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A field study was conducted in the Willamette Valley near Corvallis, Oregon, to determine the influence of seeding rate, drill row spacing, grass association, and variety on the yield of dry matter and quality (crude protein content and leafiness) of alfalfa. Treatments included seeding rates of 7.5, 10, 15 and 20 pounds per acre in various combinations with row spacings of 3, 6 and 12 inches. Orchardgrass (*Dactylis glomerata* L.) was included in three treatments. Complete data were obtained for three harvests and yield data only for an aftermath harvest. Alfalfa varieties were Vernal and DuPuits.

Plant population and stem numbers per unit area increased with increasing seeding rates and with closer row spacing, but stem size, dry weight of the stems, leafiness and crude protein were not affected by seeding rate or row spacing. Grass grown in association with alfalfa did not influence any of the characteristics studied except for an increase in stem size at second harvest and increased protein content of the alfalfa at first harvest.

Vernal and DuPuits yielded the same weight of dry material for the season. Vernal maintained a higher plant population, more stems per square foot at each harvest and a higher percentage of leaves than DuPuits. Stem size and weight and crude protein content of whole plants was higher in DuPuits than in Vernal.

Both varieties decreased in yield, plant population, stem size and stem weight with each successive cutting. Stem number per square foot and per plant increased with each successive cutting.

It was concluded that seeding rates from 7.5 to 20 pounds per acre and row spacings up to 12 inches had very little influence on quantity and quality of alfalfa hay production.

THE INFLUENCE OF SEEDING RATE ON PLANT POPULATION, YIELD AND QUALITY OF TWO ALFALFA (*MEDICAGO SATIVA* L.) VARIETIES

by

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THE INFLUENCE OF SEEDING RATE ON PLANT POPULATION, YIELD AND QUALITY OF TWO ALFALFA (MEDICAGO SATIVA L.) VARIETIES

INTRODUCTION

Medicago sativa L., known by its arabic name, alfalfa, in the United States and Canada but commonly called lucerne in other parts of the world, is generally regarded as one of the world's most valuable cultivated forage crops. Few, if any, crops are equal to it in capacity to produce high yields of nutritious and palatable feed. The excellent soil improving ability of the crop is also generally recognized. A combination of desirable attributes, such as a high production and adaptation to a wide diversity of soil and climatic conditions has led to the utilization of alfalfa in the world to an extent probably exceeding that of any other single legume or grass species. It is utilized as a cultivated crop on every inhabited continent and in many countries extending from near polar regions to the tropics.

Alfalfa is the most important forage species in the United States with a total acreage of over 30 million acres. It is often referred to as the "Queen of the Forage Crops" because of its many advantages relative to other forage species. Besides the advantages mentioned above, there are some other advantages including higher mineral and vitamin content, higher total feed value, often higher total yield and deeper root system. Alfalfa is an important legume crop in western Oregon with over 40 thousand acres in production. The acreage is increasing in the Willamette Valley. In most cases in western Oregon, relatively high production can be obtained, and there apparently are no serious production problems. There are problems, however, in regard to utilization of the feed produced. The major utilization problem is that of conserving the first harvest in May or early June with suitable nutritional quality.

DuPuits is the most popular alfalfa variety at present in the Willamette Valley. It is high yielding, has early growth and produces a very heavy first cutting by late May on fertile soil. In producing a heavy first cutting, the variety characteristically becomes very stemmy even by mid-May when crown buds are developed but before any blooming occurs. Large stems, accompanied by leaf loss under heavy top growth (reduction of leaf-stem ratio) is reflected in reduced quality and increased curing time during the usual unsettled weather of May. Many complaints have been heard regarding stemminess of the first crop, primarily when grown on Willamette, Woodburn, Chehalis, or Newburg soils. On hill soils, DuPuits is normally shorter and less productive. It is probable that first cutting DuPuits on hill soils is of better quality than on the more fertile valley soils.

There is the opinion of some growers and the recommendation of some seed dealers, that stemminess and low quality is a result of too low seeding rate, and that if the rate were increased from the usual 12-14 pounds per acre to 20 pounds per acre, stems would be smaller and quality improved.

No reference could be found in the literature regarding influence of seeding rate on quality of alfalfa.

It was hypothesized that seeding rate would influence number of tillers per plant but not number of tillers per unit area. The French type alfalfa is known to be stemmy and is rejected in some countries regardless of high yield.

Vernal alfalfa is also recommended in the Willamette Valley. Although intensive comparison with DuPuits has not been made, it is known that yields approach those of DuPuits, and the first cutting appears to be of better quality. In addition, if perennials adjust the plant population in accordance with the environment, it might be expected that a heavier seeding rate of alfalfa (under dryland conditions) would be a temporary effect in plant population, and in quality also, if seeding rates did influence quality at all.

The experiment described herein represents an attempt to evaluate the influence of seeding rate and plant spacing (row width and grass association) on the yield and quality of DuPuits and Vernal alfalfa varieties.

REVIEW OF LITERATURE

Many investigations have been carried out with alfalfa. Most of them have been concerned with cutting management and with soil fertility conditions as they influence yield of dry matter, chemical composition and plant longevity. Reports concerning seeding rates and row spacings are few and concern only the influence on yield of forage.

Influence of Plant Population on Yield

Marten *et al*. (24, p. 343-344) stated that results in a New York study (unpublished data) showed a slight, but progressive increase in yield of a pure stand of alfalfa when plant numbers were increased from 11 to 28 per square foot. They further observed that the failure of stands with differing alfalfa densities to yield differently appeared to be at least partially due to production of more tillers by alfalfa plants in the less dense stands.

Cowett and Sprague (7, p. 294-297) showed that as the stand density increased from one to eight plants per square foot, the number of stems and dry weight per plant decreased. They observed that with the increase in stand density, the yield per acre increased. This agrees with the report of Rumbaugh (27, p. 423-424) who concluded that as the population density increased, dry matter per plant and stem number per plant decreased.

Cowett and Sprague (6, p. 432-434) made a similar observation that stem production decreased as stand density increased, but stem production per plant was not always closely associated with yield.

Jarvis (20, p. 281-286), working with alfalfa and alfalfa-grass mixtures, noted that the yield increased with density of plants but individual stems decreased in weight.

A study by Hueg (18, p. 76) showed that dry matter yield of alfalfa-brome mixture in greenhouses increased when alfalfa plant numbers were increased from about two to five per square foot, with little change in yield beyond the latter density when brome was seeded at a constant rate.

Kramer and Davis (23, p. 470-473) concluded that the number of six-inch gaps, in drill-seeded rows, was negatively correlated with yields in the first two years of the study. The relation was strongest in the first harvest year.

Ronningen and Hess (26, p. 92-93) found that preliminary observations suggested a strong relationship, especially in the third harvest year between yield and number of surviving plants per unit area.

Seeding rates of 10 to 40 pounds per acre in five-pound intervals results in no significant differences in forage yield of alfalfa in the Mississippi Delta of Arkansas (Jacks, 19, p. 2).

A more fundamental approach was used by Donald (10, p. 355) in studying the importance of light in intraspecific competition. He showed that with annual species, seeding rate is very important in that the sooner all the available light is intercepted, the greater the forage production. In the case of perennial species, seeding rate is less important because the plants establish more slowly and produce tillers more abundantly. The plant population is then maintained or decreased in accordance with the environmental factors. Thus, a high rate of seeding and dense population of plants will likely decrease with time to that population most suited for the environment.

An investigation of a three-year old seeding of non-irrigated alfalfa in western Oregon showed that alfalfa seeded at 1, 2, 4, 8 and 16 seeds per inch had reduced to 11, 17, 19, 22 and 22 plants per linear yard, respectively, in three years. The reduction was similar in 6- or 12-inch drill rows[1].

In the study reported by Jacks (19, p. 2), stand counts were made in March, June and September for each of the 10, 15, 20, 25, 30 and 40 pounds per acre seeding rates. In the first count, the lowest seeding rate resulted in 13.4 plants per square foot, 30.8 plants per square foot for the 40-pound seeding rate and intermediate plant populations for the other seeding rates. In the second plant counts, there were no significant differences

[1] McGuire, W. S. and Madhat Al-Hassani. Unpublished research on longevity of alfalfa plants. Corvallis, Oregon. Agricultural Experiment Station. Department of Farm Crops, 1962.

in stand between plots with different seeding rates above ten pounds per acre. At the higher rates of seeding, 25 to 35 percent of the plants were lost during the first year, and 12 percent were lost from the 15 to 20 pound seeding rates. The ten-pound seeding rate lost only two percent of the original plants. It was concluded that the plant population required for maximum production was about 20 plants per square foot and this could be accomplished with the usually recommended seeding rate of 15 pounds per acre, including losses resulting from adverse conditions.

Bolton (1, p. 210) has stated that there are about 220,000 seeds per pound for alfalfa, or enough for five seeds per square foot at the rate of one pound per acre. If all seeds should grow, four pounds of seed per acre would be sufficient for the required plant population in humid areas.

Lower seeding rates are used where moisture is a limiting factor. Also, lower rates are used for seed production since yield of dry matter is not of importance and, in time, plant tillering offsets the effects of lower plant population. This has been demonstrated in alfalfa by Carlson and Steward (4, p. 52) in subterranean clover (*Trifolium subterraneum*) by Donald (11, p. 585) and in crimson clover (*Trifolium incarnatum*) by Knight and Hollowell (22, p. 73-76).

No reference could be found in the literature regarding the influence of seeding rate of alfalfa on quality or on any morphological characteristics.

Influence of Grass in Association with Alfalfa

There is incomplete agreement regarding the influence of grass in increasing total yield of grass-alfalfa compared with pure alfalfa. Increased yields have been reported by Ensminger et al. (13, p. 23) and by Fuelleman et al. (15, p. 491). Results in western Oregon with DuPuits alfalfa showed no change in total yield of forage during a four-year period by including any of three grasses and each at three seeding rates[1].

The quality of grass-alfalfa is usually lower than pure alfalfa, based on chemical analyses of crude protein or crude fiber (refer to Woodman et al., Ellet and Carrier, Wilsie et al., and Koonce; 30, p. 266-296, 12, p. 85-87, 29, p. 266-273, 15, p. 491, 21, p. 19).

No report was found regarding the influence of grass on the chemical composition or on the morphological characteristics of the alfalfa growing in association.

Influence of Time of Harvest on Yield and Quality

Many studies have been conducted with alfalfa to determine the stage of maturity to harvest in order to obtain suitable quantity and quality. Dawson et al. (8, p. 2-4) reviewed the literature and concluded that the data indicate that the early

[1]McGuire, W. S. Unpublished research on alfalfa production. Corvallis, Oregon. Agricultural Experiment Station. Department of Farm Crops, 1963.

bloom stage is the most desirable stage for cutting in respect to yield and quality. This stage of maturity generally coincides with the development of crown buds which is therefore often used as an indication of time to harvest.

Recent work in western Oregon (5, p. 72) indicated that crown bud development and early bloom stages do not occur together at the first cutting. Crown buds are developed about mid-May and early flowering occurs about mid-June. In addition, alfalfa left past mid-May lodges, is difficult to harvest, and becomes stemmy with resulting loss of quality. Cutting the first crop at the crown bud stage resulted in improved quality and yield for both Vernal and DuPuits varieties. Therefore, in the investigation being reported, the varieties were cut on the basis of crown bud development.

Determination of Alfalfa Quality by Laboratory Methods

The ultimate test for hay quality is in terms of animal response. A chemical analysis can give some indication of the nutritive value. Total digestible nutrients (TDN) and digestible protein can be predicted from a chemical analysis for lignin, crude fiber, or crude protein. Meyer and Jones (25, p. 8-9) stated that even though an analysis of modified crude fiber did not predict digestible protein, it was superior for predicting TDN. Crude protein was used as a measure of alfalfa quality in this study because the analysis is more standardized. Crude protein is used as a measure of hay quality testing in Oregon, while lignin is used in Washington, and modified crude fiber is used in California.

The factors affecting quality in forage crops have been reviewed by Sullivan and Garber (28, p. 6-9). Varieties of a species often differ in chemical composition. Stage of maturity and season or time of year are also important in this respect. The same workers related that, since about 75 percent of the crude protein is contained in the leaves, the leafiness of a variety, either as an inherited characteristic or as a result of cultural practices, becomes very important. Because of the effect of stage of maturity on leafiness, an attempt was made to cut the two alfalfa varieties at the same stage of growth.

Dent and Zaleski (9, p. 131-140) showed that the French varieties of Flamande are relatively stemmy. They have wider and longer leaves than the other varieties, with resulting lower leaf-stem ratios. Hittle et al. (17, p. 82-88) studied leafiness of five varieties at different stages of maturity. Vernal appeared to be finer stemmed and had a higher leaf-stem ratio than DuPuits.

An average of 16 harvests showed DuPuits had a leaf-stem ratio of 0.90 and Vernal had a ratio of 1.06. DuPuits averaged 2.67 percent nitrogen and Vernal averaged 2.80 percent for the entire plant. At the same time, DuPuits produced sufficiently more dry matter per acre that, even with lower percentage leaves, it produced 0.05 tons per acre more leaves than Vernal.

Higher percentage of leaves early in the season (first cutting) compared with later cuttings has also been reported (2, p. 5-14).

Foster and Merrill (14, p. 160-175) observed that the early cut contained the highest percentage of protein and the lowest percentage of fiber. The former decreased constantly while the latter increased rapidly from early bloom to full maturity of the plant. The proportionate amount of leaves to stem is greater at early bloom than at any subsequent time, and both leaves and stems contain a greater percentage of protein and a lesser percentage of crude fiber at this time than at any later period in the growth of the plant. The relative proportion of leaves to stems in the different cuttings were as follows: early, 42 to 58; medium, 40 to 60; late, 33 to 67. Alfalfa leaves, compared with stems, are very much richer in protein, fat and nitrogen free extract, and they contain a much smaller proportion of crude fiber in feeding tests. The highest gains were made from the early cutting and the lowest from the late cuttings. The variation in the amount of the different cuttings eaten per day was very slight, being the highest for the early cuttings and the lowest for the late, but the quantity of dry matter and also digestible matter required for a good gain was decidedly lowest for the early cuttings and highest for the late. The relative amount of dry matter produced as follows: early cutting, 100; medium, 131; and late, 161.

Henrici (16, p. 386) found that when alfalfa is fed to animals, the ratio of leaves to stems influences the amount and the quality of the carbohydrate of the food to a large extent. Young alfalfa has a higher percentage of digestible carbohydrates.

In order to obtain further information regarding relative stemminess and relative stem size of the varieties for each cutting, and as the season advanced, stem sizes were measured and the percentage leaves determined. It would be expected that the characteristics would also serve to indicate quality of the alfalfa as influenced by seeding rates or variety.

MATERIALS AND METHODS

The experiment was conducted on the Hyslop Agronomy Farm near Corvallis, Oregon, during the 1963 growing season.

The climate of Corvallis (3), which is fairly representative of much of the Willamette Valley, may be described as a mild sub-coastal type with moist open winter, a dry harvest period in late summer and a fairly long growing season. The average frost-free period (217 days) is from April 2 to November 5.

The alfalfa growing season is of similar length with growth commencing about three weeks before the last average frost date and practically terminating in early October. Average annual rainfall (1901-1960) is 39.24 inches. The average total for the four-month period of June through September is 3.38 inches.

The soil type at the test site is Woodburn silt loam, typically moderately acid and deficient in phosphorus. Lime was applied in 1960 sufficient to reduce soil acidity to approximately pH 6.5. Borated superphosphate was applied in October 1962 at the rate of 400 pounds per acre.

The soil was severaly contaminated with annual ryegrass and subterranean clover seeds. Eptam (EPTC) was applied at two pounds per acre three weeks before seeding and disced into the soil to reduce ryegrass seed germination. Subterranean clover is not a problem in growing spring seeded alfalfa.

I. Varieties

A. DuPuits

DuPuits alfalfa was developed by Tournur Freres of Coulommiers, France, released to European farmers in 1937 and received for testing in the United States in 1947. It was improved by Etienne J. Vitrac. Its unique characteristics are winter hardiness, early growth in spring and rapid recovery after harvest. It is relatively stemmy, upright in growth and moderately resistant to certain foliar diseases, although susceptible to crown rots and bacterial wilt.

B. Vernal

Vernal is a synthetic variety developed by the Wisconsin Agricultural Experiment Station. It was released in 1953. Fifty percent of the germ plasm was derived from six Cossack plants. The remainder was derived from crosses between selected plants of Ladak, Kansas common and diploid stock of *Medicago falcata*. It is an outstanding variety in forage production under hay and grazing management in the North Central states. It is fine stemmed and leafy with dark green foliage and broad crowns. It has a high level of winter hardiness and resistance to bacterial wilt with some tolerance to leaf spot and yellow leaf blotch.

II. Experimental Design and Treatments

The experiment was conducted to determine the influence of eight different seeding rates or plant spacings on plant population, yield and quality of two alfalfa varieties, DuPuits and Vernal.

Three basic seeding rates of 10, 15 and 20 pounds per acre were used in conventional six-inch drill rows. The commonly used seeding rate of 15 pounds per acre was used with three drill row spacings of 3, 6 and 12 inches. Three treatments included grass in association with alfalfa at a seeding rate of 15 pounds per acre, and at a lower rate of 7.5 pounds per acre in either 6- or 12-inch rows, as shown in Table 1.

Table 1. Row spacing and seeding rate for two alfalfa varieties

Treatment No. Vernal	Treatment No. DuPuits	Row Spacing	Attempted Seeding Rate/Acre	Actual Seeding Rate/Acre
1	9	6"	10 lbs.	9
2	10	6"	15 lbs.	13.5
3	11	6"	20 lbs.	22.5
4	12	3"	15 lbs.	12.5
5	13	12"	15 lbs.	12.9
6	14	12"	7½ lbs.	6.7 + orchardgrass 3.6#
7	15	12"	15 lbs.	12.9 + orchardgrass 3.6#
8	16	6"	7½ lbs.	6.3 + orchardgrass 3.6#

Actual seeding rates differed from the attempted rates because of the limitations of the planting plates of the drill. The actual rates were determined by weighing seed into the drill box and re-weighing that left after seeding.

The inoculated seed of the Vernal and DuPuits alfalfa varieties were seeded on June 2, 1962, with a Planet Jr. drill on plots 6 x 20 feet. Treatments 6, 7 and 8 of Vernal and 14, 15 and 16 of DuPuits were overseeded with S-143 orchardgrass in September, 1962, to determine the effect of orchardgrass, grown in association, on the quality of alfalfa. Plots were irrigated in July to obtain better establishment. An excellent stand was obtained.

A stand count was taken from each plot in the experiment in October, 1962, after removal of a hay crop when the plants were short and easy to count. The stand count was taken from two random subplots, two feet in length and converted to plant numbers per square foot.

III. Determination of Yield and Quality

A. Yield of Dry Matter

Plots were harvested with a National sickle-bar mower with a cutter bar 36 inches in length. Mowing was done along the length of the plot, cutting half the breadth of the alfalfa in a swath 3 x 20 feet, which was removed from each plot and weighed, leaving the other half of the plot for other work.

A random subsample of approximately two kilograms was obtained from each plot which was weighed, then dried at 160^{o}F for

24 hours and reweighed for calculation of percentage of dry weight yield per plot. The first harvest for both varieties was on May 25, 1963. The second and third harvests were on July 9 and August 26 for DuPuits, and nine days later in each harvest (second and third) for Vernal. The experiment ended with the fourth harvest taken in late September, 1963. Vernal and DuPuits were harvested on the same day and measurements on yield only were taken.

B. Estimates of Plant Populations and Tiller Numbers

On the remainder of the plot, the following observations were taken:

1. Duplicate two-foot lengths of row, each representing a subplot at two random locations in each plot, were cut one inch above the ground level. All the tillers more than six inches in height were counted in each subplot.

2. Total number of plants were counted in each subplot. Because of different drill widths, all counts were converted to a square foot basis.

C. Weight and Size of Stems

Ten large stems were selected from each subsample. The leaves and branches were removed from the stems and the green weight of stems was taken. The total volume of the ten stems was determined by immersing the stems in a graduated cylinder. The water displacement gave the measure of the volume. The ten stems, bundled together, were put back into the sample from which they were taken. The whole sample was then dried at 160°F for 24 hours and the ten stems reweighed.

D. Leaf Percentage and Leaf-Stem Ratio

The leaves and stems were separated in the whole sample of the subplot to determine the leaf percentage, and then the leaf-stem ratio. Leaf percentage was determined by dividing the weight of leaves by the weight of the entire plant. Leaf-stem ratio was determined by dividing the weight of leaves by the weight of stems. Both were on a dry weight basis.

E. Crude Protein

The stems and leaves were ground and the crude protein determined by the Kjeldahl method for total nitrogen. Total nitrogen in the sample multiplied by 6.25 gave the crude protein.

F. Statistical Analysis

The data were subjected to the appropriate analysis of variance and the F-test used to test for significant differences. Significance of mean squares is indicated in the usual manner; one asterisk (*) indicates significant at the five percent level of probability, and two asterisks (**) indicate significance at the one percent level. The analysis of variance for all data are included in the Appendix.

Figure 1. General view of experiment (row spacing)

Figure 2. Vernal alfalfa in 6-inch rows with different rates

Figure 3. DuPuits alfalfa at harvesting time

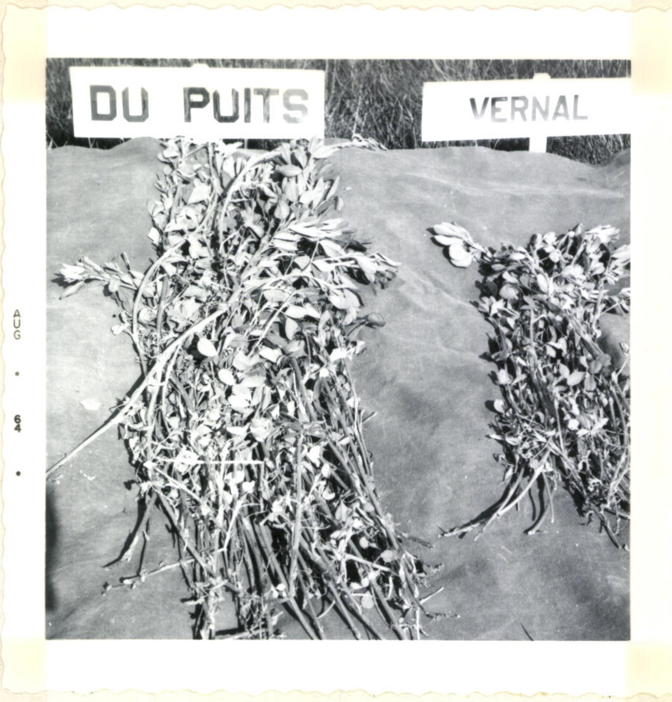


Figure 4. Comparison of DuPuits alfalfa plants with Vernal alfalfa plants

Figure 5. Selecting 10 large stems of 10-inch length for volume measurement

Figure 6. Taking volume measurement by water displacement for the 10 large stems of 10-inch length

EXPERIMENTAL RESULTS

Yield of Dry Matter

The experimental data for the yield of dry matter for four cuttings at different levels of spacing in the two alfalfa varieties are given in Table 2.

There was a significant interaction of treatments with cuttings which was due to variety reaction rather than plant spacing reaction.

Comparison of treatment yields within varieties shows that no differences existed as a result of plant spacing (seeding rate or row spacing).

The average yield of four cuttings at 1/10 bloom in Vernal and DuPuits has a decreasing trend in every successive harvest. The analysis of variance (Appendix Table 1) shows that highly significant differences existed between the four cuttings. The least significant difference (LSD) examination showed that the fourth cutting was significantly lower than the first, second and third cuttings at the one percent level of probability. The third cutting also had significantly lower values than the first and second cuttings at the same level of significance. The second cutting, at the one percent level of significance, had significantly lower values than the first cutting. Furthermore, it is seen that in the first and third cuttings, no significant difference between the average yield of Vernal and DuPuits

Table 2. The influence of spacing and variety on total yield of dry matter (pounds per 20 x 6 ft. plot)

Treatment Number	Cutting 1st 5/25/63	2nd 7/18/63	3rd 9/3/63	4th 9/24/63	Total lbs. per Treatment	Ave. lbs. per Treatment
Vernal						
1	9.29	10.99	8.00	1.40	29.68	7.42
2	11.98	10.39	7.50	1.51	31.38	7.85
3	9.97	11.04	7.97	1.57	30.55	7.64
4	10.75	9.91	8.33	1.53	30.52	7.63
5	8.56	9.92	10.00	1.45	29.93	7.48
6	11.14	8.65	6.32	1.25	27.36	6.84
7	9.16	8.87	6.52	1.23	25.78	6.44
8	10.90	10.14	8.52	1.63	31.19	7.80
Average	10.22	9.99	7.90	1.45	29.61	7.39
	1st 5/25/63	2nd 7/9/63	3rd 8/26/63	4th 9/24/63		
DuPuits						
9	10.36	8.21	8.58	3.06	30.21	7.55
10	10.12	8.78	8.21	3.06	30.17	7.54
11	11.60	7.41	6.96	2.50	28.53	7.13
12	10.71	9.77	8.26	2.86	31.60	7.90
13	11.61	8.62	8.17	3.11	31.51	7.87
14	11.44	7.72	8.39	2.90	30.45	7.61
15	10.06	6.84	7.00	3.34	27.24	6.81
16	11.72	9.11	8.14	3.00	31.97	7.99
Average	10.95	8.31	7.96	2.99	30.21	7.55
Total Ave.	21.17	18.30**	15.86**	4.44**	59.82	14.94

**Fourth cutting < First, second and third cutting
**Third cutting < First and second cutting
**Second cutting < First cutting

Standard error of difference between cutting means = 0.56
L.S.D. 5% (cutting means) = 1.12
1% (cutting means) = 1.49

existed. At the second cutting, Vernal yielded more than DuPuits, while in the fourth cutting, DuPuits yielded significantly more than Vernal. Treatments 6, 7 and 8 of Vernal and 14, 15 and 16 of DuPuits alfalfa varieties, which were grown in mixture with S-143 orchardgrass, yielded the same as did the pure stand of alfalfa.

Plant Number per Square Foot

Plant number per square foot for the varieties Vernal and DuPuits are given in Table 3. It is seen from the table that in both of these varieties, the number of plants per square foot decreased sharply as the season advanced. The least significant differences (LSD) show the fourth cutting was significantly lower than the first, second and third cuttings. The third cutting similarly showed lower values than the first and second. The second cutting is significantly lower than the first cutting at the one percent level of probability.

Among the spacing and seeding rate treatments in both varieties, plant numbers per square foot increased with increased seeding rate (treatments 1, 2, 3, 9, 10 and 11). At the same seeding rate, plant numbers increased with closer drill spacing. These results are shown in Table 4. At a constant rate of 15 pounds per acre, drill spacing of 12 inches contained approximately one-half as many plants per square foot as did

Table 3. The influence of spacing and variety on plant number per square foot.

Treatment Number	Cutting 1st 10/20/62	2nd 5/25/63	3rd 7/18/63	4th 9/3/63	Average Plant Number
Vernal					
1	32.00	26.33	19.00	16.83	23.54
2	50.00	27.50	22.50	17.50	29.38
3	66.00	41.50	29.33	21.33	41.04
4	61.33	58.67	37.00	26.67	45.92
5	43.33	18.50	13.92	10.25	21.50
6	24.33	17.75	15.25	8.50	16.46
7	40.33	24.00	14.25	11.75	22.58
8	22.00	22.83	21.33	10.83	19.25
Average	42.42	29.64	21.57	15.46	27.46
	1st 10/20/62	2nd 5/25/63	3rd 7/9/63	4th 8/26/63	
DuPuits					
9	20.67	17.00	11.17	9.67	14.63
10	37.33	23.00	14.84	13.83	22.25
11	65.33	25.00	20.17	19.33	32.46
12	42.67	36.00	34.33	24.00	34.25
13	40.33	16.00	9.33	9.42	18.77
14	24.33	9.60	7.92	7.00	12.21
15	39.33	15.58	10.58	8.16	18.41
16	20.67	18.00	14.50	10.83	16.00
Average	36.33	20.02	15.35	12.78	21.12
Total Average	78.75	49.66**	36.92**	28.24**	48.58

**Fourth cutting $<$ First, second and third cutting
**Third cutting $<$ First and second cutting
**Second cutting $<$ First cutting

Standard error of differences between cutting means = 2.84
L.S.D. 5% (cutting means) = 5.89
1% (cutting means) = 7.83

the three-inch drill spacing. The six-inch spacing was intermediate in plant numbers. The reaction of the varieties to drill row width was similar.

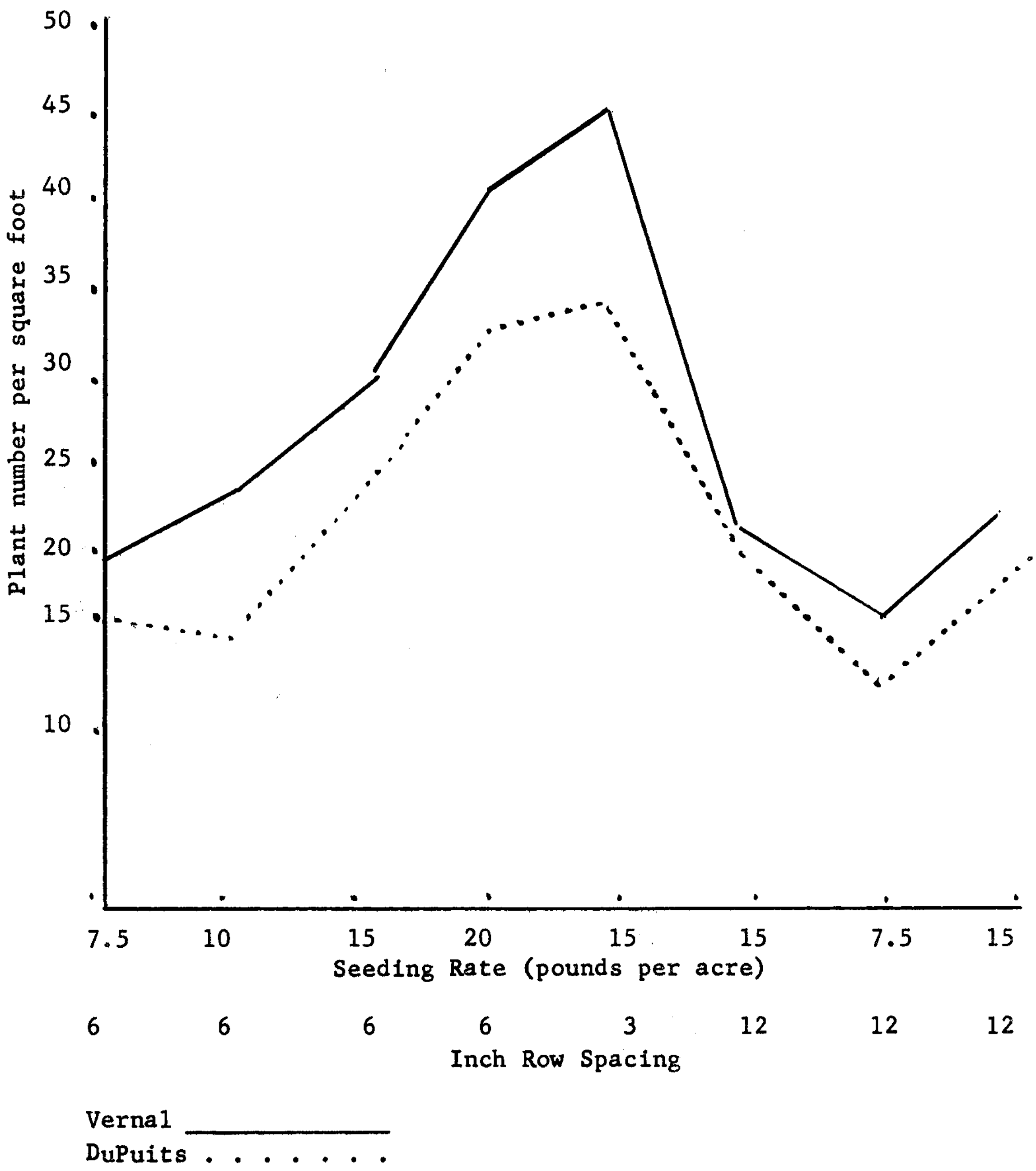
Orchardgrass grown in association with the alfalfa apparently had no influence on plant population during the growing season. Comparison of treatments 5 and 7 for Vernal and 13 and 15 for DuPuits show that alfalfa plant numbers were reduced similarly with or without the grass.

Table 4. The influence of drill row spacing on plant population when seeded at 15 pounds per acre

Treatment Number	Spacing	Plant Numbers per Square Foot DuPuits	Vernal
4, 12	3 inch	34.25	45.92
2, 10	6 inch	22.25	29.38
5, 13	12 inch	18.77	21.50

The average number of plants of Vernal was significantly higher than the number of plants of DuPuits. The similarity of the varieties in plant number response to treatments is shown in Figure 7.

Figure 7. Comparison of plant numbers per square foot for DuPuits and Vernal alfalfa with different seeding rates and row spacings



Stem Number per Square Foot

The data for stem number per square foot (Table 5) show that the stem number in one square foot in Vernal is significantly higher than in DuPuits in all cuttings. The second and third cuttings within the same treatments in Vernal and DuPuits showed a higher number of stems in one square foot than found in the first cutting. In Vernal the highest number of stems was obtained in the second cutting, while in DuPuits the third cutting gave the highest stem number in one square foot. However, the stem number per square foot in Vernal or DuPuits showed no significant difference among the three cuttings. The total average of the two varieties, Vernal and DuPuits, per each cutting, showed a significantly lower stem number per one square foot at the five percent level in the first cutting than in the second and third cuttings. The first cutting is, however, significantly lower than the second cutting at the one percent level.

The 15-pound seeding rate at three-inch spacing (treatments 4 and 12) gave the highest number of stems in one square foot in both varieties. The treatments 6, 7 and 8 of Vernal and 14, 15 and 16 of DuPuits, which were grown in mixture with orchardgrass, showed the same trend for the stem number in one square foot as described for alfalfa grown in pure stand. Increased seeding rate resulted in increased stem number in alfalfa, with or without grass in association. Increased width of drill spacing resulted in

Table 5. The influence of plant spacing and alfalfa variety on stem number per square foot

Treatment Number	Cutting 1st 5/25/63	2nd 7/18/63	3rd 9/3/63	Average Stem Number
Vernal				
1	76.83	84.83	82.83	80.61
2	79.33	90.33	85.17	84.94
3	86.33	101.50	89.83	92.55
4	133.33	149.33	109.69	130.78
5	37.17	51.58	57.75	48.83
6	41.67	67.50	48.83	52.67
7	52.58	56.33	68.08	59.00
8	68.67	82.83	65.50	72.33
Average	71.99	85.53	75.96	77.71
	1st 5/25/63	2nd 7/9/63	3rd 8/26/63	
DuPuits				
9	41.00	51.50	50.33	47.61
10	53.17	63.67	67.50	61.45
11	48.00	62.33	64.17	58.17
12	59.67	108.67	126.00	98.11
13	24.67	36.42	41.50	34.20
14	28.42	30.83	40.67	33.31
15	32.67	42.50	42.25	39.14
16	52.33	55.17	76.83	61.44
Average	42.49	56.39	63.66	54.18
Total Average	114.48**	141.92	139.62	131.89

**First cutting $<$ second and third cutting

Standard error of differences between cutting means = 9.879

L.S.D. 5% (cutting means) = 19.88

1% (cutting means) = 26.20

decreased stem number per square foot in alfalfa, with or without grass in association.

Size of Stems (as measured by volume displacement)

The volume (cc) of the ten large stems of ten-inch length in the varieties Vernal and DuPuits are given in Table 6. Stem size or volume was significantly greater in DuPuits than in Vernal at all cuttings. The largest stems were obtained in the first cutting in either variety. Successive cuttings showed decreased stem size. Stem size in the third cutting was significantly less than in the first two cuttings, and the second cutting stem size was significantly less than stem size in the first cutting.

Apparently seeding rate did not influence size of stems as shown by comparison of treatments 1, 2 and 3 for Vernal and 9, 10 and 11 for DuPuits. There appears to be a trend to smaller sized stems as a result of increased seeding rate in the first cutting of DuPuits alfalfa. The volume decreased approximately 4 cc with each successive increased seeding rate. The analysis of variance did not show the difference to be significant.

In the third cutting, there was a statistical difference among the spacing treatments. The largest stems came from the 12-inch row spacings compared with six-inch or three-inch row spacings. This situation exists in both varieties. In addition, grass association had no influence on stem size in Vernal alfalfa at the third cutting, while DuPuits stems were larger when grown with the grass.

Table 6. The influence of spacing and variety on volume (cc) of ten large stems (ten-inch length)

Treatment Number	Cutting 1st 5/25/63	2nd 7/18/63	3rd 9/3/63	Average
Vernal				
1	26.92	22.50	15.83	21.75
2	27.00	22.00	10.50	19.83
3	25.33	21.33	15.17	20.61
4	27.42	18.75	14.50	20.22
5	25.33	19.57	20.08	21.66
6	27.67	23.67	13.75	21.70
7	24.50	24.33	15.67	21.50
8	23.50	20.33	14.17	19.33
Average	25.96	21.56	14.96	20.83
	1st 5/25/63	2nd 7/18/63	3rd 9/3/63	
DuPuits				
9	41.67	31.50	16.33	29.83
10	37.67	32.33	17.17	29.06
11	33.17	27.33	15.58	25.36
12	32.83	25.33	18.75	25.64
13	35.83	31.17	25.83	30.94
14	33.83	27.75	23.58	28.39
15	42.00	29.50	20.83	30.78
16	36.67	29.66	20.80	29.04
Average	36.71	29.32	19.86	28.63
Total Average	62.67	50.88**	34.82**	49.46

**Third cutting < first and second cutting
**Second cutting < first cutting

Standard error of differences between cutting means = 2.185
L.S.D. 5% (cutting means) = 4.362
1% (cutting means) = 5.795

Dry Weight of Ten Large Stems, Ten-Inch Length

The data in Table 7 show that in all the treatments in the three cuttings, DuPuits stems had more grams dry weight than Vernal stems. Within the varietal treatments, the first cutting gave higher gram dry weights than the second and third. These observations are also true for the treatments grown in mixture with orchardgrass. The analysis of variance (Appendix Table 5) for the dry weight of the ten large stems, ten-inch length, showed that significant differences existed among the three cuttings. Least significant differences (LSD) evaluation shoed the third cutting was significantly lower than the first and second cuttings, while at the same level of significance, the second cutting was significantly lower than the first cutting in stem weight.

The analysis of variance also indicates a difference in stem weights in the third cutting. This treatment effect in the third cutting apparently occurred in DuPuits variety. Stem weight was considerably larger with the 12-inch row spacings (treatments 13 and 14) and with the lower seeding rates when in grass association (treatments 14 and 16).

Table 7. The influence of spacing and variety on grams dry weight of ten large stems (ten-inch length)

Treatment Number	Cutting 1st 5/25/63	2nd 7/18/63	3rd 9/3/63	Average grams per treatment
Vernal				
1	7.65	5.51	3.86	5.67
2	6.05	4.73	2.42	4.40
3	6.94	4.85	3.60	5.13
4	6.31	5.03	3.58	4.97
5	5.71	5.24	4.75	5.23
6	6.81	5.77	3.59	5.39
7	5.80	5.78	4.23	5.27
8	6.19	4.69	3.42	4.76
Average	6.43	5.20	3.68	5.10
	1st 5/25/63	2nd 7/9/63	3rd 8/26/63	
DuPuits				
9	9.87	6.11	3.85	6.61
10	9.27	6.74	4.61	6.87
11	8.57	5.93	3.78	6.09
12	7.42	5.48	4.64	5.85
13	8.19	6.43	6.24	6.95
14	8.08	5.76	6.37	6.74
15	8.57	5.94	4.80	6.44
16	7.90	5.70	5.10	6.24
Average	8.48	6.01	4.92	6.47
Total Average	14.91	11.21**	8.60**	11.57

**Third cutting $<$ First and second cutting
**Second cutting $<$ First cutting

Standard error of differences between cutting means = .683
L.S.D. 5% (cutting means) = 1.305
1% (cutting means) = 1.734

Leaf Percentage and Leaf-Stem Ratio

The leaf percentages given in Table 8 show that Vernal had a higher leaf percentage than DuPuits alfalfa in all three cuttings. Only the third cutting differences were statistically different (Appendix Table 7).

Among the cuttings, the second cutting had the lowest leaf percentage. The least significant differences (LSD) shows the second cutting significantly lower than the first and third cuttings in leafiness. The first and third cuttings showed similar leafiness.

Leaf percentage data were converted to leaf-stem ratios for the convenience of readers more familiar with leaf-stem ratio data. The results are included in Appendix Table 6. The same differences occur in the ratio data and the variance analysis showed the same difference as for the percentage data.

Crude Protein Percentage

Crude protein percentages are tabulated in Table 9. DuPuits, in comparison with Vernal, had significantly higher crude protein in the first and second cuttings. In the third cutting, Vernal contained more crude protein than DuPuits. A significant difference was found between cuttings for the crude protein percent in the analysis of variance for all cuttings (Appendix Table 8). The

Table 8. The influence of plant spacing and variety on leaf percentage in alfalfa

Treatment Number	Cutting 1st 5/25/63	2nd 7/18/63	3rd 9/3/63	Average
Vernal				
1	39.99	39.99	47.70	42.56
2	44.45	37.54	49.03	43.67
3	44.42	39.28	43.80	42.50
4	47.15	38.91	47.59	44.55
5	46.02	41.80	44.73	44.18
6	52.18	40.66	53.14	48.66
7	49.56	43.94	47.10	46.87
8	43.92	38.60	47.32	43.28
Average	45.96	40.09	47.55	44.53
	1st 5/25/63	2nd 7/9/63	3rd 8/26/63	
DuPuits				
9	42.50	39.13	45.17	42.27
10	41.02	37.17	41.92	40.04
11	43.09	41.18	42.67	42.31
12	43.06	36.08	43.44	40.86
13	38.87	39.49	42.37	40.24
14	46.29	40.87	43.96	43.71
15	45.99	41.20	40.63	42.61
16	43.43	36.91	42.50	40.95
Average	43.03	39.00	42.83	41.62
Total Average	44.50	39.55**	45.19	86.15

**Second cutting $<$ First and third cutting

Standard error of difference between cutting means = 2.554
L.S.D. 5% (cutting means) - 2.55
1% (cutting means) = 3.39

Table 9. The influence of plant spacing and variety on crude protein percentage

Treatment Number	Cutting 1st 5/25/63	Cutting 2nd 7/18/63	Cutting 3rd 9/3/63
Vernal			
1	17.67	20.23	18.97
2	16.59	21.64	19.24
3	15.93	20.69	18.83
4	17.44	22.51	20.05
5	16.96	22.80	17.33
6	18.31	21.88	18.92
7	22.28	22.48	18.50
8	20.10	22.24	19.87
Average	18.16	21.81	18.96
	1st 5/25/63	2nd 7/9/63	3rd 8/26/63
DuPuits			
9	17.05	25.70	19.84
10	18.79	25.37	17.77
11	19.37	25.79	18.02
12	20.48	23.21	18.68
13	19.58	24.83	17.54
14	20.51	25.34	16.50
15	19.75	24.49	18.51
16	20.86	24.38	16.49
Average	19.55	24.89	17.91
Total Average	37.71**	46.70	36.87**

First and third cutting < Second cutting

Standard error of differences between cutting means = .9752

L.S.D. 5% (cutting means) = 1.9465

1% (cutting means) = 2.5862

second cutting was significantly higher than the first and the third at the one percent level of probability (Table 9).

Among the treatments, no trends in protein percentage are in evidence. Statistical analysis shows a difference among treatments in the first cutting. The average values are higher in grass association than in pure stand for both varieties. It would appear also that crude protein increased with the seeding rate in the first cutting of DuPuits alfalfa. The reverse occurred in the first cutting of Vernal.

Interrelationships of Quantity of Quality Factors

The several factors used to determine the influence of plant spacing and variety on yield and quality of alfalfa were studied for possible relationships to either yield or quality and for relationships among the factors themselves. Results of several calculations for possible correlations are shown in Table 10.

According to the hypothesis, the factors which might influence yield of dry matter were plant number and stem number per square foot and stem size. Then the same factors might influence quality through their relationship to yield, in that if protein is used as a measure of quality, yield and quality in alfalfa are very often negatively correlated. Stem size and leafiness would be considered quality factors, since approximately three-fourths of the crude protein of alfalfa is in the leaves.

Table 10. Simple correlation coefficients (r) between various quality and quantity factors in alfalfa

Characters	Cutting 1st	2nd	3rd	Total of three cuttings
Yield of dry matter and:				
Plants/sq. ft.	-.0790	.5455*	-.0262	.1474
Stems/sq. ft.	-.0288	.8124**	.1121	.2954
Stem size (volume)	.2589	-.6936**	.3229	.0841
Crude protein	.1513	-.8230**	.1559	-.1865
Stem size (volume) and:				
Crude protein	.1825	.8062**	-.7266**	.5940
Dry weight of stems	.8918**	.8742**	.9719**	.9477**
Leaf-stem ratio	-.3368	-.1540	-.1628	-.5314
Leaf-stem ratio and:				
% crude protein	-.0878	-.0430	.1218	-.1977
Plants/sq. ft. and:				
Stems/sq. ft.	.8160**	.7107**	.8973**	.8568**

*Significant at the 0.05 percent level of probability
**Significant at the 0.01 percent level of probability

Yield Factors: Plants per square foot showed a relationship to yield only in the second cutting. This relationship was positive. Similarly, stem number per square foot showed a positive relationship to yield of dry matter only in the second cutting. Stem size was related to yield of dry matter only in the second cutting and the relationship was negative.

Quality Factors: Stem size showed a positive correlation with crude protein content in the second cutting and in the total seasonal results. The relationship in the third cutting was negative. The leaf-stem ratio showed no relationship to crude protein content for any of the three cuttings. Finally, the only relationship between crude protein content and yield of dry matter was in the second cutting. This relationship was negative as expected.

Relationships Among the Factors: Highly significant positive correlation coefficients were obtained between plant number and stem number per square foot. The higher the plant number, the more stems that were present in the same unit area.

Stem size and dry weight of ten stems were positively correlated at all three cuttings. This would be expected; the larger the stems, the more weight there should be.

Stem size showed no relationship to the leafiness of alfalfa in any of the three cuttings.

DISCUSSION

Yield of Dry Matter

Yield per unit of area is the product of the number of plants, stem number in each plant, and the average yield per plant. It has been shown by various workers that yield is the total product of vegetative growth. The yield per plant (Y) varies with plant population (P) according to the equation (20) $1/Y = AP + B$, where A and B are constants. The yield of a crop is not a linear function of the density of seed sown because, over a wide range of densities, further increase brings diminishing returns.

Dry matter production is achieved at moderate densities and can be maintained at a maximum value even to extremely high densities.

The decrease in yield of dry matter with each successive cutting was expected. This is a normal situation in most areas regardless of varieties or species of alfalfa. The decrease in yield with advance in season would be most severe in non-irrigated conditions. The experiment reported herein was irrigated once after the second harvest in order to obtain a sizeable yield for the third cutting. The relatively low yield of aftermath (fourth cutting) was a result of a short growing period between the third cutting and the final harvest date in September.

Apparently the yielding ability of the two varieties is similar. They were similar in yield at the first and third cuttings. The advantage of DuPuits in aftermath production can be accounted for in the differential growth period. The varieties were cut when either reached one-tenth bloom at the second and third cuttings. Vernal is a later variety and was cut eight days later than DuPuits. Thus, DuPuits aftermath represented 29 days regrowth, while Vernal aftermath represented only 21 days regrowth.

The lack of differences within either variety as a result of seeding rate, row spacing, or grass association, is an indication that under the conditions of the experiment, the lowest seeding rate and widest row spacing still provided a plant population sufficient to obtain maximum yields of dry matter. It is probable that moisture was a limiting factor during part of the season and light was a limiting factor in the later stages of each growth cycle. In the presence of limiting factors, maximum yield would be obtained at a lower plant population.

Plant Population

Apparently, plant population was not related to yield of dry matter, since relatively large differences in numbers of plants per square foot occurred as a result of seeding rates and row spacings. Table 4 reveals that density of plants per square foot is influenced by both seeding rate and row spacing. The increase of plant numbers with closer drill row spacing was not cumulative with each individual treatment of both varieties. Counts were made only on one-year old stands. Intraspecific competition and loss of plants would be more severe in wider spaced rows where plants per linear foot were more numerous. For example, as shown in Table 4, plants in 12-inch row spacing (18.77 and 21.50 respectively for DuPuits and Vernal) represent a linear foot as well as a square foot. In six-inch rows, the number per linear foot originally would be just one-half that of 12-inch rows and the same number on a square foot basis. Competition should be much more severe in wider spaced rows in the young stand.

The alfalfa grown in mixture with orchardgrass, in the present investigation, show the mixture has no influence on plant population. This is in agreement with McGuire and Al-Hassani[1]. The findings of Ensminger <u>et al</u>. (13) and Fuelleman <u>et al</u>. (15) are not in conformity with these results. It is probable that loss of alfalfa plants from grass competition would occur in succeeding years as the grass became better established.

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1 McGuire, W. S. and Madhat Al-Hassani. Unpublished research on longevity of alfalfa plants. Corvallis, Oregon. Agricultural Experiment Station. Department of Farm Crops, 1962.

Stem Number per Square Foot

It is seen in Table 5 that an increase in seeding rate resulted in increased stem number with or without grass in association. Increased width of drill spacing resulted in decreased stem number. Cowett and Sprague (7) showed that with increased density, the stem number decreased, which is not in concurrence with these results.

It has been generally believed that in a more dense stand, each plant tillers less so the number of tillers per unit area tend to remain constant. Since both varieties reacted similarly, it is suggested that environmental conditions were satisfactory for stimulation of bud formation and production of new tillers. With high fertility and irrigation, crown bud and stem development would be less affected than in a more difficult environment.

The larger number of stems in Vernal than in DuPuits was expected. Observation of the varieties indicates the larger number of stems in Vernal.

Size of Stems

The main difference in stem size was a variety effect. Again, by observation, it is observed that stems of DuPuits are larger than those of Vernal. Results here agree with those of Dent and Zaleski (9) regarding the relative stemminess of the French type alfalfa varieties. This is evidently an inherited varietal difference.

Dry Weight

The relative stemminess of DuPuits was verified in that it had both larger and heavier stems than Vernal. Weight of stems was fairly consistent with stem size. Even though DuPuits stems are hollow, they still weighed approximately 20 percent more than Vernal stems. Consistency of stem size with stem weight was apparent in plant spacing effects, since no definite trends resulted in either case as a result of seeding rate or row spacing.

Leaf Percentage

The results agree with those of Hittle *et al.* (17), in that Vernal was leafier than DuPuits.

There was a lower percentage of leaves at the second cutting compared with the first and third cuttings. It is often considered that second and third cuttings are of better quality than first cutting, although this is probably a reflection of more weeds and less favorable haying weather at the time of the first cutting.

Crude Protein Percentage

Since most of the protein in alfalfa is contained in the leaves, it would be expected that leafier varieties would be higher in protein than the less leafy varieties, as reported by Foster and Merrill (14) and Hittle et al. (17). In this experiment, Vernal was leafier than DuPuits, but DuPuits showed a higher concentration of crude protein. The most logical explanation is that Vernal has an inherently lower concentration of protein in either the leaves or stems relatively to DuPuits. No analyses were made of leaves or stems separately.

Interrelationship of Quantity and Quality Factors

A. Yield Factors. Plant number per square foot has a very conflicting relationship with yield, as evidenced by various reports by different workers. The present investigation shows plant number to be positive and significantly related to yield in the second cutting only. However, Marten et al. (24), Cowett and Sprague (7), Jarvis (20), Hueg (18) and Ronningen and Hess (26), reported increased yield with an increase in plant number. Lack of relationship between these characteristics is reported by Cowett and Sprague (6), Kramer and Davis (23), Jacks(19) and Donald (10). Similarly, stem number per square foot showed that it is positively related to yield only in the second cutting. The observation made for plant number per square foot is in agreement with this, but Cowett and Sprague (7) showed a negative relationship between these characteristics. No work has been reported regarding the relationship of stem size with total plant yield.

B. Quality Factor. In many cases, an indirect relationship exists between yield of dry matter and crude protein. Of the several factors which influence chemical composition of forage plants, the stage of maturity of the plant is the most important. When yield differences arise as a result of cutting at different times, protein content varies inversely. In this experiment, all plants of a variety were cut at the same time, and an attempt was made to cut the varieties at the same stage of maturity. Since differences, resulting from plant spacing treatments, in yield of dry matter were small, no significant differences in crude protein were observed and the two were not significantly correlated except at the second cutting, when the yield differences were greatest.

Although results here show the quality of DuPuits equal to Vernal (based on crude protein content), there might be other quality factors involved in stem size. It is well known that ruminants prefer forage plants with smaller stems. This is a common observation with hay as well as with green forage. An advantage of the hay conditioner, in addition to allowing more rapid curing of hay, might be that the stems are crushed and made more edible for ruminants.

SUMMARY AND CONCLUSIONS

A study to evaluate the influence of seeding rate, row spacing, and grass association on the yield and quality of DuPuits and Vernal alfalfa varieties was conducted at Hyslop Agronomy Farm. Seeding rates varied from 7.5 to 20 pounds per acre and row spacings were 3, 6 and 12 inches apart. Three treatments of each of the varieties were grown in mixture with orchardgrass.

The characteristics studied were yield of dry matter, plant population and stem number per unit area, stem size and weight, leaf percentage and crude protein percentage.

First cutting was at the crown bud development stage; second and third cuttings were at the one-tenth bloom stage. An aftermath cutting was taken in late September for yield only.

On the basis of data from one growing season, the following results were obtained:

1. Yield of dry matter was not influenced by seeding rate, row spacing or grass grown with the alfalfa. The varieties did not differ significantly in total yield although both varieties decreased in yield with each successive cutting.
2. Plant population in both varieties increased with increased seeding rate and with closer row spacing. Grass association did not influence alfalfa plant population. Vernal maintained a higher population than did DuPuits.

Both varieties decreased in plant numbers during the season.

3. Stem number per unit area and per plant increased with higher seeding rates and with closer row spacing. Grass association did not influence stem number in alfalfa. Both varieties increased stem numbers as the season advanced, and Vernal maintained higher stem numbers than DuPuits.

4. Stem size was not influenced by seeding rate or row spacing. When grown in association with orchardgrass, alfalfa stems tended to be slightly larger only in the third harvest. DuPuits stems were approximately 30 percent larger than Vernal stems. Both varieties showed a decrease in stem size as the season advanced.

5. Stem weight was not influenced by seeding rate. Stems were heavier in the third harvest in 12-inch drill rows than in closer rows. Grass association had no influence of stem weight of alfalfa. DuPuits stems were about 20 percent heavier than Vernal stems on a dry weight basis. Stems decreased in weight per 10-inch length in both varieties with advance in season.

6. Leaf percentage was not changed by seeding rate or row spacing of alfalfa or by growing grass with the alfalfa. Vernal was leafier than DuPuits at all harvests. In both

varieties, leaf percentage was lowest at second harvest; leafiness was similar at first and third harvests.

7. Rate of seeding and row spacing had no effect on crude protein content of alfalfa. Protein content was somewhat higher at first harvest when grass was grown with the alfalfa. DuPuits contained a higher percentage of crude protein than Vernal at first and second harvests, even though it had larger stems and lower percentage leaves. The second harvest of both varieties had a higher level of protein than the other harvests.
8. There were highly significant correlations between plant number and stem number per unit area and between size and dry weight of the ten largest stems in each subsample.
9. Plant and stem number per unit area and stem size were related to yield only in the second harvest.
10. Stem size was not related to leafiness nor to crude protein content, except at the second harvest.

It is concluded that, under the conditions of the experiment, seeding rate, row spacing, and orchardgrass grown in association, did not influence yield or crude protein content of Vernal or DuPuits alfalfa to any significant extent during the first growing season.

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A P P E N D I X

Appendix Table 1. The analysis of variance for yields of dry matter

Source of Variation	S.S.	d.f.	M.S.	F
Replication	1.348	2	.674	.345
Treatment	35.409	15	2.361	1.208
Variety (total yield)	1.259	1	1.259	.644
Spacing	27.325	7	3.904	1.998
Spacing x Variety	6.825	7	.975	.499
Rep x Treat. (error)(a)	58.627	30	1.954	
Sub total	127.178	47		
Cutting	1934.966	3	644.989	342.751**
Cutting x Treatment	144.004	45	3.200	1.701*
Variety, 1st cutting	6.475	1	6.475	2.432
Variety, 2nd cutting	34.527	1	34.527	24.989**
Variety, 3rd cutting	.057	1	.057	.029
Variety, 4th cutting	28.475	1	28.475	75.230**
Spacing, 1st cutting	18.451	7	2.636	.990
Spacing, 2nd cutting	22.214	7	3.173	2.297
Spacing, 3rd cutting	22.121	7	3.160	1.600
Spacing, 4th cutting	.401	7	.057	.015
Cutting x Rep.	2.403	6	.400	
Cutting x Rep. x Treat.	133.323	90	1.481	
Total	2310.080	191		

*Significant at the 0.05 level of probability
**Significant at the 0.01 level of probability

Appendix Table 2. The analysis of variance for plant numbers per square foot

Source of Variation	S.S.	d.f.	M.S.	F
Replication	149.851	2	74.926	20.979**
Treatment	16812.964	15	1120.864	298.897**
Variety	2042.325	1	2042.325	571.856**
Spacing	14315.001	7	2045.000	572.605**
Spacing x Variety	455.638	7	65.091	18.226**
Rep. x Treat. (error)(a)	107.142	30	3.571	
Sub total	23675.991	47		
Cutting	17498.162	3	5832.721	111.646**
Cutting x Treatment	5762.888	45	128.064	2.451**
Variety, 1st cutting	462.521	1	462.521	24.521**
Variety, 2nd cutting	1448.702	1	1448.702	64.511**
Variety, 3rd cutting	464.074	1	464.074	27.994**
Variety, 4th cutting	86.001	1	86.001	7.572**
Spacing, 1st cutting	9674.668	7	1382.095	73.272**
Spacing, 2nd cutting	4972.531	7	710.362	31.632**
Spacing, 3rd cutting	2867.405	7	409.629	24.094**
Spacing, 4th cutting	1527.405	7	218.201	19.212**
Cutting x Rep.	182.092	6	30.349	
Cutting x Rep. x Treat.	1970.500	90	21.894	
Total	42483.598	191		

**Significant at the 0.01 levelof probability

Appendix Table 3. The analysis of variance for stem number per square foot as influenced by seeding rate, row spacing, variety, and grass association

Source of Variation	S.S.	d.f.	M.S.	F
Replication	41.420	2	20.710	.053
Treatment	93026.382	15	6201.759	15.850**
Variety	20134.428	1	20134.428	51.457**
Spacing	70289.703	7	10041.386	25.664**
Spacing x Variety	2602.251	7	371.750	.950
Rep. x Treat. (error)	11738.552	30	391.285	
Sub total	104806.354	47		
Cutting	5559.621	2	2779.810	6.328**
Cutting x Treatment	10201.340	30	340.044	.774
Variety, 1st cutting	10443.000	1	10443.000	97.488**
Variety, 2nd cutting	10193.756	1	10193.736	25.591**
Variety, 3rd cutting	1816.096	1	1816.096	5.436*
Spacing, 1st cutting	18802.724	7	2686.103	25.075**
Spacing, 2nd cutting	31216.333	7	4459.4761	11.195**
Spacing, 3rd cutting	21975.645	7	3139.378	1.417
Cutting x Rep.	860.502	4	215.126	
Cutting x Rep. x Treat.	13447.651	60	224.128	
Total	134875.437	143		

*Significant at 0.05 level of probability
**Significant at 0.01 level of probability

Appendix Table 4. The analysis of variance for stem volume (cc) as influenced by seeding rate, row spacing, variety and grass association

Source of Variation	S.S.	d.f.	M.S.	F
Replication	218.337	2	109.169	13.928**
Treatment	2448.304	15	163.220	20.823**
Variety	2093.063	1	2093.063	267.030**
Spacing	220.963	7	31.566	4.027**
Spacing x Variety	134.278	7	19.183	2.447*
Rep. x Treat. (error)	235.150	30	7.838	
Sub total	2901.790	47		
Cutting	4707.233	2	2353.616	109.541**
Cutting x Treatment	731.129	30	24.371	1.134
Variety, 1st cutting	1386.75	1	1386.75	110.961**
Variety, 2nd cutting	627.130	1	627.130	73.920**
Variety, 3rd cutting	287.630	1	287.630	35.153**
Spacing, 1st cutting	130.146	7	18.592	1.488
Spacing, 2nd cutting	84.333	7	12.048	1.420
Spacing, 3rd cutting	314.286	7	44.898	5.487**
Cutting x Rep.	43.293	4	10.823	
Cutting x Treat.	639.761	60	10.663	
Total	9023.206	143		

*Significant at 0.05 level of probability
**Significant at 0.01 level of probability

Appendix Table 5. Analysis of variance for stem weight as influenced by plant spacing and variety

Source of Variation	S.S.	d.f.	M.S.	F
Replication	11.987	2	5.994	9.264**
Treatment	86.855	15	5.790	8.950**
Variety	67.445	1	67.445	104.243**
Spacing	10.470	7	1.496	2.312
Spacing x Variety	8.940	7	1.277	1.974
Rep. x Treat. (error)	19.410	30	.647	
Sub total	118.251	47		
Cutting	241.689	2	120.844	62.789**
Cutting x Treatment	48.795	30	1.627	.845
Variety, 1st cutting	50.553	1	50.553	34.121**
Variety, 2nd cutting	7.873	1	7.873	22.854**
Variety, 3rd cutting	18.563	1	18.563	28.946**
Spacing, 1st cutting	16.086	7	2.298	1.551
Spacing, 2nd cutting	3.247	7	.464	1.346
Spacing, 3rd cutting	19.031	7	2.719	4.239**
Cutting x Rep.	4.058	4	1.014	
Cutting x Rep. x Treat.	54.613	60	.910	
Total	467.406			

*Significant at 0.05 level of probability
**Significant at 0.01 level of probability

Appendix Table 6. The influence of spacing and variety on leaf-stem ratio in alfalfa

Treatment Number	Cutting 1st 5/25/63	2nd 7/18/63	3rd 9/3/63	Average leaf-stem-ratio
Vernal				
1	.666	.666	.917	.750
2	.807	.603	.967	.792
3	.799	.651	.789	.746
4	.904	.637	.912	.818
5	.853	.718	.810	.794
6	1.211	.695	1.153	1.020
7	.983	.784	.891	.886
8	.785	.630	.899	.771
Average	.876	.673	.917	.822
	1st 5/25/63	2nd 7/9/63	3rd 8/26/63	
DuPuits				
9	.739	.643	.825	.736
10	.696	.593	.724	.671
11	.759	.702	.758	.740
12	.756	.568	.768	.697
13	.678	.655	.735	.689
14	.864	.694	.786	.781
15	.857	.701	.687	.748
16	.771	.585	.753	.703
Average	.765	.643	.754	.721
Total Average	1.641	1.316**	1.671	1.543

Second cutting $<$ First and third cutting

Standard error of differences between cutting means = .0874

L.S.D. 5% (cutting means) = .1745

1% (cutting means) = .2319

Appendix Table 7. The analysis of variance for percentage leaves in alfalfa as influenced by plant spacing and variety

Source of Variation	S.S.	d.f.	M.S.	F
Replication	13.245	2	6.623	.328
Treatment	706.814	15	47.121	2.334*
Variety	305.288	1	305.288	15.124**
Spacing	298.911	7	42.702	2.116
Spacing x Variety	102.615	7	14.659	.726
Rep. x Treat. (error)	605.552	30	20.185	
Sub total	1325.612	47		
Cutting	910.212	2	455.106	33.565**
Cutting x Treatment	475.551	30	15.852	1.169*
Variety, 1st cutting	102.275	1	102.275	3.754
Variety, 2nd cutting	14.127	1	14.127	1.840
Variety, 3rd cutting	267.294	1	267.294	21.624**
Spacing, 1st cutting	316.011	7	45.144	1.657
Spacing, 2nd cutting	147.338	7	21.048	2.741*
Spacing, 3rd cutting	128.182	7	18.312	1.481
Cutting x Rep.	63.205	4	15.801	.540
Cutting x Rep. x Treat.	813.533	60	13.559	
Total				

*Significant at 0.05 level of probability
**Significant at 0.01 level of probability

Appendix Table 8. The analysis of variance for crude protein percentage in alfalfa as influenced by plant spacing and variety

Source of Variation	S.S.	d.f.	M.S.	F
Replication	2.617	2	1.309	.535
Treatment	100.873	15	6.725	2.748**
Variety	46.569	1	46.569	19.028**
Spacing	24.764	7	3.538	1.446
Spacing x Variety	29.539	7	4.220	1.724
Rep. x Treat. (error)	73.423	30		
Sub total	176.912	47		
Cutting	712.221	2	356.111	83.209**
Cutting x Treatment	247.063	30	8.235	1.924**
Variety, 1st cutting	22.991	1	22.991	15.820**
Variety, 2nd cutting	113.929	1	113.929	46.757**
Variety, 3rd cutting	13.324	1	13.324	6.685*
Spacing, 1st cutting	78.463	7	11.209	7.710**
Spacing, 2nd cutting	4.344	7	.621	.255
Spacing, 3rd cutting	20.342	7	2.935	1.472
Cutting x Rep.	10.248	4	2.562	
Cutting x Rep. x Treat.	103.068	60	1.718	
Total	1249.512	143		

*Significant at 0.05 level of probability
**Significant at 0.01 level of probability