	.46	.65	.64
	4.5	.77	.94	.84	1.33	.97
	9.0	1.07	1.59	.90	1.39	1.24
	13.5	1.10	1.41	1.26	1.92	1.42
	18.0	1.38	1.85	1.42	1.79	1.61
	22.5	1.56	1.95	1.23	2.01	1.63
	36.0	1.31	1.77	1.48	1.81	1.59
	Avg.	1.10	1.49	1.09	1.56	1.31
Average, late		1.03	1.47	1.13	1.67	1.33
Average, dates		1.06	1.43	1.17	1.57	1.31

LSD between: Dates = NS; Irrigations = NS; Varieties = NS; Cuttings = .15***.



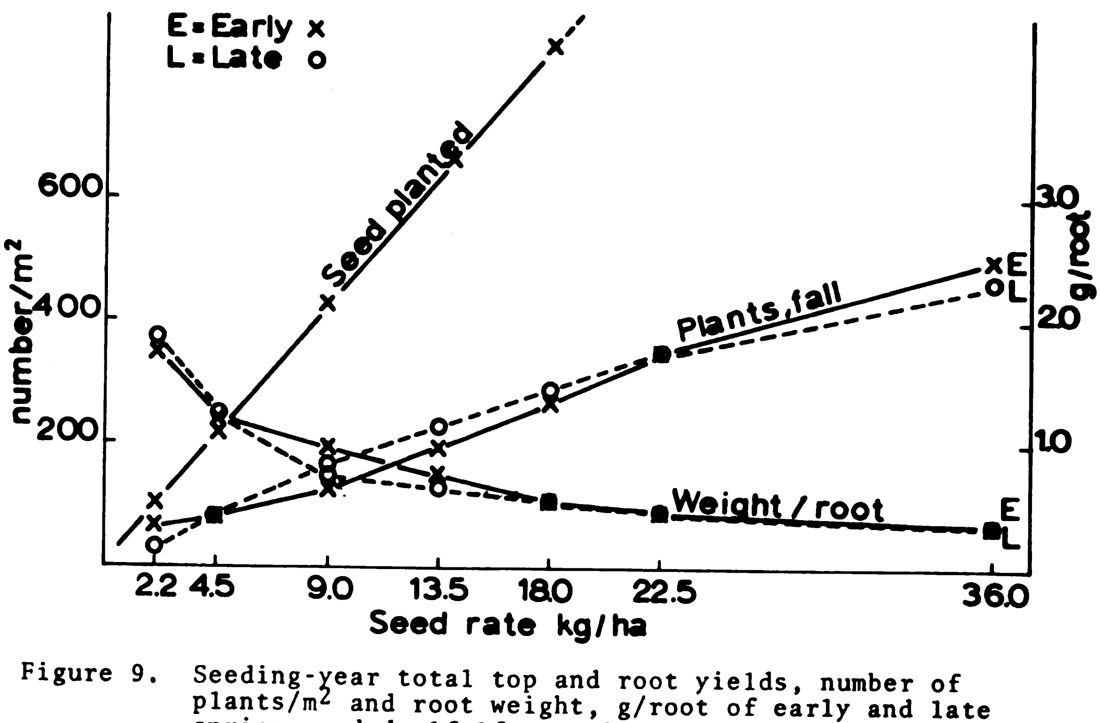


Figure 9. Seeding-year total top and root yields, number of plants/m^2 and root weight, g/root of early and late spring-seeded alfalfa at six seeding rates harvested in 1972 (Exp. II).

population increased almost linearly with increases in seed rate. As a result of fewer plants, the weight per root in late seedings was slightly higher than in early seedings at all seeding rates. In Experiment II, Figure 9, the number of plants surviving in the first fall was much lower than observed in 1971 and this coincided with lower forage yield in 1972 than in 1971. This was probably a result of the later establishment in both seeding dates because of a cool, rainy spring and above-normal rainfall during the growing season which also increased root rot disease on the fine-textured Conover loam soil. The number of plants surviving in the fall was almost identical between early and late seeding and similar to late seeding in 1971.

Weight per root in both years was very similar except that lower seeding rates in 1971 had heavier roots than in 1972, probably a result of more favorable growing conditions in the first experiment in 1971.

The plant density requirements in the first fall for maximum yield were high in 1971 with 325 plants per m^2 at the 9-kg/ha seeding rate in the early seeding and 210 plants in the late seeding. The percent survival in the early seeding from seed planted at the optimum 9-kg/ha rate was 75% which can be considered excellent, Tesar and Jackobs (42), and 49% in the late seeding which is considered good. In the second experiment in 1972, plant density requirements for the maximum yield at 13.5-kg/ha seeding rate were 194 plants m^2 in the early seeding and 228 plants m^2 in the late seeding. The survival percent of early seeding from the seeds planted was considered poor averaging 28% in the two seeding dates.

II. Total Nonstructural Carbohydrates

Experiment I

Total nonstructural carbohydrates (TNC) in the fall in roots of alfalfa spring-seeded in 1971 are presented in Table 13. High levels of TNC are generally associated with good survival of older established stands especially in cold climates according to Smith (36). However, there is no published information on TNC levels in spring-seeded alfalfa harvested during the year of seeding. The data in Table 12 show that levels of TNC averaged 44.9% in the roots of the last cutting on October 2 in a 2-cut system. Levels of TNC decreased only slightly--1.4%--as the seed rate increased from 1.1 to 36 kg/ha.

In the 3-cutting system sampled on October 28 in the third cutting, TNC averaged 43.9% compared to 44.9% in the second cutting of the 2-cutting system and were similar in early and late seedings and in the two varieties. As in the 2-cut system, TNC decreased only 1.2% as seed rates increased with very few exceptions.

In the late fall on November 26 after fall growth had stopped, roots from both cutting systems were analyzed to observe the effects of seeding year treatments on TNC in roots of alfalfa. Although there was a decline in percent TNC, since the last cuttings in October, TNC levels were high, near 37%. There were no differences in TNC levels attributable to dates of seeding or cutting frequencies so it can be concluded that managing seeding-year alfalfa under a high-yield system

Table 13. Total nonstructural carbohydrates of alfalfa roots in percent dry matter (DM) in 1971 spring seedings sampled in the last cutting and late fall, 1971 (Exp. I).

Variety	Seeding Rate kg/ha	Cuttings per Year 3-Cut Oct 28	3-Cut Nov 26	2-Cut Oct 2	2-Cut Nov 26	Av. Cut. Nov 26
		Percent	Percent	Percent	Percent	Percent
				Early Seeding		
Saranac	1.1	44.5	37.7	45.4	38.2	38.0a
	2.2	44.3	37.4	45.4	38.5	37.9ab
	4.5	44.0	37.0	46.1	38.4	37.7ab
	9.0	43.9	36.3	45.6	38.0	37.1bc
	18.0	43.7	35.8	44.9	37.7	36.8c
	36.0	42.6	35.9	44.6	37.0	36.4c
	Avg.	43.9	36.6	45.3	38.0	37.3
Vernal	1.1	44.2	37.1	44.9	37.8	37.5a
	2.2	44.0	37.0	44.9	37.9	37.4a
	4.5	43.9	36.5	45.4	36.7	36.6ab
	9.0	43.7	35.9	45.5	36.7	36.3b
	18.0	43.6	35.8	45.1	36.4	36.1bc
	36.0	43.2	35.0	44.8	35.8	35.4c
	Avg.	43.8	36.2	45.1	36.9	36.6
				Late Seeding		
Saranac	1.1	44.4	38.6	44.4	37.8	38.2a
	2.2	44.2	38.4	44.9	37.7	38.0a
	4.5	43.8	37.4	44.8	37.4	37.4ab
	9.0	43.7	37.3	45.6	36.2	36.7bc
	18.0	43.4	37.1	45.6	36.0	36.5c
	36.0	43.4	37.0	44.6	36.0	36.5c
	Avg.	43.8	37.6	45.1	36.9	37.2
Vernal	1.1	44.3	38.1	44.3	37.5	37.8a
	2.2	43.9	37.7	44.5	37.3	37.5ab
	4.5	43.8	37.3	45.6	37.3	37.3ab
	9.0	43.6	37.0	45.2	36.5	36.7bc
	18.0	43.4	36.5	44.1	36.2	36.3c
	36.0	43.1	36.2	43.7	35.6	35.9c
	Avg.	43.7	37.1	44.6	37.0	36.9
		Average, date and variety				Av. date, cut, variety
	1.1	44.3	37.9	44.8	37.8	37.6a
	2.2	44.1	37.6	44.9	37.8	37.7a
	4.5	43.9	37.0	45.4	37.4	37.2b
	9.0	43.7	36.6	45.5	36.8	36.7c
	18.0	43.5	36.3	44.9	36.6	36.4cd
	36.0	43.1	36.0	44.4	36.1	36.0d
	Avg.	43.8	36.9	44.9	37.0	36.9

LSD, Nov. 26, between: dates = NS; Cuts = NS; Varieties = NS. Means with the same letter are not significantly different at .05 level.

of early seeding and an intensive 3-cutting harvest system will not injure plants appreciably during the seeding year because the TNC levels in both cuttings systems were equal after fall growth had stopped. The next year's yields were similar in a uniform 4-cut system, Table 3, again indicating there were no residual effects due to any differences in the 2- or 3-cut system in the seeding year.

Levels of TNC declined slightly with few exceptions in every variety, cutting system, and date of seeding as seed rates increased from 1.1 to 36 kg/ha. The decline over all treatments was from 37.6 to 36.0% TNC which are levels adequate for excellent winter survival.

Experiment II

Levels of TNC at each cutting and in late fall in roots of alfalfa spring-seeded in Experiment II in 1972 are presented in Table 14. Levels of TNC showed that percentages were lowest when sampling began in the first cutting in summer and increased with each successive cutting in both the 2- and 3-cutting systems.

There was no difference in TNC levels between early- or late-seeded alfalfa in any cutting in either the two- or three-cut system. Levels of TNC in roots increased from 30.2% in cut 1 to 38.9% in cut 2 to 40.0% in cut 3. Levels in the first cut of the 2-cut system were higher than in the 3-cut system because of an approximately 2-week later sampling date. The first cut of the 2-cut system had 36.0 and the second cut had 44.4% TNC indicating that percent of TNC in roots of seedlings increases gradually during the summer season as

Table 14. Percentage total nonstructural carbohydrates in roots of early and late spring-seeded alfalfa seeded at seven seeding rates and cut two or three times in the year of seeding (Exp. II).

Variety	Seeding rate kg/ha															
	3-Cut								2-Cut							
	2.2	4.5	9.0	13.5	18.0	22.5	36.0	Avg.	2.2	4.5	9.0	13.5	18.0	22.5	36.0	Avg.
Early Seeding																
				Cut 1, Aug 1								Cut 1, July 18				
Saranac	35.9	35.4	36.4	36.8	36.5	36.6	35.2	36.1	30.7	30.1	28.9	28.9	28.8	29.0	28.0	29.2
Vernal	35.6	37.4	36.8	37.5	37.4	37.3	37.2	37.0	29.4	29.7	30.6	31.9	32.1	30.9	30.3	30.7
Avg.	35.8	36.4	36.6	37.2	37.0	37.0	36.2	36.6	30.1	29.9	29.8	30.4	30.5	30.0	29.2	30.0
				Cut 2, Oct 10								Cut 2, Aug 31				
Saranac	44.1	44.4	45.4	45.6	45.6	45.1	44.7	45.0	40.7	40.5	39.8	38.9	39.2	38.6	38.8	39.5
Vernal	43.9	44.2	45.0	44.2	43.7	43.5	42.5	43.9	36.4	37.4	38.1	37.8	37.9	37.9	37.7	37.6
Avg.	44.0	44.3	45.2	44.9	44.7	44.3	43.6	44.5	38.6	39.0	39.0	38.4	38.6	38.3	38.3	38.6
												Cut 3, Oct 20				
Saranac									41.1	41.6	41.7	42.5	42.2	42.4	39.3	41.5
Vernal									40.9	41.4	40.5	40.9	40.7	41.0	39.9	40.8
Avg.									41.0	41.5	41.2	41.7	41.5	41.7	39.7	41.2
Late Seeding																
				Cut 1, Aug 4								Cut 1, July 26				
Saranac	34.3	34.5	35.0	35.6	36.0	35.7	35.1	35.2	31.7	29.5	31.0	31.0	30.7	30.6	32.3	31.0
Vernal	35.1	35.3	35.5	35.6	36.1	35.9	36.0	35.6	29.0	29.3	28.8	30.4	30.9	30.4	31.1	30.0
Avg.	34.7	34.9	35.3	35.6	36.1	35.8	35.5	35.4	30.4	29.4	29.9	30.7	30.8	30.5	31.6	30.5
				Cut 2, Oct 10								Cut 2, Sept 6				
Saranac	43.9	45.2	44.8	44.6	44.4	44.2	44.3	44.5	39.3	39.2	39.2	39.3	39.2	40.0	40.5	39.5
Vernal	44.0	44.7	44.5	44.5	44.3	44.0	44.0	44.3	39.4	38.3	38.3	38.4	38.6	39.2	39.9	38.9
Avg.	44.0	45.0	44.7	44.6	44.3	44.1	44.2	44.4	39.4	38.8	38.8	38.9	38.9	39.6	40.2	39.2
												Cut 3, Oct 20				
Saranac									41.9	41.5	41.3	41.4	41.5	40.7	40.6	41.2
Vernal									40.8	40.8	40.7	40.7	40.3	40.1	39.8	40.4
Avg.									41.4	41.2	41.0	41.1	40.9	40.4	40.2	40.8

LSD between:	Cutting 2		Cutting 3		
	Cut 1	Cut 2	Cut 1	Cut 2	Cut 3
Dates	NS	NS	NS	NS	NS
Varieties within date	NS	NS	NS	NS	NS
Rates within date and variety	1.5*	0.7**	NS	NS	1.8**

shown by Reynolds (41) and Graber *et al*. (16) for older established stands of alfalfa.

The higher TNC level in the second cut of the 2-cut series (44.4%) as compared to the third cut of the 3-cut series (40.6%) was likely due primarily to the longer interval since the previous cutting. The interval between the last two cuttings in the 2-cut systems averaged 69 days whereas it was only 37 days in the 3-cut systems. Both systems should have adequate levels of carbohydrates for high winter survival since levels of 35% are generally considered adequate for high survival, Smith (36).

All seven seeding rates in each cutting had similar carbohydrate levels with some exceptions where a slightly lower level of TNC might have been the result of *Phytophthora* disease. Since plant numbers/m^2 in the fall of the year averaged 37 plants at the 2.2-kg/ha seeding rate and 482 plants at the 36-kg/ha rate, it is evident that large increases in plant density are not harmful to percent TNC levels in the roots of alfalfa cut two or three times in the seeding year.

III. In Vitro Dry Matter Disappearance Studies

Experiment II

In vitro dry matter disappearance (IVDMD) of the forage of alfalfa was determined under different frequencies and management practices in the seeding year as an estimate of digestibility by animals. Results are presented in Table 15. A generalized conclusion is that percent IVDMD was a function of age of the plant tissue after seeding or cutting and relative position in the growing season.

Table 15. Percentage *in vitro* dry matter disappearance (IVDMD) of alfalfa varieties in the seeding year as affected by frequency of cutting, date of seeding, and irrigation (Exp. II).

Variety	Seeding Rate kg/ha	Early Seeding 3-Cutting Cut 1	Early Seeding 3-Cutting Cut 2	Early Seeding 3-Cutting Cut 3	Early Seeding 2-Cutting Cut 1	Early Seeding 2-Cutting Cut 2	Late Seeding 3-Cutting Cut 1	Late Seeding 3-Cutting Cut 2	Late Seeding 3-Cutting Cut 3	Late Seeding 2-Cutting Cut 1	Late Seeding 2-Cutting Cut 2
						Irrigated (I)					
Saranac	2.2	72.7	70.8	76.0	66.2	72.2	73.5	74.3	75.8	72.9	72.2
	4.5	73.1	72.8	76.8	66.3	72.0	76.1	74.3	76.0	72.3	72.6
	9.0	73.3	72.8	76.7	66.2	71.0	75.7	73.4	76.8	72.4	71.7
	13.5	73.5	72.4	77.1	66.6	70.5	75.7	73.6	76.2	72.5	71.8
	18.0	73.0	72.7	76.1	66.6	71.1	76.0	74.7	76.2	72.5	72.6
	22.5	73.9	72.3	76.1	66.9	70.8	75.2	72.8	76.0	72.7	71.8
	36.0	74.2	71.8	77.0	67.2	70.8	76.0	73.4	76.3	72.8	72.2
	Avg.	73.5	72.4	76.5	66.5	71.2	75.4	73.8	76.2	72.6	72.1
Vernal	2.2	73.4	72.6	75.3	66.1	72.1	73.1	73.0	75.1	70.8	71.5
	4.5	74.1	72.9	76.2	65.8	72.3	74.1	73.0	75.0	71.9	71.5
	9.0	74.0	73.2	76.4	66.0	72.3	73.9	73.1	75.0	71.5	71.4
	13.5	72.8	73.4	76.0	67.5	71.5	74.0	73.7	75.9	71.2	71.4
	18.0	72.3	73.2	76.5	65.4	69.7	73.7	73.8	75.3	71.3	70.6
	22.5	72.6	72.3	76.5	65.4	70.3	73.6	72.5	75.7	71.4	71.1
	36.0	72.4	72.9	75.8	65.7	70.8	73.5	72.8	75.9	71.9	70.2
	Avg.	73.6	72.9	76.1	65.7	71.3	73.7	73.1	75.4	71.4	71.1
	Avg. I	73.6	72.7	76.3	66.1	71.2	74.6	73.5	75.8	72.0	71.6
						Nonirrigated (NI)					
Saranac	2.2	70.1	72.9	74.9	65.4	71.8	73.3	73.4	75.2	71.3	71.7
	4.5	71.5	72.6	76.3	65.7	72.1	73.7	73.0	75.5	71.2	71.3
	9.0	71.8	71.1	76.4	65.9	72.0	73.7	73.0	76.7	71.3	71.2
	13.5	71.7	72.3	76.7	66.0	72.1	74.0	74.2	76.0	71.6	72.2
	18.0	71.9	71.8	76.9	65.9	72.3	74.9	73.7	76.3	71.5	72.2
	22.5	71.7	72.3	76.5	66.6	70.9	74.9	73.7	76.6	72.3	71.9
	36.0	72.5	71.8	76.6	65.2	70.5	75.4	73.1	75.9	72.4	71.9
	Avg.	71.6	72.1	76.3	65.8	71.7	74.3	73.4	76.0	71.7	71.8
Vernal	2.2	70.3	73.2	76.6	64.2	72.2	72.9	73.8	76.2	70.5	71.9
	4.5	70.7	73.2	76.0	64.3	72.5	72.6	73.7	75.9	71.2	70.8
	9.0	71.5	73.0	76.6	65.2	70.4	73.9	73.6	75.8	71.2	71.2
	13.5	72.7	71.2	76.7	64.5	70.6	74.0	73.8	76.1	71.5	70.5
	18.0	72.4	71.5	76.9	64.2	71.0	73.8	73.8	76.1	71.0	70.5
	22.5	71.9	71.7	76.9	64.4	70.8	73.1	73.6	76.5	70.9	71.2
	36.0	73.0	72.2	76.8	64.3	70.9	72.6	73.0	75.9	71.2	70.9
	Avg.	71.8	72.2	76.6	64.4	71.0	73.3	73.6	76.0	71.0	71.0
	Avg. NI	71.7	72.2	76.5	65.1	71.4	73.8	73.5	76.0	71.4	71.4
						Average, varieties and irrigation treatments					
	2.2	71.5	72.7	75.7	65.5	72.1	73.2	73.6	75.5	71.4	71.8
	4.5	72.4	72.9	76.3	65.5	72.3	74.1	73.5	75.6	71.7	71.5
	9.0	72.8	72.5	76.5	65.8	71.5	74.3	73.2	76.0	71.6	71.4
	13.5	72.9	72.3	76.6	65.7	71.2	74.4	73.8	76.0	71.7	71.5
	18.0	72.7	72.3	76.6	65.5	70.6	74.6	73.9	75.9	71.6	71.5
	22.5	72.8	72.1	76.5	65.8	70.4	74.2	73.1	76.2	71.8	71.5
	36.0	73.2	72.1	76.5	65.6	70.7	74.3	73.1	76.0	72.0	71.3
	Avg.	72.6	72.4	76.3	65.6	71.3	74.2	73.5	75.9	71.7	71.5
	Avg.		73.8		68.3			74.5		71.6	

LSD between:

	2-Cutting Cut 1	2-Cutting Cut 2	3-Cutting Cut 1	3-Cutting Cut 2	3-Cutting Cut 3
Dates	.6***	NS	NS	NS	NS
Irrigations	NS	NS	NS	NS	NS
Varieties	NS	NS	NS	NS	NS
Rates within dates	NS	1.2**	1.5***	NS	NS

Frequently cut alfalfa in this experiment had a higher IVDMD value in agreement with Allinson *et al*. (2) for 2-year old alfalfa stands in Michigan. The average of all 3-cut systems was 74.2% for the 3-cut system compared to 70.0% for the 2-cut systems, indicating the superiority in quality related to frequent cutting in the seeding year. *In vitro* dry matter disappearance was high in both early- and late-seeded alfalfa in this relatively immature forage of seeding-year alfalfa. Late-seeded alfalfa, however, was higher in percent IVDMD than early-seeded alfalfa in both the 3- and 2-cut systems. This is shown by average IVDMD values of 68.3 and 73.8% for early-seeded alfalfa cut two or three times, respectively, and higher values of 71.6 and 74.5% for late-seeded alfalfa cut two or three times.

Values of percent IVDMD were in the order of Cut 1 = Cut 2 < Cut 3 for both early and late seedings in the 3-cut system. IVDMD was in the order of Cut 1 < Cut 2 for early seedings and Cut 1 = Cut 2 for late seedings in the 2-cut systems.

The decrease in percent IVDMD with age of plant tissue is shown by examining values for alfalfa at different stages of maturity in the first cutting. In the first cutting of the 3-cut system of early seeded alfalfa, IVDMD on July 18 was 72.6% which was 7.0% higher than in the first cutting on August 1 of the 2-cut system. The decrease in IVDMD during this period of 14 days was 0.50% per day which agrees precisely with the decline in older stands of alfalfa in similar stages of growth in late May to early June as reported by Reid *et al* (31) in New York.

In another comparison in this experiment, the first cutting of the 3-cut system of late-seeded alfalfa had an average IVDMD of 74.2% on July 26, 2.5% higher than in first cutting of the 2-cut system on August 4, a period of nine days. The average decline during this period was 0.28%, considerably less than the 0.50% daily decline obtained from early-seeded alfalfa cut under similar 2- and 3-cut systems. The difference may be due to smaller and less mature plants in the later seeding. The shorter interval of 9 compared to 14 days may also have been a contributing reason to the lower daily decline of IVDMD in the later-seeded alfalfa.

The IVDMD of the last cuttings of the 2-cut systems made on October 10 were similar--71.3 and 71.5%, respectively--for the early- and late-cut systems. Likewise, IVDMD in the last cuttings of the 3-cut system on October 20 was similar (76.3 and 75.9%). The IVDMD in the third cutting averaged 4.7% higher than in the second cutting, probably because the plant tissue sampled since the previous cutting was 18 days less mature (68 vs 50 days). The third cutting has a higher percentage of IVDMD (75.9%) than the second cutting of the 3-cut system (73.5%) taken earlier because of a much slower decline in IVDMD in alfalfa in the fall. Slower plant growth due to cooler temperatures and less radiation may have contributed to the slow decline.

The first cutting of the 3-cut system of alfalfa seeded early at low rates had a significantly lower IVDMD than at higher rates, probably because the fewer plants at the low seed rate were more mature than when more thickly spaced at higher seeding rates. There were no differences between other seeding rates.

Total dry matter yields and total digestible dry matter yields (IVDMD) or feeding value per hectare of early- and late-seeded alfalfa are presented in Table 16. The data show that increases in utilizable feed per acre are a function not only of yield but also of IVDMD and emphasize early seeding and frequent cutting of alfalfa harvested in the year of seeding for maximum production of feeding value. The highest yield of 4.80 mt/ha of dry matter obtained from early-seeded alfalfa cut three times had a feeding value per hectare of 3.73 mt which is the product of dry matter in mt/ha multiplied by percent IVDMD. This feeding value was 0.93 mt/ha greater than alfalfa seeded late and cut only twice (2.80 mt/ha).

Experiment I

Studies on IVDMD were conducted in Experiment I in 1972, a year after the seeding. Both spring and summer seedings were examined in all four cuttings harvested at the same time. The IVDMD results in the year after seeding alfalfa in spring and summer are presented in Tables 17 and 18, respectively.

Seeding-year treatments of 3 cuttings and 2 cuttings in early and late seedings did not produce any differences between those treatments in any of the four cuttings harvested in the next year, Table 17. The average IVDMD values in the four harvests were similar to the two cutting systems of the previous year. Comparisons between varieties or seeding rates showed no significant differences.

Summer seedings, Table 18, did not show any differences in IVDMD between seeding rates of the previous summer. Late-summer

Table 16. Dry matter yields (DM) and *in vitro* digestible dry matter yields (IVDDM) of early- and late-seeded Saranac and Vernal alfalfa at seven seeding rates when cut two or three times in 1972. Average of irrigation and no irrigation (Exp. II).

Seeding Rate kg/ha	Early Seeding 3-Cut	Early Seeding 2-Cut	Late Seeding 3-Cut	Late Seeding 2-Cut
		mt/ha		
		DM		
2.2	2.42	2.50	2.46	2.40
4.5	3.94	3.35	3.25	3.06
9.0	5.14	4.08	4.21	2.77
13.5	5.98	5.22	4.91	4.30
18.0	6.14	5.31	5.10	4.78
22.5	6.05	5.35	5.09	4.57
36.0	5.96	5.28	5.04	4.51
Avg.	4.80	4.62	3.98	3.69
		IVDDM		
2.2	1.77	1.74	1.82	1.71
4.5	2.90	2.32	2.40	2.19
9.0	3.77	2.80	3.13	2.70
13.5	4.38	3.55	3.70	3.08
18.0	4.50	3.60	3.80	3.43
22.5	4.43	3.62	3.78	3.27
36.0	4.38	3.56	3.74	3.24
Avg.	3.73	3.03	3.20	2.80

Table 17. Percentage *in vitro* dry matter digestibility (IVDMD) in the year after seeding of two alfalfa varieties seeded in the previous spring at six rates and harvested two or three times in the seeding year (Exp. I).

Variety	Seeding Rate, kg/ha	Cutting Frequency, 1971: 2-Cuttings; Number cuttings in 1972: 1	2	3	4	3-Cuttings: 1	2	3	4
		% IVDMD				% IVDMD			
		Early Seeding, 1971							
Saranac	1.1	68.1	64.7	69.2	69.5	67.6	65.2	69.7	69.5
	2.2	68.8	65.5	69.3	69.5	67.7	64.9	69.7	69.7
	4.5	68.9	65.7	70.1	69.8	67.4	65.1	70.2	69.6
	9.0	68.3	64.9	71.1	71.7	67.8	65.1	70.4	70.0
	18.0	68.6	65.6	71.0	71.3	68.1	65.5	69.4	70.3
	36.0	69.3	64.6	71.3	72.6	68.3	65.4	69.1	70.9
	Avg.	68.7	65.2	70.4	70.7	67.8	65.2	69.7	70.0
Vernal	1.1	68.8	65.5	70.1	68.7	67.8	64.9	70.3	68.7
	2.2	68.8	65.6	70.2	69.6	67.4	65.0	69.0	69.1
	4.5	68.3	65.4	70.1	70.1	67.9	64.5	69.2	69.5
	9.0	68.8	65.7	69.6	70.8	68.6	65.2	69.8	69.8
	18.0	68.8	65.7	70.2	70.4	68.7	65.4	69.0	69.9
	36.0	69.3	66.4	71.0	69.9	68.1	65.3	69.3	70.0
	Avg.	68.8	65.7	70.2	69.8	68.0	65.1	69.4	69.5
		Late Seeding, 1971							
Saranac	1.1	68.4	63.7	68.8	69.1	67.5	63.5	68.6	68.8
	2.2	68.5	64.1	69.4	69.6	67.4	64.4	68.9	69.1
	4.5	69.1	64.1	69.0	69.4	68.2	64.3	68.8	69.5
	9.0	68.7	63.9	69.0	69.4	69.0	64.4	68.6	69.5
	18.0	68.8	63.6	69.2	70.1	68.6	64.5	69.2	69.4
	36.0	69.0	65.0	69.0	70.8	68.8	64.5	69.2	69.4
	Avg.	68.8	64.1	69.0	69.7	68.3	64.3	68.9	69.3
Vernal	1.1	68.8	63.9	70.2	68.8	68.3	64.6	69.5	68.8
	2.2	68.5	64.3	68.7	69.1	68.4	64.0	69.5	69.6
	4.5	68.5	63.7	68.7	68.9	69.8	64.1	68.6	69.1
	9.0	69.2	63.9	70.3	69.0	68.9	64.1	68.5	69.1
	18.0	69.2	64.9	69.5	69.4	69.8	65.6	69.6	69.8
	36.0	69.3	64.3	70.0	70.4	69.8	65.6	69.3	69.6
	Avg.	68.9	64.2	69.5	69.2	69.0	64.6	69.1	69.3
		Average, Variety and Seeding Date							
Average	1.1	68.5	64.4	69.6	69.0	67.8	64.5	69.5	69.0
	2.2	68.7	64.9	69.4	69.5	67.7	64.7	69.3	69.4
	4.5	68.7	64.7	69.5	69.5	68.1	64.5	69.2	69.4
	9.0	68.6	64.6	69.9	70.2	68.6	64.7	69.3	69.6
	18.0	68.9	65.0	69.9	70.3	68.8	65.2	69.3	69.9
	36.0	69.2	65.0	70.3	70.9	68.8	65.2	69.2	70.0
	Avg.	68.8	64.8	69.8	69.9	68.3	64.8	69.3	69.5
	Avg. harvests		68.3				68.0		

$LSD_{.05}$

	Dates	Cuts	Varieties	Rates
Cut 1	NS	NS	NS	NS
Cut 2	NS	NS	NS	NS
Cut 3	NS	NS	NS	NS
Cut 4	NS	NS	NS	NS

Table 18. Percentage *in vitro* dry matter disappearance (IVDMD) of Saranac *alfalfa* in the year after establishment in summer at six rates and three seeding dates (Exp. 1).

Seeding Rate kg/ha	Cuttings Cut 1	Cut 2	Cut 3	Cut 4	Avg.
		Early (July 31)			
1.1	67.7	65.8	68.1	69.5	
2.2	67.8	65.5	68.5	70.1	
4.5	68.9	65.9	68.7	70.2	
9.0	69.4	65.2	68.8	69.6	
18.0	68.4	65.4	69.1	70.8	
36.0	67.3	65.3	69.9	69.1	
Avg.	68.2	65.5	68.7	69.9	68.1
		Medium (Aug 13)			
1.1	68.3	66.9	68.3	69.6	
2.2	67.9	67.3	70.1	69.7	
4.5	68.0	66.8	70.7	70.5	
9.0	68.8	67.1	70.2	70.2	
18.0	68.6	67.2	70.2	69.6	
36.0	68.5	66.9	70.6	70.5	
Avg.	68.3	67.0	70.0	70.0	68.8
		Late (Aug 27)			
1.1	70.0	68.5	69.3	68.6	
2.2	71.6	67.6	69.2	69.9	
4.5	71.0	68.5	69.3	70.0	
9.0	71.7	68.4	70.0	70.9	
18.0	71.4	67.6	71.6	70.2	
36.0	71.4	68.6	71.5	69.2	
Avg.	71.2	68.2	70.1	69.8	69.8
		Average, Seeding Dates			
1.1	68.6	67.1	68.6	69.2	
2.2	69.1	66.8	69.3	69.9	
4.5	69.3	67.0	69.5	70.2	
9.0	69.9	66.9	69.5	70.2	
18.0	69.4	66.7	70.3	70.2	
36.0	69.1	66.9	70.6	69.6	
Avg.	69.2	66.9	69.6	69.9	68.9

LSD .05: Dates, NS; Rates, NS.

seedings were 2.1% higher in IVDMD than medium- and early-summer seedings in the first cutting which indicates that the plants were at a less mature growth stage. The same trend continued in the second cutting in which the late-summer seeding was 1.2% and 2.7% higher than medium- and early-summer seeding, respectively.

Comparisons of spring and early- and medium-summer seedings in the next year showed that the IVDMD values were similar in the next year--68.4 compared to 68.4%, respectively. Late-summer seedings had a slightly higher percentage of 69.8% than early- and medium-summer seedings in the year after seeding, probably because of smaller plants.

IV. Phytophthora Root Rot Studies

Experiment II

Root rot (*Phytophthora megasperma* Drechs) of alfalfa was identified in Michigan by Dr. A. E. Ellingboe of the Department of Botany and Plant Pathology in roots of alfalfa in September, 1972, in seeding-year studies in Experiment II, Figure 10. Roots were obtained from the field from three samples each 0.325 m^2 in size after the last cutting in the two- or three-cut systems (October 10 and 20, respectively) and categorized into four classes, 1 to 4, based on increasing severity of infection. The data are presented in Table 19 along with a brief description of the classes presented earlier under Materials and Methods.

The highest numbers of healthy plants, 70.3% in class number 1, occurred in early-seeded alfalfa cut only twice during the seeding year. When the alfalfa was seeded late, the healthy roots declined

Table 19. Percentage distribution in October, 1972 of diseased roots of alfalfa from *Phytophthora megasperma* evaluated in four classifications on spring-seeded alfalfa given various treatments during the seeding year (Exp. II).

Variety	Seeding Rate, kg/ha	Early Seeding 2-Cutting 1	2	3	4	Early Seeding 3-Cutting 1	2	3	4	Late Seeding 2-Cutting 1	2	3	4	Late Seeding 3-Cutting 1	2	3	4
		% diseased in classes															
		Irrigated (I)															
Saranac	2.2	65.7	27.2	7.1	-	39.5	53.7	5.3	1.5	69.9	18.0	9.7	2.4	36.7	32.5	21.3	9.5
	4.5	56.7	30.7	10.7	1.9	27.9	62.4	4.9	4.8	52.4	22.2	16.6	8.8	16.5	63.3	18.0	2.2
	9.0	44.1	36.3	14.0	5.6	26.1	53.3	11.5	9.1	44.4	30.9	18.0	6.7	22.6	37.9	31.0	8.5
	13.5	54.2	23.3	16.5	6.0	23.4	59.5	8.7	8.4	56.2	19.8	17.1	6.9	23.9	47.8	17.8	10.5
	18.0	56.8	21.7	11.8	9.7	25.0	44.7	22.0	8.3	47.6	32.8	10.6	9.0	17.5	48.8	18.6	15.1
	22.5	47.9	32.2	10.5	9.4	29.1	45.6	14.5	10.8	31.5	37.3	17.8	13.4	27.8	38.0	19.6	14.6
	36.0	59.4	22.5	9.0	9.1	28.2	50.3	11.6	9.9	42.7	21.2	12.0	24.1	20.9	52.9	15.1	11.1
	Avg.	54.9	27.7	11.4	6.0	28.5	52.8	11.2	7.5	49.2	26.0	14.5	10.3	23.7	45.9	20.2	10.2
Vernal	2.2	63.7	31.5	4.8	-	50.5	44.5	5.0	-	62.9	29.3	5.9	1.9	52.2	39.4	2.8	5.6
	4.5	78.5	12.1	6.1	3.3	53.9	34.2	6.3	5.6	50.4	20.2	22.2	7.2	44.1	45.1	7.7	3.1
	9.0	59.2	23.8	11.9	5.1	36.1	38.3	17.1	8.5	48.7	27.0	18.7	5.6	42.9	42.4	7.6	7.1
	13.5	54.2	27.9	13.2	4.7	35.1	46.4	13.0	5.5	53.9	22.8	17.9	5.4	43.8	37.9	10.1	6.2
	18.0	57.1	29.5	7.9	5.5	37.5	45.6	11.2	6.7	51.9	27.9	12.6	7.6	52.7	18.8	18.9	9.6
	22.5	62.8	24.9	9.4	2.9	46.3	40.3	8.5	4.9	53.3	22.0	11.0	13.7	39.0	45.4	12.4	3.2
	36.0	70.6	16.6	7.0	5.8	46.5	24.0	21.7	7.8	54.3	21.7	11.3	12.7	38.4	42.6	12.8	5.2
	Avg.	63.7	23.8	8.6	3.9	43.7	39.0	11.8	5.5	53.6	24.5	14.2	7.7	44.7	39.2	10.3	5.8
	Avg., I	59.3	25.8	10.0	4.9	36.1	45.9	11.5	6.5	51.4	25.3	14.3	9.0	34.2	42.6	15.2	8.0
		Nonirrigated (NI)															
Saranac	2.2	86.5	13.5	-	-	71.9	28.1	-	-	87.9	12.1	-	-	80.0	20.0	-	-
	4.5	79.8	20.2	-	-	68.0	24.2	6.6	1.2	79.1	14.9	5.3	.9	77.3	19.1	2.3	1.3
	9.0	93.3	5.8	.9	-	69.1	26.5	3.5	.9	72.2	20.6	5.5	1.7	59.0	36.9	2.9	1.2
	13.5	81.1	15.3	2.1	1.5	73.5	19.2	5.5	1.8	79.1	15.4	4.2	1.3	56.0	27.4	10.1	6.5
	18.0	70.8	24.5	3.2	1.5	72.5	19.9	3.5	4.1	77.9	14.6	4.7	2.8	60.1	25.7	9.2	5.0
	22.5	90.8	6.9	1.7	.6	62.4	29.3	5.1	3.2	72.9	16.5	4.3	6.3	59.6	30.3	6.4	3.7
	36.0	88.3	7.2	2.5	2.0	59.9	30.0	6.7	3.4	76.0	12.6	3.9	7.5	65.0	17.6	8.7	8.7
	Avg.	84.4	13.3	1.5	.8	68.2	25.3	4.4	2.1	77.9	15.2	4.0	2.9	65.3	25.3	5.7	3.7
Vernal	2.2	91.1	8.9	-	-	71.3	26.2	2.5	-	84.6	10.3	5.1	-	64.1	31.7	4.2	-
	4.5	78.1	12.6	4.6	4.7	52.7	39.6	6.7	1.0	89.5	1.8	.6	8.1	59.5	35.9	1.5	3.1
	9.0	68.2	23.3	5.6	2.9	50.6	40.0	4.7	4.7	88.7	7.9	1.2	2.2	62.9	25.1	9.1	2.9
	13.5	80.1	13.2	5.4	1.3	44.9	45.6	5.4	4.1	79.1	11.3	6.5	3.1	67.7	25.4	2.4	4.2
	18.0	78.3	15.5	3.8	2.4	51.0	41.4	3.7	3.9	74.0	16.4	4.0	5.6	54.8	36.6	4.4	4.2
	22.5	84.6	11.5	2.2	1.7	53.3	36.1	6.4	4.2	75.6	16.7	4.4	3.3	46.4	41.2	6.7	5.7
	36.0	66.2	24.3	4.1	5.4	43.0	46.7	6.8	3.5	82.7	10.7	1.9	4.7	46.6	35.8	11.4	6.2
	Avg.	78.0	15.6	3.8	2.6	52.4	39.4	5.2	3.0	82.0	10.7	3.4	3.9	57.4	33.1	5.7	3.8
	Avg., NI	81.2	14.5	2.7	1.6	60.3	32.4	4.8	2.5	80.0	13.0	3.7	3.3	61.4	29.2	5.7	3.7
		Average, Varieties and Irrigation Treatments															
Average	2.2	76.7	20.3	3.0	-	58.3	38.1	3.2	.4	76.3	17.4	5.2	1.1	53.3	30.7	7.1	3.8
	4.5	73.3	18.9	5.4	2.5	50.6	40.3	6.0	3.1	67.9	14.8	11.2	6.3	49.4	40.9	7.4	2.4
	9.0	66.2	22.3	8.1	3.4	45.5	39.5	9.2	5.8	63.5	21.6	10.9	4.1	46.9	35.6	12.7	4.9
	13.5	67.4	19.9	9.3	3.4	44.2	42.6	8.2	5.0	67.1	17.3	11.4	4.2	47.8	34.6	10.1	6.9
	18.0	65.8	22.8	6.7	4.8	46.5	37.9	10.1	5.8	62.9	22.9	8.0	6.3	46.3	32.5	12.8	8.5
	22.5	71.5	18.9	6.0	3.7	47.7	37.7	8.6	5.7	58.3	23.1	9.2	9.2	43.2	38.7	11.3	6.8
	36.0	71.1	17.7	5.7	5.6	44.4	37.8	11.7	6.2	63.9	16.6	7.3	12.3	42.7	37.2	12.0	7.8
	Avg.	70.3	20.1	6.3	3.3	48.1	39.2	8.1	4.6	65.7	19.1	9.0	6.2	47.8	35.7	10.5	6.0

[a]Classes: (1) health plants, (2) slightly-diseased plants, (3) heavily diseased, recovering, winter survival likely, (4) heavily diseased, winter survival not likely.

to 65.7%. When the alfalfa was cut three times instead of twice, the percentage of healthy plants declined to similar levels of 48.1 and 47.8% for early- and late-seeded alfalfa, respectively. The data indicate that injury was more severe when the plants were put under greater stress, i.e., cutting three times instead of twice.

Irrigation decreased the percentages of healthy plants, class 1, and strikingly increased the percentage of slightly diseased plants in class 2 and heavily diseased plants in class 3 under all combinations of dates of seeding and cutting frequency. The heavily diseased plants in class 4 increased in percentage under irrigation but not to the extent as in classes 2 and 3.

Saranac had lower percentages of healthy plants than Vernal under irrigation but there was little difference between the two varieties when not irrigated.

Increasing seeding rates above 4.5 kg/ha significantly decreased the percentage of healthy plants in the various treatments with some exceptions.

The combined disease values described in the Materials and Methods section and reported in Figure 11 are a better indication of the incidence of disease than percent in the various classes, Table 20 and Figure 11. The disease values were significantly higher for irrigated than nonirrigated alfalfa substantiating the results in Table 19 which showed a higher percentage of diseased plants under irrigation, a difference significant at the 1% level. Varieties had similar disease values except that irrigated Saranac had a significantly higher value at the 1% level than Vernal. Increasing the

Table 20. *Phytophthora* disease values in alfalfa roots representing degree of disease in four classes in the seeding year fall in 1972 (Exp. II).

Variety	Seeding Rate kg/ha	Irrigated			Nonirrigated			Average		Average Cuts
		3-Cut	2-Cut	Avg.	3-Cut	2-Cut	Avg.	3-Cut	2-Cut	
Saranac	2.2	1.50	1.86	1.68	1.13	1.24	1.19	1.32	1.55	1.43
	4.5	1.70	1.96	1.83	1.24	1.34	1.29	1.47	1.65	1.56
	9.0	1.84	2.14	1.99	1.23	1.41	1.32	1.54	1.78	1.66
	13.5	1.75	2.10	1.93	1.26	1.51	1.39	1.50	1.81	1.65
	18.0	1.78	2.23	2.00	1.34	1.49	1.42	1.56	1.86	1.71
	22.5	1.97	2.15	2.06	1.28	1.52	1.40	1.63	1.83	1.73
	36.0	1.93	2.09	2.01	1.31	1.57	1.44	1.62	1.83	1.72
	Avg.	1.78	2.07	1.93	1.26	1.44	1.35	1.52	1.76	1.64
Vernal	2.2	1.44	1.58	1.51	1.15	1.36	1.25	1.29	1.47	1.38
	4.5	1.60	1.67	1.63	1.31	1.52	1.41	1.45	1.59	1.52
	9.0	1.72	1.89	1.80	1.31	1.58	1.44	1.51	1.73	1.62
	13.5	1.72	1.83	1.77	1.30	1.55	1.43	1.51	1.69	1.60
	18.0	1.69	1.87	1.78	1.36	1.59	1.48	1.52	1.73	1.63
	22.5	1.77	1.76	1.76	1.28	1.67	1.47	1.52	1.71	1.62
	36.0	1.61	1.81	1.71	1.39	1.74	1.56	1.50	1.77	1.64
	Avg.	1.64	1.77	1.71	1.30	1.57	1.43	1.47	1.67	1.57
Average varieties										
	2.2	1.47	1.72	1.60	1.13	1.30	1.22	1.30	1.51	1.41a
	4.5	1.65	1.81	1.73	1.27	1.43	1.35	1.46	1.62	1.54a
	9.0	1.78	2.01	1.90	1.27	1.50	1.38	1.53	1.76	1.64b
	13.5	1.73	1.96	1.85	1.28	1.53	1.41	1.51	1.75	1.63b
	18.0	1.73	2.04	1.89	1.35	1.54	1.45	1.54	1.80	1.66b
	22.5	1.87	1.96	1.91	1.28	1.59	1.44	1.58	1.77	1.67b
	36.0	1.77	1.95	1.86	1.35	1.65	1.50	1.56	1.80	1.68b
	Avg.	1.71	1.92	1.82	1.28	1.51	1.39	1.50	1.71	1.60

LSD between: Dates, NS; Irrigation treatments, .28***, Varieties, NS; Cuttings, .15***, Cuts at the same level of irrigation, 21**; Varieties at the same level of irrigation, cut, .22*; Varieties at the same level of irrigation, 21**; Rates, .17***.

Figure 10. Phytophthora root rot symptoms in alfalfa plant showing wilted or stunted yellowed leaves and severe damage in the root.

cuttings from two to three likewise showed a highly significant increase under both levels of irrigated and nonirrigated conditions although the disease level was greater under irrigation. Plants of the two lower seeding rates were significantly less diseased at the 1% level than at higher seeding rates. Disease values under irrigated or nonirrigated conditions were higher when the alfalfa was cut three times instead of twice.

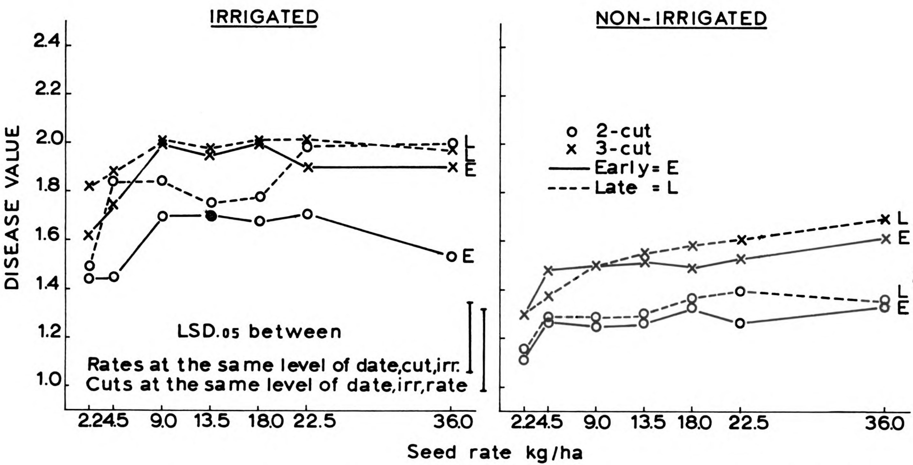


Figure 11. Disease values of early- and late-seeded alfalfa seeded at seven rates and cut two or three times in 1972 (Exp. II).

Both alfalfa varieties seeded at low rates of 2.2 and 4.5 kg/ha and irrigated had lower disease values, with one exception, than when seeded at higher rates. Varieties were equally susceptible over all treatments except that Saranac was more diseased than Vernal under irrigation.

The classification according to percentage of diseased plants together with the disease values indicates that Phytophthora root disease of alfalfa is more severe under irrigation which substantiates results of Frosheiser (14). Conditions of stress imposed in this experiment induced greater disease. Stress conditions were three cuttings rather than two and late rather than early seeding.

SUMMARY AND CONCLUSIONS

The effects of early and late spring-seeding on two varieties of alfalfa treated with a herbicide and seeded at seven rates and given two cutting systems were evaluated in seeding-year yields, population density, root development, total nonstructural carbohydrates in roots, *in vitro* dry matter disappearance of forage, and incidence of *Phytophthora megasperma* Drechs root rot in experiments in 1971 and 1972 at East Lansing, Michigan. Yields in the year after seeding were used to compare the yield levels and *in vitro* dry matter disappearance of spring seedings with summer seedings in the year after seeding.

The following conclusions can be drawn from the two experiments involving various factors of establishment and management of spring-seeded herbicide-treated alfalfa:

1. Yields of alfalfa in the seeding year were reduced when spring seeding was delayed from the earliest possible date in spring until 3 to 4 weeks later.

2. Yields in the seeding year were higher under the 3-cutting system than when the alfalfa was cut twice. Levels of total nonstructural carbohydrates in the fall of the seeding year indicated no differences due to effects of the two cutting systems which was verified by no differences in next year's yield.

3. The highest yield was obtained from early-seeded Saranac alfalfa cut three times during the seeding year. Yields in the

subsequent year were as high as from other treatments indicating this treatment should be exploited for maximum use of alfalfa harvested in the year of seeding.

4. Saranac yielded more than Vernal in the year of seeding when seeded early but not when seeded late.

5. Yield levels in the year after seeding were similar after early- or late-spring seeding or cutting three times instead of twice indicating that alfalfa was not injured more by increasing cutting frequency or delayed seeding in the spring. Irrigation decreased seeding-year yields when compared to nonirrigation in a year of above-normal rainfall primarily because of a marked disease incidence of *Phytophthora megasperma* Drechs, especially in the late-seeded alfalfa cut three times.

6. Alfalfa yields in the seeding year increased up to a seeding rate of 9.0 kg/ha when the seeding was early and weed control satisfactory but the rate of 13.5 kg/ha was necessary for maximum yields in the seeding year when weed control was unsatisfactory and the seeding was delayed.

7. Yields in the year after seeding from spring-seeded herbicide-treated alfalfa were similar to the recommended early or medium dates of summer seeding.

8. Plant population in the fall of the first and second year after seeding was significantly higher from early than late seedings.

9. Cutting either variety two or three times in the seeding year had no significant effects on the number of plants/m^2 in the fall of the cutting or in the second year.

10. The number of plants/m^2 at the 9-kg/ha seeding rate which produced the maximum yield was 268 over all treatments of cutting and seeding date in Experiment I and 211 at the optimum rate of 13.5 kg/ha in Experiment II.

11. Higher seeding rates of 18 or 36 kg/ha produced lower survival of seedlings with the late seeding or with Saranac in contrast to late seedings or the Vernal variety.

12. Cutting alfalfa two or three times in the seeding year had no effect on weight per root or root yield in the fall of the first and second year.

13. Weight per root and total root yields were influenced more by population density than seeding time at the end of the seeding year.

14. Root yield was constant for any seeding rate beyond the rate necessary for the maximum yield and paralleled top growth at seeding rates beyond maximum yields.

15. Over three-fourths of the roots in the spring of the year after seeding were in the top 30 cm, 14.5% were in the 30- to 60-cm zone, and 6.6% were in the 60- to 90-cm zone.

16. Seeding-year levels of total nonstructural carbohydrates in percent were very similar or showed only a slight decrease in both varieties, in all cutting systems, and seeding dates as rates increased from 1.1 to 36.0 kg/ha. Percentages of TNC in roots of seedlings

increased gradually as cutting progressed during the seeding year.

17. Irrigation, variety and seeding rate had no effect on dry matter disappearance of the seeding-year forage of alfalfa.

18. The three-cutting system produced higher *in vitro* dry matter disappearance values and *in vitro* dry matter yields than 2-cuttings in the seeding year.

19. Summer seedings and spring seedings produced similar percentages of *in vitro* dry matter disappearance in the year after seeding except for late summer seeding which had a higher *in vitro* dry matter disappearance in the first and second cut.

20. Irrigation treatment increased incidence of *Phytophthora* root rot in alfalfa roots when the natural precipitation between April 1 to October 31 was 56 cm, 4.5 cm above normal.

21. Varieties were equally susceptible to *Phytophthora* root rot except that Saranac under irrigation showed somewhat greater susceptibility.

22. Alfalfa seeded at lower seeding rates of 2.2 and 4.5 kg/ha was significantly less diseased than the higher seeding rates when irrigated.

23. Maximum *Phytophthora* root rot was induced by a combination of stress factors including high moisture levels in the soil, frequent cutting, high seed rates resulting in smaller plants and a susceptible variety.

Agronomic Application

Cutting early-seeded, herbicide-treated alfalfa three times in the seeding year maximized yields when seed rates were 9.0 kg/ha with satisfactory weed control and 13.5 kg/ha when weed control was not satisfactory. Maximum yields produced under this intensive system of establishment and management produced higher yields of digestible feed than when cut less frequently or seeded later without impairing the survival and productivity of the alfalfa in the following year.

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