EFFECT OF SEEDING RATE AND HARVEST MANAGEMENT ON YIELD AND STAND PERSISTENCE IN ALFALFA (*MEDICAGO SATIVA* L.)

by

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ABSTRACT

Two experiments were conducted at Tucson, Arizona during 1963 and 1964 to determine the effects of harvest management and seeding rate upon forage production, plant survival, number of stems and buds per plant, crown diameter, dry weight of roots and crowns per plant, and plant height of Sonora alfalfa.

Experiment I

Plants sown at eight different seeding rates ranging from 1.12 to 143.76 kg/ha were harvested at the 50 per cent bud and 25 per cent bloom stages of growth. Greater forage yields were obtained from heavier seeding rates than from light seeding rates. During the first year, extremely high seeding rates caused a decrease in forage yield. Average forage production was higher during the first year than the second. More forage was produced from plants cut at 25 per cent bloom than from those cut at 50 per cent bud.

Per cent plant survival was highest in plots with the lowest seeding rates and the lowest per cent survival occurred in plots with the highest seeding rates. Actual number of plants surviving was highest in plots seeded at the high seeding rates and the fewer plants remained in thinly seeded plots.

The average number of stems and buds, crown diameter, and root and crown weight per plant was greatest in plots seeded at the lowest rate. The magnitude of these variables became progressively smaller with each increase in seeding rate. Also the magnitude of these variables was greater for plants harvested at the 25 per cent bloom stage of growth but only the weight of roots and crowns were significantly different under the two harvesting practices.

Plants were tallest in thinly seeded plots and shortest in the densely seeded plots. Differences in plant height among seeding rates were greatest during the first year.

Experiment II

Alfalfa plants established at six different densities were cut at 25 per cent bloom stage of growth during 1963 and 1964. Larger forage yields and shorter plants were observed in plots of high density whereas the reverse was observed for plants growing in thin densities.

Average number of stems and buds, crown diameter, and weight of roots and crown were larger in thinner stands compared with these variables in plants having higher stand densities.

INTRODUCTION

Alfalfa (*Medicago sativa* L.) is the oldest crop grown solely for forage, and is the most important forage crop grown under irrigated conditions of the Southwestern United States. From a livestock standpoint, alfalfa is unsurpassed for feed. It is a valuable soil improver and usually produces a stimulating effect on the succeeding crop.

Among the criteria used in determining the value of any forage crop are production and stand persistence. Stand persistence and productiveness can be, and often are, greatly influenced by frequency of harvest and stage of growth at harvest. Any method that improves persistence and productiveness would be of importance in alfalfa production. Much research has been conducted which showed that early or frequent cutting of alfalfa causes rapid stand depletion. A reduction in stand is usually followed by a subsequent decrease in forage yield. Deferred harvesting until the full-bloom stage of growth has usually been accompanied by an increased life of stand.

Some research has been conducted on seeding rates and stand densities of alfalfa. Much of this research indicated that seeding rates above ten pounds per acre did not significantly increase yield. However there has been little research to determine if high seeding rate will compensate for rapid stand decline under frequent cutting. The purpose of seeding rates in the present study is to determine if high seeding rate will increase forage production and stand persistence.

The primary objectives of this investigation were:

1. To determine forage production under different seeding rates, stand populations, and harvesting frequencies.
2. To determine if high seeding rates will deter a rapid stand decline under frequent harvesting conditions.
3. To determine effect of stage of growth at harvest and seeding rate upon stand persistence, plant height and stem, bud and crown development.

LITERATURE REVIEW

Effects of Harvest Management on Yield

Numerous investigators (8, 11, 15, 26, 29, 36, 38) working with alfalfa have shown that frequent and consistent removal of immature topgrowth generally results in a drastic reduction in forage yields. Results obtained by Kust (25) showed that yields of alfalfa hay were significantly reduced when four, five, or six cuttings were made each year rather than three cuttings. Kust's results further indicated that with each increase in number of cuttings there was a decrease in total yield. Woodman et al. (42) working at the Cambridge Station in England compared the relative effects of taking five cuts at the pre-bud stage, three cuts at the bud stage, and three cuts at the flowering stage of growth. In a very dry season, they found that consistent early cutting reduced the total yield. Yields were only 84.4 and 52.5 per cent as great when harvested in the bud and pre-bud stages of growth respectively as when cut at full bloom. Jackobs and Oldemeyer (23) reported that increasing the number of cuttings per season from three to four and from four to five, reduced seasonal yields an average of 0.77 and 0.96 tons per acre respectively.

Willard et al. (39) working with alfalfa in Ohio, found that no other management problem is comparable in importance to the time of harvest and number of cuttings. The yield and quality of the hay obtained and the longevity of the stand depend primarily on the cutting system adopted. Research of Buller and Sanchez (2) showed that alfalfa cut at one-tenth bloom and at mid-bud stages produced significantly higher yields than plants harvested at more immature stages. These workers reported that alfalfa harvested at one-tenth bloom during a four-year period, yielded 26.9 tons of hay per acre for 24 cuttings. This compared to a total of 16.8 tons per acre for 30 cuttings made at the pre-bud stage of growth. In Oklahoma, Graumann et al. (20) also found that removal of the first cutting at one-fourth bloom as compared with pre-bud cutting increased the succeeding pre-bud cutting by 75 per cent. Likewise, the substitution of a first cutting at one-fourth bloom for the pre-bud cutting increased the total yield of hay in 1946 by one-third over pre-bud harvesting only. Evans et al. (13) reported with timothy that forage yields and corm weights were inversely related to clipping frequency.

Work in England by Woodman and Evans (41) showed that plots cut systematically at the pre-bud stage of growth yielded only 52.5 per cent as much forage as plots cut at the flowering stage. During the second year of treatment, plants cut at pre-bud produced only 26.8 per cent as much forage as those cut when flowering. Under Connecticut conditions, Brown and Munsell (1) reported highest alfalfa forage yields from plants cut three times per year at intervals exceeding 50 days each. Lowest yields under these conditions were obtained from plots cut two times per year at intervals of less than 40 days. In all but one instance, the yields of dry matter for the two cutting systems were higher in the second than the first year, but for the systems with three cuttings, yield was always lower the second year when compared with first year yield. Robison (31) reported from work conducted in Arizona that harvesting alfalfa plants at the 50 per cent bud stage of growth resulted in greater decline of forage yield, carbohydrate root reserves and general vigor of plants than when harvested at 25 per cent bloom.

Under Iowa conditions, Gross, Wilsie and Pesek (21) have shown that some alfalfa varieties have greater flexibility in cutting management than others. Results of studies in 1954 and 1955 indicated that Vernal out-produced Atlantic, Buffalo, Grimm, Ladak, Ranger, and Narragansett under both a one-tenth bloom cutting treatment and a simulated grazing condition. Davies (7) observed that all varieties do not respond in the same way to frequency of cutting. He reported that some varieties give a reasonable yield under a wide range of cutting frequencies while others are more exacting in their requirements. Davies concluded that early maturing varieties such as Du Puits and Chartainvilliers were more flexible in their management requirement than were late maturing varieties such as Grimm and Rhizoma. In England, Ridgman et al. (30) demonstrated that the variety of alfalfa used has a pronounced effect on establishment, persistence, recovery from defoliation, early spring growth, and total yield when grown in an alfalfa-grass association. These workers stated that the yield of a variety was closely associated with that variety's ability to establish itself.

Effect of Fall and Spring Clipping on Yields

Several investigators have shown that fall and spring cutting treatments have a pronounced effect upon subsequent forage yields. Jackobs (22) experimented with spring clipping of alfalfa followed by cutting intervals varying from 25 to 41 days. Under conditions prevailing in the State of Washington, he found that spring clipping had little effect on the total yield, but forage from the first cutting following spring clipping was definitely of higher quality. He also stated that a late fall cut retarded spring growth. Later research conducted by Jackobs and Oldemeyer (23) gave substantially the same results. Law and Patterson (27) reported a 15.6 per cent yield reduction for alfalfa plants cut in the spring as compared to yields from plants receiving no spring cutting. Dent (8) also indicated there was no advantage in taking a spring cut before the crop had reached a height of about 18 inches, and that cutting at 12 inches resulted in a reduced total yield.

Harvest Management Reflected in Subsequent Years

Several investigators have shown that cutting treatments followed in one year are reflected in forage yields of succeeding years. Graumann et al. (20) found that the relative yields in 1948 for alfalfa plants harvested in the pre-bud and one-tenth bloom stages of growth in 1947 were 100 and 102 per cent respectively while for the more mature harvest stages the range was from 119 to 129 per cent. Woodman et al. (42) reported that when a plant which had previously been cut at a flowering stage was subjected to a pre-bud cutting treatment it produced nearly two and one-half times as much forage as a plant which had previously been cut at pre-bud. Jackobs (22) showed that alfalfa cut every 25 days during 1947 and 1948 produced only 90.5 per cent as much dry matter in 1949 as plants cut at 41-day intervals the two previous years. Gross et al. (21) showed that alfalfa plants previously cut for hay in 1954 and 1955 yielded 6,528 pounds per acre in 1956 while those cut frequently during 1954 and 1955 yielded only 5,502 pounds of dry matter per acre during 1956. Graber and Sprague (19) reported that plants receiving deferred summer cuttings in 1931, 1932, and 1933 produced 36 per cent greater yields in 1934 when compared with plants receiving early cutting treatments. Jackobs and Oldemeyer (23) believed that reduction in yield because of cutting treatments could be attributed mainly to depleted root reserves and not to a permanent reduction in plant vigor. They found no significant residual effect, except in plants receiving a fall cutting treatment. Feltner and Massengale (15) reported that numerous cuttings during periods of cool temperatures may not be detrimental to stand and subsequent forage yields, if cuttings are delayed during periods of high temperature.

Gräber and Sprague (19) showed that the removal of vegetative cover in late fall without reducing storage of root reserves lowered yield by 26 per cent on soils moderately low in fertility. Under similar conditions, both the elimination of vegetative cover and the lowering of root reserves reduced subsequent forage production by 46 per cent. Dexter (9) likewise found that late fall cutting had detrimental effects upon subsequent yields of alfalfa.

Influence of Seeding Rate and Stand Density Upon Forage Yield

Alfalfa research conducted in Ohio by Williams (40) indicated nonsignificant increases in forage production from rates of seeding higher than 10 pounds per acre. Other research conducted in Ohio by Willard et al. (39)

where seeding rates of 2.5 to 50 pounds per acre were used indicated no significant increase in forage production for rates of seeding greater than 10 pounds per acre. The increased yield of forage from a 10 pound per acre seeding rate over a 7.5 rate was only four per cent. In England, Zaleski (43) obtained significantly lower alfalfa yields from a five pound per acre seeding rate than from a 10 pound per acre rate, but observed no significant difference in yield between seeding rates of 10 and 15 pounds. Carmer and Jackobs (3) studied seeding rates of 4, 8, 12, and 16 pounds of seed per acre in four- and eight-inch row spacing and broadcast seedings. They observed that total seasonal yields were higher at the eight pound seeding rate than at the four pound rate but no additional yield increase was obtained at the 12 and 16 pound rates.

Donald (10) conducted experiments to determine the influence of density, stage of growth and fertility level on competition among annual pasture plants. In 1948, he studied subterranean clover using seven seeding rates ranging from 6 ounces to 1800 pounds per acre. In a closely related experiment he seeded Wimmera ryegrass, using seeding rates of 7 ounces to 1400 pounds per acre. The results of these two closely related experiments indicated that in populations of sufficiently low densities no competition occurred at any stage of growth. As densities were increased, the stage of growth at which competition became evident was progressively earlier, until in very dense stands competition began at emergence. Maximum yield of Wimmera ryegrass was obtained at 70 pounds per acre and yields continued at this level for all higher seeding rates. There was some indication from Donald's work that as the nutrient level falls, competition becomes more acute and fewer plants are needed to fully exploit the environment.

Fribourg and Kennedy (16) in a two-year study, reported that alfalfa yield was independent of the mixture when seeded with grasses during the first year of production and dependent on it at only one of the three locations in the second year. On the other hand, Chamblee and Lovvorn (4) found that at high seeding rates grass reduced the total number of alfalfa plants and subsequent yield. The influence of plant population on yield in an alfalfa-cocksfoot ley was demonstrated by Garner and Sanders (17). They found that alfalfa drilled at a constant seed rate per acre, in narrow rows (3.5 and 7 in.), gave a greater yield per acre than when drilled in rows 10.5 and 14 in. in width. Cocksfoot broadcast within plots at time of seeding the alfalfa led to a large increase in total yield within plots.

In South Dakota, Rumbaugh (33) positioned young plants of Ranger and Teton alfalfa equidistant from each other at spacings of 42, 21, 10.5, and 5.25 inches. He reported that crown width and stem number showed a closer association with yield than did length of longest stem. However, it was found that stem length was the most important component of the three at the widest spacing. Rumbaugh concluded that selection based upon yield in spaced clonal nurseries may not accurately portray the forage potentials of genotypes in solid seeding. Feltner and Massengale (15) reported plant density and plant height were more closely related to forage yield in plants of Moapa than in Lahontan and within Moapa these variables were more closely related in plants harvested more frequently.

Jarvis (24) compared eight different plant populations of alfalfa. The distances between plants being 1, 2, 3, 6, 9, 12, 24, and 36 inches with equidistant spacing. He found that as plant population increased, the yield of alfalfa increased rapidly up to a level of about 750,000 plants per acre. This plant population corresponds to the three-inch equidistant spacing. Further increases in plant population led to much smaller increments in yield. Jarvis believed that yield per acre would reach maximum only when plant population was infinite.

Willard (37) working in Ohio with alfalfa and sweet clover reported no significant correlation between stand count and yields; however, older stands were not distinguished from younger stands in this study. Contrary to Willard's data, Ronningen and Hess (32) showed that correlations of stand counts with third-year yields of alfalfa were highly significant. Cowett and Sprague (6) reported that increasing stand density of alfalfa from one to eight plants per square foot decreased number of stems and dry weight per plant, although yield per acre increased. Marten et al. (28) in an experiment designed to study the effect of alfalfa plant density upon productivity of an alfalfa-bromegrass sward under differential nitrogen treatments reported that yields of mixed stands of alfalfa and bromegrass ranged from 4.43 tons per acre where two alfalfa plants remained per square foot up to 5.19 tons per acre where no thinning of plants was done. These yields compared with 3.41 tons per acre for the pure bromegrass stand.

Effect of Harvest Management and Stand Density on Number of Stems and Crown Diameter

Graber et al. (18) reported that although frequent harvesting of topgrowth ultimately reduced the yield and vigor of alfalfa, there was an apparent immediate increase in number of new shoots and stems per plant. These results followed premature cutting early in the growing season. Cowett and Sprague (6) showed that alfalfa stem production per plant decreased as stand density was increased. They found that stem production per plant was not always closely associated with yield. Gross et al. (21), in an experiment using eight alfalfa varieties, stated that plants cut frequently exhibited smaller crown and root diameters. Plants cut frequently also had fewer stems per crown and were generally less vigorous than plants cut at a more advanced stage of growth. Robison (31) reported that Moapa alfalfa plants harvested at 25 per cent bloom had crown diameters approximately seven mm larger than plants harvested at the 50 per cent bud stage. He reported no significant difference in number of stems per plant because of stage of growth at harvest. Feltner (14), using three harvest treatments, showed that as number of plants decreased, average crown diameter and weight of roots increased regardless of cutting treatment. Cowett and Sprague (6) stated that each of 17 significant factors were found to be associated with number of stems per plant when considered independently. Stand density and light intensity were significantly related to the number of stems per plant when considered alone. However, when all variables were considered together, stand density, soil and air temperature and light intensity were only of minor importance.

Investigators (19, 34, 35) indicate that stand count may be misleading. Graber and Sprague (19) stated that stand counts may be misleading because crown size is more dependent on available space than varietal characteristics among similar varieties. Tysdal and Kiesselbach (35) reported findings similar to those of Graber and

Sprague. They concluded that plant numbers in excess of those needed for most efficient ground cover do not necessarily contribute to greater yield. Salmon et al. (34) working in Kansas, have shown that vigor and vitality of plants, in a stand, may be more important than plant numbers.

MATERIALS AND METHODS

This study was conducted under field conditions at the University of Arizona's Casa Grande Highway Farm. Certified Sonora alfalfa seed was used in all experiments.

One hundred and twelve kg per hectare of actual phosphorus, in the form of treble super phosphate, were applied and incorporated into the soil during seedbed preparation. Two-thirds of the land used in these experiments was Comore sandy loam with the west one-third of the field being Grabe sandy clay. All seeding was done with a hand cyclone seeder on September 20, 1962. Immediately after seeding, the soil was firmed with a Brillion culti-packer seeder. All borders were irrigated four days after planting to insure adequate moisture for seedling emergence. Data reported in this thesis were obtained during 1963, 1964, and 1965.

Two experiments were conducted in connection with this study. In Experiment I, the field design was a split-plot with four replications. The total land area consisted of four borders. The main plots were cutting the plants when approximately 50 per cent of the plants had visible buds (50 per cent bud) and when 25 to 30 per cent had one or more open flowers (25 per cent bloom). Subplots consisted of eight different seeding rates. The seeding rates used were 1.12, 2.25, 4.49, 8.99, 17.97, 35.94, 71.88, and 143.76 kilograms per hectare. The subplots (seeding rate) were 7.62 meters square. There were no alleys between plots. A five-meter guard strip was left at the east end of each border where the irrigation water was released. Guard strips at the west end of each border varied from 3 to 11 meters depending on the length of the border. The cutting schedule previously described was followed during the three years of this study except on April 26, 1963 when all plots were initially harvested at the same time. During the first two years data were taken at each harvest on all variables studied. No data were taken during the third year, but harvests were made at the same stage of growth as during the two previous years.

During late December of 1962 and early January of 1963, plant counts were taken in a 5.18 x 7.62 m area of each plot. The height of plants during the period that plant counts were taken ranged from 2.5 to 18 cm, with the average being 10 cm. The number of plants within a 30.48 x 60.96 cm area was taken at 25 locations picked at random within this 5.18 x 7.62 m area. These areas were then staked and the location of each stake was recorded on a field map so that this exact same area could be found at a future date in determining plant survival.

Stand depletion was evaluated by comparing the number of plants dug throughout the study with the number of plants present during the original count. After three harvest years a visual estimate was made to determine the percentage of ground cover within plots. Root samples were taken at each forage harvest. At each root sampling, the frame was placed in the same spot as for the original count and the surface of the soil was marked on the outside of the wooden frame used in counting. The plants within this area were dug. All areas dug in these samplings were reseeded to alfalfa to discourage weed growth. After digging, the number of plants was counted and the roots and crowns of all plants were washed. Stem and bud counts were made after the plants were clipped at 3.8 cm above the base of the crown. The taproot was clipped 15.2 cm below the base of the crown. The number of stems and buds at least 0.5 cm in length and the diameter of the crown were recorded. No differentiation was made between buds and stems in this study. Crown diameter measurements were obtained by measuring the widest portion of the crown. In samples which had fewer than 25 plants, all plants were measured. In those samples with more than 25 plants, 25 plants were selected at random, and data on stem and crown characteristics obtained. At each harvest, all roots and crowns were dried in a forced-air drier at 65 to 70 C. The weight of the dried roots and crown from each plot was recorded.

Forage yields were determined by cutting strips .91 m in width the entire length of each plot with a Milbrant power mower and weighing. An area 2.44 m wide running the length of the plot was used for this purpose. A green weight sample was taken from Replications II and IV, dried in a forced-air drier at 65 to 70 C, then reweighed and used for dry matter calculation.

Height measurements were made throughout the study. Initial measurements were made April 6, 1963 and at each harvest thereafter. The portion of the border being used for forage samples and yield data was also used for height measurement of plants. Four height measurements were made at random within each plot. Height data were obtained by measuring the distance from the soil level to the terminal bud of the longest stem on that plant.

Experiment II was located in a small area of an adjacent border. This border was seeded with Sonora alfalfa at the rate of 17.97 kilograms per hectare. The portion of the border with the most uniform stand was selected for this study. The experimental design was a randomized complete block with six replications. Treatments consisted of six plant densities of .5, 1, 2, 4, 8, and 18 plants per 929 cm^2. Individual plots were 1.83 m square. All plots were set off from one another by .91 m alleys around each plot. The initial hand thinning of the plants to the desired densities was done about the middle of January of 1963. Final thinning was completed in late February of the same year.

All harvests in this experiment were made when the plants were in the 25 to 30 per cent bloom stage of growth.

Forage yields, height measurements, and dry weight samples were made in the same manner as in Experiment I. Replications I, III, and V were used in determining dry weight percentages. Stem, bud, and crown measurements were made only on April 12, 1965 in Replication II. The method previously described was used in obtaining these measurements.

Both experiments were irrigated frequently enough to provide maximum growth. Insects were controlled by dusting with a commercial insecticide containing 15 per cent toxaphene, 5 per cent DDT, and 40 per cent sulfur.

RESULTS AND DISCUSSION

Two field experiments were conducted to determine the influence of seeding rate and stage of growth at harvest on forage production, plant survival and various plant characteristics associated with yield of alfalfa. The data from each experiment are discussed separately.

Experiment I

Forage Production

The total yield of dry matter for 1963 and 1964 was recorded for each sub-plot (seeding rate) under the two management systems. Average forage yields for each seeding rate during the two years are shown in Table 1. The analysis of total forage for the two-year period (Table 2), showed that differences between seeding rates were significant at the one per cent level. Dry matter production was highest from plots seeded at the rate of 17.97 kg/ha. The only plots which produced significantly less forage were those seeded at 1.12 and 2.25 kg/ha. The seeding rate which produced the smallest amount of dry matter for the two-year period yielded 84 per cent as much forage as the top-producing seeding rate (17.97 kg/ha). First-year forage production (Table 1) was highest from plants seeded at the rate of 17.97 kg/ha, and lowest from plants seeded

Table 1. Mean separations[1/] for several variables taken on alfalfa plants during 1963 and 1964 when seeded at eight different rates.

Variable	Year	Seeding rate kg/ha 1.12	2.25	4.49	8.99	17.97	35.94	71.88	143.76
Forage production (kg/plot)	1963	12.6 c	13.5 bc	13.4 bc	14.8 a	15.1 a	14.7 a	14.6 a	14.0 ab
	1964	9.7 c	10.3 bc	11.2 ab	11.3 ab	11.4 a	11.6 a	11.6 a	11.9 a
Per cent plant survival	1963	101.1 a	91.4 a	90.1 a	62.2 b	48.2 b	44.4 b	21.9 c	12.8 c
	1964	45.9 a	30.4 abc	35.2 ab	26.0 abcd	22.6 abcd	17.9 bcd	11.4 cd	7.0 d
No. of stems & buds/plant	1963	22.4 a	16.9 b	13.6 c	9.5 d	8.1 de	6.6 e	6.0 e	6.0 e
	1964	26.5 a	20.1 b	19.1 b	15.8 c	12.9 d	10.1 e	10.8 de	9.9 e
Crown diameter (mm)	1963	26.4 a	22.2 b	18.6 c	15.5 cd	12.6 de	10.4 ef	9.1 f	8.9 f
	1964	41.1 a	35.5 b	32.6 b	28.4 c	23.8 c	20.5 d	20.0 d	18.2 d
Root & crown weight/plant	1963	6.2 a	4.2 b	3.4 b	2.1 c	1.5 cd	1.0 de	.7 e	.5 e
	1964	10.0 a	7.4 b	6.6 b	4.8 c	3.8 d	2.7 e	2.8 e	2.3 e

Table 1.--Continued

Plant height (cm)	1963	66.6	64.5	62.2	64.5	60.6	60.9	58.2	54.8
		a	ab	bc	ab	cd	c	d	e
	1964	59.1	58.6	59.0	59.1	58.2	57.2	56.9	56.9
		a	a	a	a	a	a	a	a

1/Means with same letters are not significantly different using Duncan's multiple range test (12).

Table 2. Mean separations[1/] of several variables evaluated on alfalfa plants during 1963 and 1964 when seeded at eight different rates. A summation of Table 1 giving average for the two-year period.

	Seeding rate (kg/ha)							
	1.12	2.25	4.49	8.99	17.97	35.94	71.88	143.76
Forage production kg/plot	11.2 bc	11.8 bc	12.3 ab	13.1 a	13.2 a	13.1 a	13.1 a	13.0 a
Per cent plant survival	73.5 a	60.9 a	62.3 a	44.1 b	35.4 b	31.1 b	16.6 c	9.9 c
No. of stems & buds/plant	24.4 a	18.5 b	16.4 b	12.6 c	10.5 cd	8.4 d	8.4 d	7.9 d
Crown diameter (mm)	33.8 a	28.9 b	25.6 c	20.9 d	18.2 de	15.4 ef	14.6 f	13.8 f
Root & crown weight (g/plant)	8.1 a	5.8 b	5.0 b	3.4 c	2.7 cd	1.8 de	1.8 de	1.4 e
Plant height (cm)	62.9 a	61.6 ab	60.8 bc	61.8 a	59.4 cd	59.1 de	57.6 e	55.8 f

[1/] Means with similar letters are not significantly different using Duncan's multiple range test (12).

at 1.12 kg/ha. During the second year (Table 1) the 1.12 kg/ha seeding rate produced the lowest yield, and each consecutively higher seeding rate produced larger yields of forage. Excessively high seeding rates actually caused a slight reduction in forage yield during the first year of production, but during the following year forage production was higher than that obtained from lower seeding rates. Data from this research indicated that when alfalfa was harvested for two years seeding rates above 17.97 kg/ha (16 lbs/a) were not justified.

Plants in all seeding rates were not at the same stage of development at time of harvest (25 per cent bloom). The average per cent of plants flowering at time of harvest varied from 49 per cent in the 1.12 kg/ha seeding rate, to 15.1 per cent in the 143.76 kg/ha seeding rate. The average per cent of plants flowering within all sub-plots at time of harvest was 28.7 per cent. Thinly seeded plants were therefore harvested at a more advanced stage of growth and possibly could have produced more harvests per year than heavily seeded stands if each seeding rate were harvested separately when the plants were at 25 per cent bloom.

Total forage analysis for the two-year period showed a significant difference, at the five per cent level, between the 50 per cent bud and 25 per cent bloom management practices. The bud-harvested plants produced only 87 per cent as much forage as those plants cut at 25 per cent bloom. The bloom plots produced essentially the same amount of forage each year. First-year forage yields of plants harvested at 50 per cent bud were significantly higher than were forage yields from plants harvested at 25 per cent bloom during both the first and second years and for plants harvested at 50 per cent bud during the second year. Forage yields were 100, 92.2, 90.1, and 57.9 per cent respectively, for plants harvested at 50 per cent bud during the first year, 25 per cent bloom during second year, 25 per cent bloom during first year, and 50 per cent bud during the second year.

Numerous investigators (13, 19, 21, 22, 30, 41) have shown that alfalfa plants respond adversely to frequent cutting. Frequent cutting (50 per cent bud) during the first year is desirable if high quality forage and high yield are prime considerations and the crop will not be grown for forage a second year. However, frequent harvesting may not be economically feasible. Results of too frequent cutting are illustrated in Table 3 when the plants are harvested for forage during the second and succeeding years. The interaction of management practice and seeding rates was not significant. Management practice apparently had no influence upon forage production between seeding rates.

Table 3. Mean separations[1/] for forage yield, per cent survival, number of stems and buds, crown diameter, root and crown weight, and height of alfalfa plants during two years when cut at the 50 per cent bud and 25 per cent bloom stages of growth.

	Harvesting schedule			
	1963		1964	
Variable	50 per cent bud	25 per cent bloom	50 per cent bud	25 per cent bloom
Forage production (kg/plot)	14.8 a	13.3 b	8.6 c	13.7 b
Per cent plant survival	59.3 a	58.7 a	15.3 c	33.8 b
No. stems & buds per plant	10.4 d	11.8 c	14.2 b	17.0 a
Crown diameter (mm)	15.7 c	15.2 c	26.0 b	28.7 a
Root and crown wt. (g/plant)	2.1 d	2.8 c	4.2 b	5.9 a
Plant height (cm)	55.9 b	67.2 a	48.5 c	67.8 a

[1/]Means with same letters are not significantly different using Duncan's multiple range test (12).

The analysis of total forage showed that differences between years were significant at the one per cent level. When averaged over all seeding rates and stage of growth at harvest, forage yields in the first year of the study were 26.5 per cent greater than were yields in the second year. The interaction between seeding rate and years was not significant.

Per Cent Survival

Per cent survival was determined at the last forage harvest in each of 1963 and 1964. Per cent survival for each seeding rate in each year is shown in Table 1. At the end of the first year, per cent survival was slightly above 100 per cent in the 1.12 kg/ha rate (lowest rate). This discrepancy may be due to additional plants emerging after plant counts were made and/or two closely spaced plants being counted as one at time of original plant count. Means of number of plants surviving at the end of one year were found to be significantly different at the one per cent level, with seeding rates of 71.88 and 143.76 kg/ha (highest rates) having a significantly lower per cent survival than rates of 1.12, 2.25, and 4.49 kg/ha (Table 1).

When surviving plant populations were evaluated for actual number of plants present at the end of the first year, plots (30.48 x 60.96 cm area) with the lowest seeding rate contained an average of ten plants. Plots with highest seeding rate contained an average of 43 plants. After two harvest years plots with the lowest and highest seeding rates contained an average of 4.8 and 16.8 plants respectively. After two harvest years essentially the same number of plants remained in the three highest seeding rates. These data indicated that plant survival was not improved by seeding above 35.94 kg/ha.

Harvesting at different stages of growth was found to be nonsignificant in regard to plant survival, but stage of growth at harvest by year interaction was found to be significant at the five per cent level. These data indicated that stand depletion for plants cut at the 50 per cent bud stage of growth did not significantly differ from those cut at 25 per cent bloom until the second harvest year (Table 3). After two years of growth, survival in the bud plots was lowest (15.34 per cent). Figure 1 shows differences observed between management practices after the second year of harvest. Stand survival was higher after one year of production under the 50 per cent bud cutting practice compared with the 25 per cent bloom management plots. Stand survival was drastically reduced as compared to early bloom managed plots at the end of the second year.

Interaction between seeding rate and stage of growth at harvest with regard to plant survival was not significant.

Fig. 1. Photographs showing differences in density of alfalfa plants when seeded at the same rate but harvested for two years at the 50 per cent bud (upper photo) and 25 per cent bloom (lower photo) stages of growth.

Figure 2 illustrates the dramatic differences between time of harvesting at the completion of this study. Figure 3 presents in graphic form the results of visual estimates for ground cover. Much greater ground cover or plant survival occurred when the plants were harvested at 25 per cent bloom.

A highly significant difference in per cent survival was found between years. After one year of growth 59 per cent of the original plants remained when averaged over all seeding rates but after the second year only 24.6 per cent of the original number plants were still alive.

Number of Stems and Buds

The average number of stems and buds per crown under each seeding rate is shown in Table 1. Largest number of stems and buds per plant was observed in plots of the lowest seeding rate. In all but one instance, number of stems and buds per plant decreased with each higher seeding rate. The 71.88 kg/ha seeding rate produced slightly more (.6) stems and buds per plant than did the 35.94 kg/ha seeding rate. However, this difference was not significant. Number of stems and buds per plant among the different seeding rates was found to be significantly different at the one per cent level. During the two years of the study, the 1.12 kg/ha seeding rate was found to have a significantly greater number of stems and buds per plant

Fig. 2. Photograph of alfalfa plots showing differences in stand at the end of three years. Plants at left were cut at 25 per cent bloom and plants at right cut at 50 per cent bud. Note differences in seeding rates within borders.

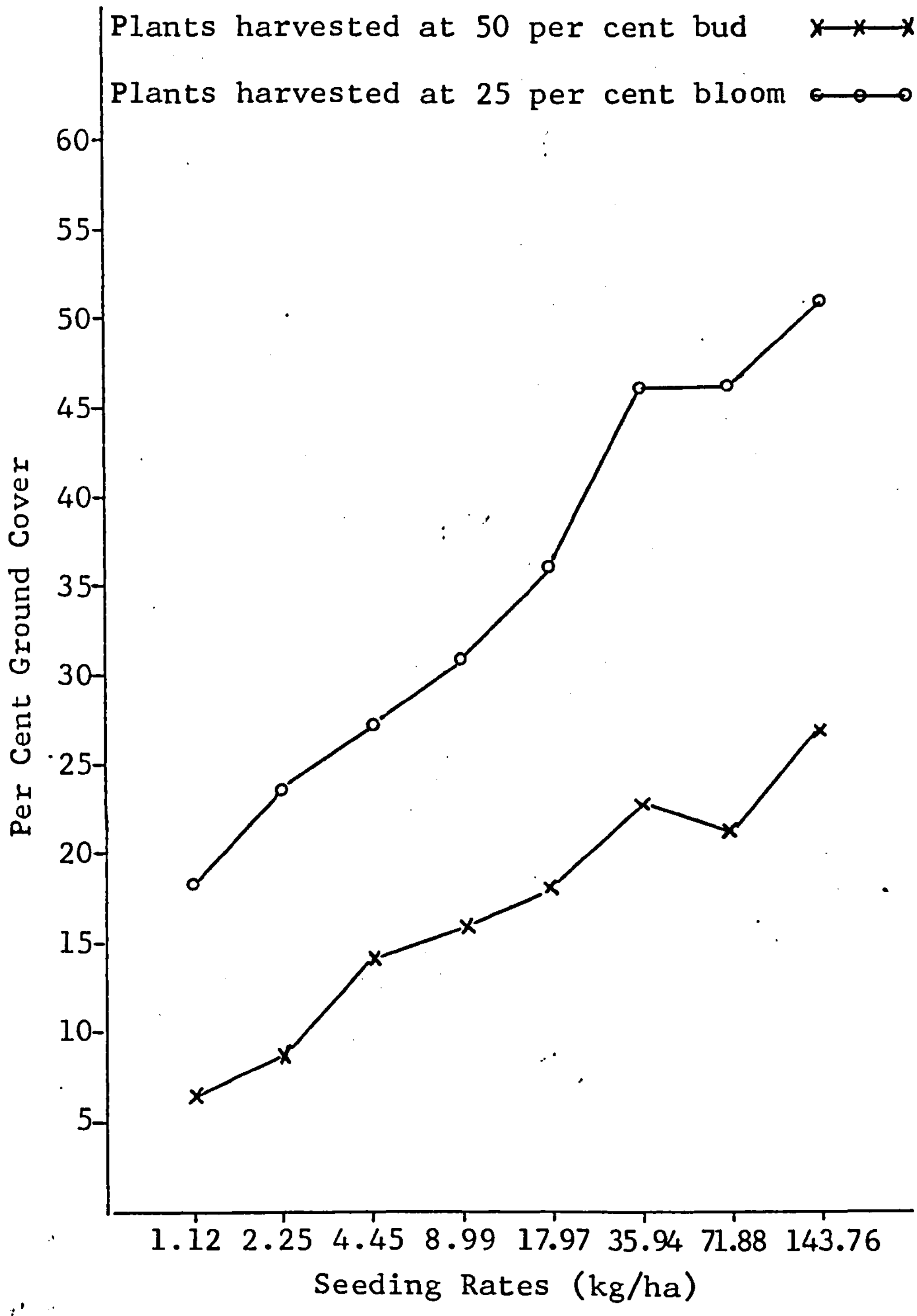

Fig. 3. Percentage ground cover (estimated) for 8 seeding rates. Data were taken on February 16, 1966, after three years harvesting at two stages of growth.

than any other seeding rate producing 3.1 times as many as the 143.76 kg/ha seeding rate.

Cutting alfalfa at the 50 per cent bud or 25 per cent bloom stages of growth did not influence the number of stems and buds. No significant differences in the number of stems and buds were found in the seeding rate by management, seeding rate x year, and management by year interactions. This indicates that although there were differences between seeding rates, these differences were found to be similar regardless of the management practice used and regardless of the year in which these counts were made. Differences did exist between years, but these differences were similar in relationship to management practice used.

A highly significant difference was found between the number of stems and buds per plant during the first and second years of the study (Table 1). When averaged over all seeding rates and time of harvest, the average number of stems and buds per plant was 40 per cent greater the second year than the first year. This increase in stems the second year was undoubtedly due to the increase in size of the crown.

Crown Diameter

Data on the average crown diameter for each of the two years was determined for each seeding rate and are presented in Table 1. Smallest crown diameter was found in the highest seeding rate and crown diameter increased with each decrease in seeding rate. This same trend was observed in root and crown dry weights and number of stems and buds per plant (Table 2). Mean crown diameter, for the two-year period, showed that differences in seeding rate were significant at the one per cent level (Table 4). The influence of harvesting at different stages of growth on crown diameter was not significant.

Crown diameter at the end of the first harvest year was significantly less than at the end of the second year. At the end of the first year, crown diameter was only 56.6 per cent as large as that at the end of the second year. The increase in crown diameter during the second year was due to the growth of plants and the fact that many of the smaller and weaker plants had died.

Seeding rate by harvest management interaction was not significant in relation to crown diameter.

Although no significant differences were found between the crown diameter of alfalfa plants cut at the 50 per cent bud and 25 per cent bloom stages of development during the first year, a significant difference was found between these two times of harvest during the second year (Table 3). Average crown diameter of plants during the second year was found to be 88 per cent larger than that of the first year, when harvested at 25 per cent bloom while

Table 4. Analysis of variance table for different variables studied in Experiment I using eight seeding rates and two stages of growth at harvest during 1963 and 1964. Numbers represent the F values.

Source	df	Forage production	Per cent survival	No. stems & buds/plant	Crown diameter	Root crown wt.	Plant height
Seeding rate	7	6.20**	25.34**	39.55**	60.54**	42.79**	21.29**
Harvest management	1	14.83*	4.91	5.65	1.49	17.19*	848.96**
Year	1	299.75**	90.44**	109.83**	518.50**	380.17**	76.51**
S x M	7	.48	.70	1.56	.83	1.80	.45
S x Y	7	1.50	4.21**	.70	1.60	3.93**	7.18**
M x Y	1	368.70**	6.87*	2.56	9.55**	15.57**	102.01**

*Significant at the .05 level.

**Significant at the .01 level.

the second-year increase in plants harvested at 50 per cent bud was 65 per cent.

No significant difference in crown diameter was found in the seeding rate x year interaction. These results indicated that although seeding rates were significantly different, these differences were similar regardless of year.

Root and Crown Weight

Average root and crown weights per plant for all seeding rates for 1963 and 1964 are shown in Table 1. Average root and crown weights in the 1.12 kg/ha seeding rate were found to be significantly higher (Table 2) than weights from any other seeding rate, and were 5.6 times heavier than roots and crowns dug from the 143.76 kg/ha seeding rate.

Root and crown weight was found to be 37 per cent greater when plants were cut at 25 per cent bloom than when cut at 50 per cent bud. Differences in root and crown weight between years were even greater. Second-year root and crown weights were found to be over two times higher (2.05) than those obtained during the first year and were significantly different at the one per cent level.

Seeding rate by time of harvest interaction was not significant in regard to average root and crown weight per plant, but seeding rate by year interaction was significant at the one per cent level. Alfalfa plants cut at the 25 per cent bloom stage of development produced roots and crowns that were 30 and 40 per cent heavier than roots and crowns from alfalfa plants cut at the 50 per cent bud stage of growth during 1963 and 1964 respectively (Table 3). In 1964 plants cut at 25 per cent bloom produced roots and crowns that were 2.1 times heavier than those dug in 1963, whereas plants cut at 50 per cent bud in 1964 produced root and crown weights that were 2.0 times heavier than those harvested in 1963.

Height

Average height data for plants taken throughout this study are presented in Table 2. The effect of seeding rate upon plant height was found to be highly significant with greatest differences observed during the first year (Table 1). Height of plants in the 1.12 kg/ha seeding rate during the first year of this study averaged 11.9 cm taller than plants in the 143.76 kg/ha seeding rate, but during the second year only a 2.2 cm difference (nonsignificant) was observed. The height of different plant populations was more uniform among seeding rates during the second year than during the first year. Apparently competition for nutrients and moisture under high seeding rates had a deleterious effect upon plant height. During the second year plant density had decreased to a level at which little competition between plants existed, therefore only a small difference in plant height was observed among seeding rates.

A highly significant difference in plant height was found between stage of growth at harvest. As might be expected, plants cut more frequently were shortest at time of harvest. A highly significant difference in height was also observed between years. Plants averaged 3.4 cm taller during the first year than the second. This difference in height is attributed to differences observed in the plots harvested at bud where plants were 7.4 cm shorter the second year than the first year (Table 3). An apparent reduction in plant vigor was undoubtedly related to decreased plant height.

The interaction of seeding rate x management practice was not significant. Although there were highly significant differences in plant height between seeding rates, these differences were found to be similar regardless of the harvest management practices used (Table 1). The interaction of harvest management x year was highly significant. This difference was due to plant height in plots cut at 25 per cent bloom being greater the second year than the first, whereas the reverse was true in the bud plots.

Experiment II

Forage production and plant height of six specific populations of Sonora alfalfa, harvested at 25 per cent bloom were recorded during 1963 and 1964. The plant densities were one-half, one, two, four, eight, and eighteen plants per 929 cm^2. Data on number of stems and buds, crown diameter, and average root weight per plant were taken on April 12, 1965 after the plants had been harvested for two years.

Forage Production

Total forage produced per plot for the two-year period is shown in Fig. 4. Analysis of total forage production showed that differences in forage production between plant densities were significant. During the two years of the study, plant density five (8 plants per 929 cm^2) produced the most forage which was 44 per cent more compared to plant density one (.5 plant per 929 cm^2).

Average dry matter production per plot per harvest for years 1963 and 1964 is shown in Table 5. During the first year plant density one (.5 plant per 929 cm^2) produced significantly less forage per harvest than did any other plant density. Plant density of 18 plants per 929 cm^2 (highest production) produced 55 per cent more forage than did plant density one. During the second harvest year, highest average forage production per harvest

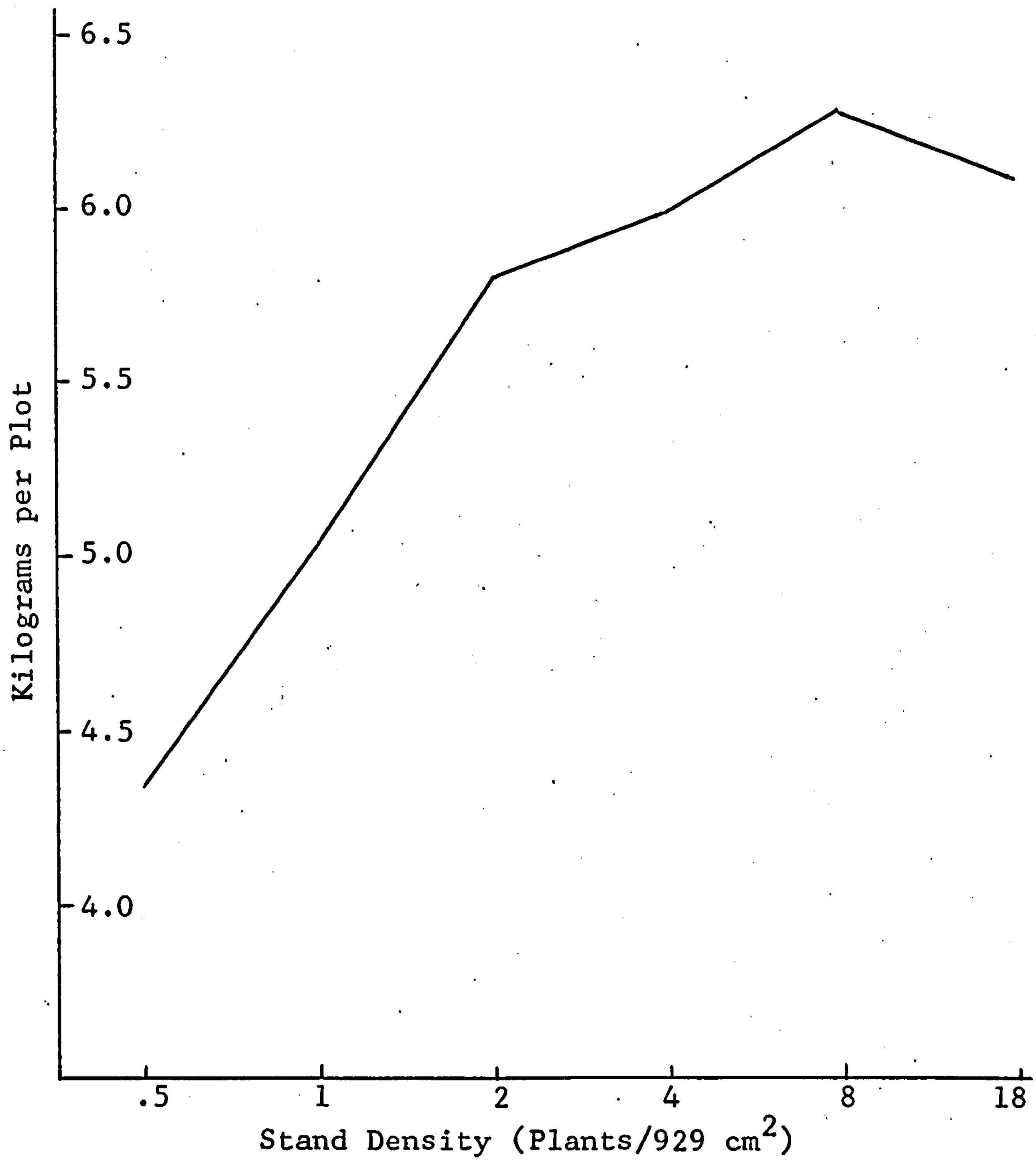

Fig. 4. Total forage production [kg/plot (1.66 m^2)] for each stand density during 1963 and 1964.

Table 5. Average yield of alfalfa per cutting in grams per plot (1.66 m^2) when averaged over all harvests in both 1963 and 1964.

	Plant density (plants per 929 cm^2)					
Year	.5	1	2	4	8	18
1963	282 c	349 b	394 ab	419 a	423 a	437 a
1964	300 c	329 c	380 b	382 ab	416 a	390 ab

was obtained from a plant density of 8 plants per 929 cm^2 which produced 39 per cent more forage than did plant density of .5 plants per 929 cm^2. Differences in forage production between plant densities were highly significant during both 1963 and 1964. Forage yields in Experiment II were not significantly different than yields from comparable stand densities in Experiment I.

Seven forage harvests were taken in 1963 and eight harvests were taken in 1964. The number of days between the first harvest and the last harvest was the same during both years. During 1963, the June 21 harvest produced the most forage which was three times greater than the production on December 13 (Fig. 5). The December 13 harvest produced significantly less forage than all other harvests. In 1964 the April 27 harvest produced 598.5

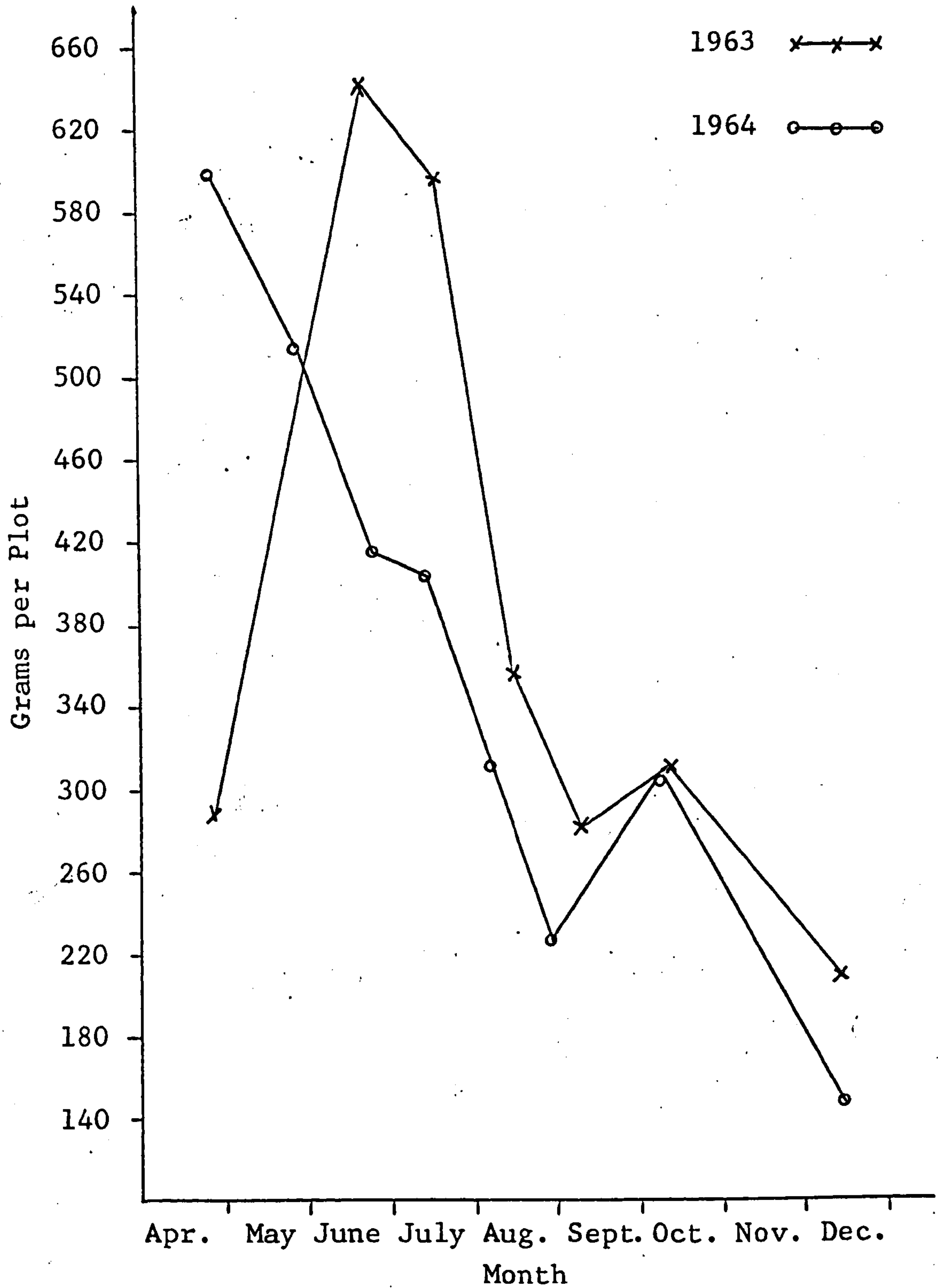

Fig. 5. Average forage production in grams per plot ($1.66\ m^2$) at each harvest during 1963 and 1964.

grams per plot (1.66 m^2), more than four times the yield obtained from the December 14 harvest (Fig. 5). The first harvest of 1963 and the last harvests of both 1963 and 1964 were low because these harvests were made before plants had reached 25 per cent bloom. In the last harvest of each year, considerable frost damage had also occurred at time of harvest. Figure 5 illustrates that under a 25 per cent bloom harvest management system highest production is early in the season and that lower production is obtained at each subsequent harvest with a small increase during the October harvest.

Height

Average plant height for each stand density is shown in Table 6. During the first year, height was inversely proportional to plant density. Plants of the lowest density averaged 13 cm taller than plants in the highest density. During 1964 tallest plants were observed in stand densities of .5, 1, and 2 plants per 929 cm^2 with shortest plants in plant densities of 8 and 18 plants per 929 cm^2. Differences in plant height between plant densities were significantly different at the one per cent level in both years. Plants in Experiment I were an average of six cm taller than were plants from similar stand densities in Experiment II.

Table 6. Average height (cm) of alfalfa plants at time of harvest for each density when averaged over all harvests in both 1963 and 1964.

	Plant density (plants per 929 cm^2)					
Year	.5	1	2	4	8	18
1963	73 a	69 ab	67 bc	63 cd	62 d	60 d
1964	72 a	72 a	71 ab	70 bc	68 d	69 cd

Differences in plant height between harvests were greater than height differences between stand densities. The August 16 harvest produced plants which were 22 cm taller than the December 13 harvest in 1963 and the May 28 harvest produced plants which were 35 cm taller than the December 14 harvest in 1964. Shorter plants were observed in the first and last harvest of each year. Taller plants were observed in harvests three and four during 1963 and in harvests two and three in 1964. Highly significant differences between harvests were found in both years. The harvests at which plants were tallest were not the harvests at which highest forage production was obtained.

Other Variables

Average number of stems and buds, average crown diameter, and average root weight per plant for each plant density are shown in Table 7. As stand density increased, number of stems and buds per plant decreased. Stand density one (.5 plant per 929 cm^2) produced 3.4 times as many stems and buds per plant as did stand density six (18 plants per 929 cm^2).

Plants with the largest crown diameter were found in stand density one (.5 plant per 929 cm^2). Each lower stand density produced plants having a larger crown diameter. Stand density one (.5 plant per 929 cm^2) produced plants with crowns which were 2.7 times larger than stand density six. Stand density four (4 plants per 929 cm^2) produced roots that were heavier than stand density three (2 plants per 929 cm^2). All other stand densities produced progressively heavier root weights as plant densities decreased.

Table 7. Average number of stems and buds per plant, crown diameter, and root weight per plant for plants harvested on April 12, 1965.

	Stand density (plants/929 cm^2)					
Variables	.5	1	2	4	8	18
Stems and buds	62.4	45.4	36.7	36.2	25.1	18.4
Crown diameter (mm)	89.0	66.8	58.4	53.4	41.4	33.3
Root weight (g)	18.2	12.9	9.5	11.1	7.9	5.2

Data on number of stems and buds per plant, crown diameter, and average root and crown weight per plant obtained during this experiment were very similar to data obtained from Experiment I.

SUMMARY

Two experiments were conducted during 1963 and 1964 to determine the effects of harvest management and plant density upon forage production, plant survival, number of stems and buds, crown diameter, dry weight of roots and crowns and plant height of Sonora alfalfa plants. This research was conducted at the University of Arizona's Casa Grande Highway Farm at Tucson, Arizona.

Experiment I

Alfalfa seeded at eight different rates was harvested at the 50 per cent bud and 25 per cent bloom stages of growth. Analysis of variance was used to determine differences between seeding rates and two harvest management practices for 1963 and 1964 and interactions of these factors.

Total forage yields from the different seeding rates varied with year. Highest yield during the first year and for the two-year total occurred in the plots seeded at 17.97 kg/ha. In the second year, highest forage yields were obtained in the plots seeded at 143.76 kg/ha. Each lower seeding rate produced a subsequent lesser amount of forage. Plots seeded at 1.12 kg/ha produced the least forage each year and for the two-year total.

When averaged over all treatments, forage production was higher during the first year than the second. More forage was produced from plants cut at 25 per cent bloom than from those cut at 50 per cent bud. During the two years, highest production was obtained from plants cut at 50 per cent bud the first year and the lowest yield was obtained from these same plants the second year. Alfalfa plants harvested at 25 per cent bloom produced essentially the same for both years.

Per cent plant survival was highest in plots seeded at 1.12 kg/ha with the lowest per cent survival in plots seeded at 143.76 kg/ha for both years. Per cent of plants surviving during the first year was significantly higher than per cent of plants surviving at the end of the second year. Although plants harvested at 25 per cent bloom had a higher percentage of survival than those harvested at 50 per cent bud, this difference was non-significant. Lowest per cent survival was observed in the plots harvested at 50 per cent bud at the end of the second year.

The actual number of plants surviving was greatest in plots seeded at 143.76 kg/ha and least in plots seeded at 1.12.

The average number of stems and buds, crown diameter and root and crown weight per plant was greatest in plots seeded at 1.12 kg/ha. The magnitude of these variables became progressively smaller with each increase in seeding rate. These three variables each produced larger measurements in the second year as compared to the first. The magnitude of these variables was always greater for plants harvested at the 25 per cent bloom stage of growth, but only the weight of roots and crowns was significantly different under the two harvesting practices.

Plants were tallest in plots seeded at 1.12 kg/ha and shortest in the 143.76 kg/ha seeding rate. Differences in plant height among seeding rates were greatest during the first year. Also plants were taller the first year when compared to the second year.

Experiment II

Alfalfa plants established at six specific densities were cut at the 25 per cent bloom stage of growth during 1963 and 1964. Highest forage yields during the first year were obtained from alfalfa having a density of 18 plants per 929 cm^2. Highest forage production during the second year and highest total production for the two years were obtained from the plant density of eight plants per 929 cm^2. Plots having a density of one-half plant per 929 cm^2 produced the smallest amount of forage during both years. Harvests made early in the year produced more forage per harvest than did harvests made later in the year.

Plant height during the first year was greatest in the plant density of .5 plant per 929 cm^2 and plants were shortest in plots of 18 plants per 929 cm^2. During the second year plants were tallest in plant densities of .5, 1 and 2 plants per 929 cm^2 and shortest in plots containing 8 and 18 plants per 929 cm^2.

Average number of stems and buds, crown diameter, and weight of roots and crown were largest and smallest in stand densities of .5 and 18 plants per 929 cm^2 respectively.

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