THE INFLUENCE OF PLANT POPULATION ON THE PRODUCTION OF ALFALFA HAY AND SEED

by

Mohammad Nazrul Islam Talukdar

A Thesis Submitted to the Faculty
of Agricultural Sciences in Partial Fulfillment of
The Requirements for the Degree of
MASTER OF SCIENCE IN AGRICULTURE

Split Major: Agronomy - Plant Pathology
Minor: Horticulture (Vegetables)

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Population Study in Alfalfa

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M. Nazrul Islam Talukdar

ABSTRACT

A two-year study was carried out at the Agricultural Research and Education Center of A.U.B. in the Beqa'a plain. The effects of various plant populations on yield and percent germination of seed, yield and percent protein of forage, number of stems per meter of row, and plant height were evaluated.

Rows spaced 50 cm. apart produced significantly higher forage and seed yields than did rows spaced 100 cm. apart. Spacings within rows (that is stand) had no significant influence on seed and forage yield.

The number of stems per meter of row were not affected by the different plant populations used. The half stand, however, produced a significantly higher percentage of stems than did the full stand. Both plant height and protein percentage of forage were not influenced by the between- or within-row plant spacings used.

In the 1964 harvest, seeds produced by the plants spaced further apart both within and between the rows, had a significantly higher germination percentage.

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INTRODUCTION

The importance of alfalfa in world agriculture can not be overestimated. It is helping to balance crop production by building soil fertility and by furnishing high quality feed for livestock. Alfalfa is among the best of the commonly grown hay crops because it is high in protein and minerals and is an excellent source of vitamin A.

Alfalfa grows satisfactorily over a wide range of soil and climatic conditions, but despite these versatile characteristics, the acreage under alfalfa hay production in most of the Middle East is negligible. The nonavailability of good quality seed is a factor in the lack of popularity of this legume in this area.

In much of the Western part of the U.S.A., acreage under dry land production of alfalfa is expanding. This expansion has been made possible by the solution of certain production problems. Correct population is one of these problems.

There is a shortage of water supply during the summer season in the Beqa'a plain which is the main agricultural area of Lebanon. It is known that alfalfa shows a relatively good performance in this area under non-irrigated conditions.

The present investigation was undertaken at the Agricultural Research and Education Center of the A.U.B., located in the Beqa'a plain. The effect of plant populations upon seed yield, forage yield, and other characteristics of alfalfa grown under non-irrigated conditions was studied.

REVIEW OF LITERATURE

Effect of Plant Population on Seed Yield

Numerous studies have been conducted by various workers to find the most suitable cultural practices that would produce the highest seed yield of alfalfa. In this review of literature, only studies that are related to the effect of plant population on yields and other characteristics in alfalfa have been considered. It was found that alfalfa gives good seed yields under a wide range of plant populations.

Engelbert (10) reviewed the findings of several workers who found that thin stands were better for seed production because of better development of the plants. Engelbert studied various stands and observed that thin stands always produced the best seed set with well developed pods and the highest seed yields. The poorest seed yields were obtained from fields with crowded stands. Pederson (28) concluded that less pod abscission occurred in thin than in thick stands. Changes in soil temperature, relative humidity and light penetration associated with a thin stand were correlated with seed yield. Thinning of established stands appeared to result in a stimulated seed yield that could be attributed to the change in stand density. According to the author, 24-inch rows seeded at a rate of 1.5 pounds of seed per acre and thinned to hills 12-inches apart produced a higher seed yield per acre than did eight-inch rows without any hill spacings. Carlson and Stewart (4) obtained better results where alfalfa was drilled in rows 28 inches apart and thinned to 21- or 28-inch hills within rows than where the rows were spaced 14, 35 or 49 inches apart. The high yields in check-row plantings might be due to the increased amount of sunlight and air available to the well distri-

buted plants. No significant differences between various check-row methods were obtained except for the 49 by 28 inch treatment which was too wide a space for high yields of seed.

Pederson (27) reported that plantings thinned to rows 24 inches apart without cross thinning yielded only slightly more nectar per flower than did the control. However, similar 24-inch spaced rows cross-thinned to 12-inch hills yielded the highest nectar production and hence the highest seed yield. It was reported by Carlson (3) that there was a close relationship between size of alfalfa plants and the production of seed. Large plants produced the most seed when pollination was adequate. Large size of plants can be obtained through appropriate spacings.

Jones and Pomery (20) during a three-year study observed that thinning within rows was beneficial for all row-widths studied. The highest yields were from rows spaced 24 inches apart and thinned to 6 inches x 18 inches (this means, thinned so that 6-inch blocks of the row remained, between which 18-inch blocks were removed) as compared to solid or 6-inch x 36-inch stands. Similarly, 36-inch row spacing gave better results when thinned to six inches x six inches than to any other combination of within or between-row spacings. It was found that within-row thinning proved beneficial throughout the life of the stand. Pederson (25) reported that crowding was harmful to seed production. In comparing hills 48 inches apart with dense hay-type stands, it was found that about twice as much seed was produced on the spaced plants as was produced on the hay-type stand. A stand thickly planted and then thinned produced as much or more seed as did a stand originally planted at a light rate. Where eight-inch rows were thinned to 24-inch rows after the first crop

year, the yield was significantly better than where 24-inch rows were planted in the first place. The author suggested that for seed production alfalfa should be grown in rows not closer than 24 inches and at a rate of seeding not more than one pound per acre. Westgate (40) suggested thinning alfalfa plants for better seed production. The most promising method was to seed the alfalfa in rows from 30 to 40 inches apart and practice thinning within rows as the plants become established. It was observed by Pederson (26) that alfalfa seeded in rows 24 inches apart at a rate of one pound per acre produced 147 percent as much seed as did a hay-stand planted at a rate of three pounds per acre. It was further observed that a thick stand could be thinned and the resulting seed production be as good as, or better than, stands planted thinly at the start. Similar results were found by Carlson, et al. (5).

Tysdal (37) revealed that plants spaced eight inches apart each way produced less seed per acre than did 32- and 64-inch spacings. The lowest seed production in all comparisons was from the thickly planted, frequently irrigated, lodged plants. There were more shrivelled seeds from stands grown under low moisture and high population conditions. Southworth (36) indicated that alfalfa plants grown in rows three feet apart produced more seed than when the plants were more or less crowded together in a broadcast-plot.

Zaleski (43) suggested that for seed production, alfalfa has to be drilled in wider rows at a low seed rate. On heavier more fertile land, alfalfa can be drilled in rows about 24 inches apart at a rate of two to three pounds of seed per acre. However, on light, poorer soil, rows 18 inches apart at a rate of about three pounds per acre were more desirable.

Weihing, et al. (39) found that seed yields in Colorado averaged 65 pounds per acre for solid stands, 84 pounds for rows 21 inches apart, 97 pounds for plants 21 x 24 inches apart, 96 pounds for rows 35 inches apart and 102 pounds for plants 35 x 36 inches apart. These results indicated the merits of a thin stand for seed production. Grandfield and Franklin (13) concluded that eight to twelve pounds of alfalfa seed per acre should be used for seed production under Kansas conditions. However, when high quality seed of adapted varieties is used, good stands may be secured with less seed.

Pederson, et al. (30) reported that seed yields from rows eight inches apart under dry land conditions were inferior whether planted at a low or high rate within the rows. Rows spaced 24 inches apart and planted at a rate of one pound of seed per acre produced the best seed yield. It was found by Jones and Pomery (20) that skip row plantings, two rows in and one row out, proved to be superior on lighter soil where moisture was a factor limiting higher populations. According to Graumann and Henson (14), with the limited moisture available under semi arid conditions, alfalfa in rows usually produced a higher average yield of seed than when close-drilled or sown broadcast. In an F.A.O. report (1), it was suggested that seeding alfalfa at lighter rates under dryland conditions would give better seed yield. Alfalfa sown at a distance of 30 to 60 cm. between rows gave higher seed production than when seeded in continuous rows. Pederson and Mcallister (29) reported that alfalfa spaced in rows 36 and 20 inches apart under dryland conditions gave good hay and seed yields. Westover (41) concluded that where rainfall was very limited, the yield from rows was somewhat greater than that from close-drilled seedings.

It can be concluded from this survey of the literature that for seed production, alfalfa should be planted thinly, in rows spaced widely apart. According to Bolton (2), widely spaced rows have special value for seed production of alfalfa.

Effect of Plant Population on Yield of Forage

The influence of plant populations on the yield of alfalfa forage has been studied extensively by a number of workers.

Garner and Sanders (11) reviewed the work of McKey of New Zealand who compared the yields obtained from rows spaced 7, 14 and 21 inches apart. It was found that rows spaced more closely together gave the highest dry matter yield per acre. The authors observed that alfalfa drilled in rows 3.5 and 7 inches apart gave a greater dry matter yield than when drilled in rows 10.5 and 14 inches apart. Over a four-year period, the yield of dry matter per acre from narrow rows was about half a ton more than rows spaced wider apart. Weihing and Robertson (38) indicated that rows spaced 12 inches apart produced more dry matter per acre than did rows spaced 20 or 36 inches apart.

Jarvis (19) reported the results of an alfalfa study where eight different between plant spacings were used, and where planting was done "on the square". It was found that as plant population increased, the yield of forage increased very rapidly up to a certain level, but further increases in plant population led to much smaller increments in yields. In general, yield decreased as the plant population decreased but the differences between the yields from the four highest populations were not significant. Higher yields of forage were obtained by Tysdal (37) from plants spaced eight inches apart both ways than from plants spaced 32

inches apart. Rumbaugh (33) indicated that 42-inch spacings both between and within rows gave higher dry matter yield per plant than did spacings of 21 or 10.5 inches. However, the dry matter yield per acre was higher in 21- than in 42-inch spacings.

According to Kramer and Davis (21), the stands of alfalfa were shown to be highly correlated with the forage yield obtained. The influence of stand on yield was greater in the first than in the second year after seeding and was attributed partially to the ability of alfalfa to produce more tillers, and thus thicken the thin stands in the second year. Marten, et al. (23) concluded that densities of more than 12 plants per square foot mixed with bromegrass gave significantly higher dry matter yields than did those having 2 to 12 plants per square foot. Ronningen and Hess (32) reported that there was a close relationship between stand counts and forage yields in alfalfa plants. According to Hosterman (16), a pure, thick stand was necessary to produce a higher yield of high-grade alfalfa hay.

Graumaunn and Henson (14) revealed that where rainfall was very limited, the yield of forage from row plantings was somewhat greater than was that of close-drilled fields. Under sufficient precipitation, a dense, uniform growth was desirable for higher yields. Bolton (2) stated that for forage production, the distance between rows of alfalfa is closely related to moisture. If water is a limiting factor, rows 12 inches or even 18 inches apart will produce better growth and allow normal harvesting.

Carmer and Jackobs (6) concluded that total season yields of dry matter were higher from plantings made at an eight pound per acre seeding rate, as compared to a four pound rate. The same was true for spacings between plants of four and eight inches. Grandfield (12) recommended that

10 to 15 pounds of seed per acre should be drilled for forage production. Hutcheson, et al. (18) concluded that a high seeding rate gave a higher yearly hay yield than did a low rate. The authors suggested seeding alfalfa at a rate of 15 to 20 pounds of seed per acre for high yield and good quality. It was reported by Delorit and Ahlgren (8) that recommended seeding rates of alfalfa vary considerably in different regions of the United States. For forage production, seeding rates of 8 to 15 pounds per acre are common in the East, 10 to 12 pounds in the semi-arid areas and 15 to 20 pounds in the irrigated sections. Good results have been obtained, however, under favorable conditions in the West with rates as low as one to five pounds per acre. Hughes and Henson (17) reviewed the work of Oakley and Westover who recommended seeding from 20 to 25 pounds in the humid section and 12 pounds under dry farming conditions. The authors also reviewed the work of Woodword where the highest yield, 1.25 tons per acre, was obtained under dry land conditions from a seeding rate of 14 pounds per acre.

In summary, it can be stated that there is a general agreement in the literature that uniform, thick plant populations are desirable for the highest forage yield.

Plant Population and Other Characteristics

Cowett and Sprague (7) reported that, of all the factors studied, stand density had the most pronounced effect on the number of stems produced by alfalfa plants. Lower stand densities resulted in less yield per unit area, but a greater number of stems per plant. According to Carmer and Jackobs (6), a decrease in number of stems per plant resulted from an increase in seeding rate and a consequent decrease in spacing between

plants. Tysdal (37) observed that alfalfa plants spaced 64 inches apart both ways, produced a significantly greater number of stems per plant than when the rows were spaced 32 or 8 inches apart. It was found by Rumbaugh (33) that the number of stems per plant increased as the spacings both within and between rows increased from 5.25 to 21 and 42 inches.

Jarvis (19) reported the protein content of alfalfa grown in an experiment described earlier. Small differences were found in the protein content in the alfalfa samples taken from the various populations studied. Zaleski (42) found that total protein was more directly related to dry matter yield than to the different seeding rates studied. The percentage of protein, however, was a bit higher in samples from thin stands than in those from thick stands.

Rumbaugh (33) studied four spacing treatments ranging from 5.25 to 42 inches within and between rows, and reported that maximum stem length was obtained at the 21-inch spacing. Stem length declined at the 42-inch spacings. Carmer and Jackobs (6) observed that the height of alfalfa plants decreased slightly as the seeding rate was incfeased from 4 to 16 pounds per acre.

It was reported by Zaleski (43) that in an exceptionally dry season, alfalfa seed grown at Cambridge, England had as much as 72 percent hard seed and only 23 percent germination.

MATERIALS AND METHODS

The investigations reported in this thesis were carried out for two years, 1963 and 1964, at the Agricultural Research and Education Center of A.U.B., located in the Beqa'a plain about 50 miles east of Beirut. The soil of the experimental field is in general high in clay content and in potassium, low in organic matter, nitrogen and phosphorus, and is calcareous in nature with a pH of about 8.0 (35).

The experiment was conducted under non-irrigated conditions. The total rainfall for the season 1962-63 beginning from July 1, 1962 to June 30, 1963 was 524.85 mm. and that of the season 1963-64 was 471.40 mm. as is shown in table 1.

The alfalfa variety used in this experiment was A.U.B. Composite which is an adapted variety for the area. Planting was done March 13, 1963, with tractor drawn "Planet Junior" seeding equipment, on land that had been fallowed the previous year. This planting was done at a rate of two pounds per acre (which is equivalent to 227 gms. of alfalfa seed per dunum), with a spacing between rows of 50 cm. On June 18, 1963, part of this field where the stand of plants was relatively uniform, was selected for the experiment.

A factorial experiment with four replications was employed for the investigations. The four treatment combinations were randomized in each replication for a study of the yield and other characteristics of both seed and forage. Different populations were obtained by removing plants from both between and within rows as required. The full stand within and 50 cm. distance between rows was the original spacing. The

Table 1. Annual rainfall and average monthly temperature at the Agricultural Research and Education Center of the American University of Beirut.++

Month	Rainfall (mm.)		Temperature (C)			
			1962-63		1963-64	
	1962-63	1963-64	Maximum	Minimum	Maximum	Minimum
July	0.00	0.00	32.50	13.20	30.45	13.61
August	0.00	0.00	34.00	15.10	32.74	14.37
September	0.00	0.00	31.43	11.78	29.68	12.45
October	19.30	49.60	24.48	9.71	23.62	9.30
November	0.00	16.40	22.32	5.89	18.00	4.36
December	164.10	70.60	11.95	3.54	11.12	-0.40
January	124.10	60.60	11.90	2.30	5.93	-4.12
February	70.00	183.80	12.24	2.60	7.70	-0.40
March	82.35	52.80	12.97	0.95	14.43	3.67
April	53.30	13.90	18.71	5.24	16.03	3.24
May	11.70	23.70	21.00	7.00	20.90	4.63
June	0.00	0.00	28.76	12.34	28.50	12.40
Total	524.85	471.40	-	-	-	-

++ Information obtained from the A.U.B Agricultural Research and Education Center Data, Beqa'a valley, Lebanon recorded by H.G. Nasr and F.M. Malouf.

half stand within rows was made by chopping out, with a hoe, 15 cm. spaces at 15 cm. intervals along the rows. Similarly the 100 cm. spacing between rows was obtained by removing the complete rows in the appropriate plots. Each replication had eight plots, four being for a study of seed production and four for a study of forage production. Thus four different combinations of plant spacings were obtained by varying the space between plants both within and between rows as is shown in table 2.

Table 2. Seeding rates in gms. per dunum as obtained by combining two within- and two between-row spacings.

Within-row spacings	Between-row spacings in cm.	
	50	100
Half stand	113.5	56.5
Full stand	227.0	113.5

Each plot of the experimental field constituted three rows, each being five meters long. Only four meters of the center row were harvested to avoid border effect. Weeds were controlled by hand, and "Gusathione" was sprayed once at a recommended rate to control an infestation of the alfalfa weevil (Hypera variabilis). Six kgs. of P_2O_5 as superphosphate were applied per dunum on October 10, 1963.

For the forage yield study, the plants were harvested twice, once in mid-December, 1963 and again in mid-May, 1964. Harvesting was done when the plants were at the one-tenth bloom stage. Data for plant height and number of stems per meter of row were recorded just before each harvesting.

For seed yield, the plants were harvested when approximately sixty percent of the seed pods had turned brown in color.

Harvesting of both forage and seed was done with handsickles, cutting the plants at a height of approximately three inches from ground level. After harvesting, green forage samples from each plot were air dried for three weeks. After air drying, the samples were weighed and chopped. This material was then dried in an oven for forty eight hours at a temperature of 70°C. The oven dry samples were weighed and dry matter yield of alfalfa in kgs. per dunum is reported on an oven dry basis.

To study the 1963 seed yields, the plants were threshed and the seed cleaned with available nursery equipment. The clean seed was then weighed to determine the seed yield in kgs. per dunum, and germination percentage was determined according to standard procedures.

Another objective of this study was to see the effect of cutting treatments given in the year of 1963 on the subsequent seed production in 1964. Unfortunately, the report on the seed yield for 1964 is not given because of the accidental destruction of the seed crop by farm animals shortly before harvest time in July of 1964. However, enough seed was harvested to enable determination of germination percentage.

For determination of protein in the forage, a representative oven dry sample of each plot was ground in a Wiley mill with a forty mesh seive. The ground samples were then put in an oven at 70°C for two hours to bring to constant weight, cooled in a dessicator, and weighed. Analysis of protein was done using duplicate samples, according to the modified Kjeldahl method as specified in the Official methods of Analysis by the Association of Official Agricultural Chemists (15), to determine the percentage of nitrogen. The nitrogen values obtained from each sample were multiplied

by the factor 6.25 to obtain the percentage of protein (9).

The data for all the characteristics under investigation were tabulated and analyzed using statistical methods appropriate to the experimental design employed (22, 24, 31).

RESULTS AND DISCUSSION

A two-year study was conducted to find the effect of different plant populations (obtained by varying spacings both between and within rows) on yield of forage and seed, and on other characteristics of alfalfa plants. The data from this experiment are summarized and reported in tables 3 to 9. The analysis of variance calculations are included with each respective table.

Dry Matter Yield

Spacings between the rows influenced yield of dry matter highly significantly in both the years as is shown in table 3. Plants of the 50-cm. spacing gave higher yields per dunum than did those spaced 100 cm. apart. It is suggested that the plots with a spacing of 100 cm. between rows yielded poorly because these rows are too far apart to make maximum use of the environment. This is in agreement with several authors (6, 11, 19, 32, 37).

The total yields of dry matter, however, were higher in 1964 which was due primarily to the better establishment of the plants after a year of growth.

The seeding rate for the 50-cm. spacing by half stand was equivalent to that of the 100-cm. spacing by full stand. However, the former treatment combination gave a higher yield of dry matter than did the latter one because of better distribution of the plants in the 50 cm. by half stand plots.

The half stand plots yielded as much dry matter as did the full stand plots in both years. It is suggested that this lack of effect of

Table 3. Yields of alfalfa in kg. of dry matter per dunum, as affected by various between- and within-row spacings during 1963 and 1964 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	1963 cut			1964 cut		
	Spacing within row			Spacing within row		
	Half stand	Full stand	Mean	Half stand	Full stand	Mean
50	42.68	43.78	43.23	128.64	130.11	129.37
100	20.53	20.27	20.40	78.96	87.26	83.11
Mean	31.60	32.02		103.80	108.68	

Analysis of Variance

Source	D.F.	1963 cut		1964 cut	
		M.S.	F.	M.S.	F.
Replication	3	250.38	2.33	269.68	0.40
Stand (Spacing within row)	1	0.71	0.006	95.50	0.14
Spacing between row	1	2085.98	19.48++	8562.26	12.95++
Stand x spacing	1	1.86	0.01	46.62	0.07
Error	9	107.05		660.81	

++ Denotes F values significant at the one percent level.

spacing on yield is a result of the extra space available to the plants in the half stand plots. This stimulated the plants to produce more stems thus equalling the production of dry matter in the full stand plots. This is shown to be true in table 6 where number of stems per meter of row are recorded.

Under the conditions of this experiment it appears that the between-row spacing had a great effect on the yield of dry matter of forage but the stand (spacing within row) had little influence on this character.

Seed Yield

Alfalfa seed yields were affected significantly by the two between-row spacings used in this investigation as is shown in table 4. A higher seed yield per dunum was obtained where the distance between the rows was 50 cm. This is explained by the greater number of plants per unit area which consequently gave more seed per unit area than did the rows spaced 100 cm. apart.

Seed yields were not influenced by the two within-row spacings (half stand and full stand) because of production of a greater number of stems by the half stand treatment. These results are in agreement with those of numerous authors (10, 20, 25, 27, 37, 40) who reported that seed yield increased where moderately wider spacings between rows combined with thinning within rows was employed.

The 1963 seed yield was very low and the following causes are suggested in explanation:-

(1) The plants were harvested the same year of planting when the plants were not well established.

Table 4. Seed yield of alfalfa in kg. per dunum as affected by between- and within-row spacings during 1963 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	Spacing within row		Mean
	Half stand	Full stand	
50	2.63	2.49	2.56
100	1.18	1.54	1.36
Mean	1.90	2.02	

Analysis of Variance

Source	D.F.	M.S.	F.
Replication	3	0.098	0.545
Stand (spacing within row)	1	0.047	0.263
Spacing between row	1	5.737	32.015++
Stand x spacing	1	0.242	1.352
Error	9	0.179	

++ Denotes F values significant at the one percent level.

(2) During the period of flowering and seed pod formation, the atmosphere was very dry which might have caused the abscission of some flowers.

Plant Height

An examination of the data given in table 5 shows that neither the between- nor within-row spacings had a significant effect on the mean height of alfalfa plants in either year. However, in general, the plants of the 1964 cut were taller than those of the 1963 cut because of better establishment of the plants after a year of growth. These data are not in conformity with those of Rumbaugh (33) and of Saad[+]. In the present experiment the range of spacings was small and all the spacing combinations left relatively large amounts of space available to the plants. Consequently, the treatments used showed similar effects on plant height.

Stems Number

(a) Number of stems per meter of row: The number of stems per meter of row was not affected significantly by either stand as determined by counts made in December and May of both 1963 and 1964. This is recorded in table 6. This lack of difference is explained by the greater production of stems per plant by the half stand treatment. This is in agreement with several authors (6, 7, 37) who found that plants spaced widely apart produced a greater number of stems per plant than did the plants spaced more closely together.

[+] Personal communication with Mr. Sami Saad, Assistant Instructor in Seed Technology, A.U.B. Information from data collected for an M.S. thesis.

Table 5. Height of alfalfa plants in cm. as affected by between- and within-row spacing during 1963 and 1964 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	1963 cut			1964 cut		
	Spacing within row			Spacing within row		
	Half stand	Full stand	Mean	Half stand	Full stand	Mean
50	20.00	20.11	20.05	40.78	40.00	40.39
100	22.12	16.50	19.31	40.75	44.75	42.75
Mean	21.06	18.30		40.76	42.37	

Analysis of Variance

Source	D.F.	1963 cut		1964 cut	
		M.S.	F.	M.S.	F.
Replication	3	54.35	3.09	34.10	1.89
Stand (spacing within row)	1	30.25	1.72	27.56	1.52
Spacing between row	1	2.25	0.12	7.56	0.41
Stand x spacing	1	33.06	1.88	7.57	0.41
Error	9	17.58		18.04	

Table 6. Number of stems of alfalfa per meter of row as affected by between- and within-row spacings during 1963 and 1964 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	1963 cut			1964 cut		
	Spacing within row			Spacing within row		
	Half stand	Full stand	Mean	Half stand	Full stand	Mean
50	124.75	141.25	133.00	133.00	146.75	139.87
100	142.25	152.50	147.37	149.75	166.25	158.00
Mean	133.50	146.87		141.37	156.50	

Analysis of Variance

Source	D.F.	1963 cut		1964 cut	
		M.S.	F.	M.S.	F.
Replication	3	643.73	1.36	540.23	0.90
Stand (spacing within row)	1	715.57	1.51	915.06	1.52
Spacing between row	1	826.57	1.75	1313.31	2.19
Stand x spacing	1	37.05	0.08	8.32	0.01
Error	9	473.12		598.61	

(b) Percent increase in number of stems per meter of row: In table 7 is presented the percent increase in stem number per meter of row, determined by comparing the initial counts of June of 1963 with those made in December and May of 1963 and 1964 respectively. It can be seen that the half stand treatment produced a significantly higher percentage increase in stem number than did the full stand treatment. This can be best explained by the extra room available to the half stand plants which enabled production of such a much greater number of stems.

The between row spacings had no significant influence on the increase in stem number per meter of row. Perhaps this was because of the small range of between row spacings chosen in this investigation.

Protein Percentage

The data in table 8 show that different plant populations, obtained by varying the distances within and between rows, had no significant effect on the protein percentage of alfalfa plants. This may be due to the small range between spacings chosen in this trial as explained under plant height.

The protein percentage, however, was higher in the 1963 cut than it was in the 1964 cut. The longer dry period of 1963 probably accounts for the higher percentage of protein in the plants. This was also suggested by Sandal and Jacks (34). The data for protein percentage agree with those of Jarvis (19) where it was found that various plant populations caused only small differences in the N-content of the plants.

Germination Percentage

The germination percentage of alfalfa seed, harvested in 1964 was affected significantly by the various plant populations. This is shown

Table 7. Percent increase in stem number of alfalfa per meter of row over the initial number[+] as affected by the between- and within-row spacings during 1963 and 1964 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	1963 cut			1964 cut		
	Spacing within row			Spacing within row		
	Half stand	Full stand	Mean	Half stand	Full stand	Mean
50	102.33	16.60	59.46	110.92	22.54	66.73
100	120.23	28.84	74.53	141.25	38.02	89.63
Mean	111.28	22.72		126.08	30.28	

Analysis of Variance[xx]

Source	D.F.	1963 cut		1964 cut	
		M.S.	F.	M.S.	F.
Replication	3	0.0366	0.78	0.0033	0.069
Stand (spacing within row)	1	1.99	42.70[++]	1.59	33.33[++]
Spacing between row	1	0.09	1.93	0.11	2.30
Stand x spacing	1	0.030	0.64	0.02	0.42
Error	9	0.0466		0.0477	

[+] Initial mean number of stems per meter of row of four replications for different treatment combinations counted in June of 1963 were as follows:

Treatment	Stem / meter of row
50 cm. x Half stand	60.25
50 cm. x Full stand	116.25
100 cm. x Half stand	62.75
100 cm. x Full stand	119.00

[++] Denotes F values significant at the one percent level.

[xx] Analysis done using logarithmic transformation.

Table 8. Protein percentage of alfalfa plants as affected by between- and within-row spacing during 1963 and 1964 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	1963 cut			1964 cut		
	Spacing within row			Spacing within row		
	Half stand	Full stand	Mean	Half stand	Full stand	Mean
50	19.70	18.54	19.12	17.12	16.52	16.84
100	20.10	18.89	19.49	17.25	16.98	17.12
Mean	19.90	18.72		17.18	16.75	

Analysis of Variance

Source	D.F.	1963 cut		1964 cut	
		M.S.	F.	M.S.	F.
Replication	3	2.50	1.85	0.77	1.31
Stand (spacing within row)	1	5.63	4.17	0.76	1.28
Spacing between row	1	0.56	0.41	0.34	0.58
Stand x spacing	1	0.01	0.007	0.12	0.20
Error	9	1.35		0.59	

Table 9. Germination percentage of alfalfa seed as affected by the between- and within-row spacings during 1963 and 1964 at the A.U.B. Agricultural Research and Education Center.

Spacing between row in cm.	1963 cut			1964 cut		
	Spacing within row			Spacing within row		
	Half stand	Full stand	Mean	Half stand	Full stand	Mean
50	79.63	81.01	80.32	76.14	70.74	73.44
100	80.25	78.43	79.34	85.62	78.43	82.02
Mean	79.94	79.72		80.88	74.58	

Analysis of Variance

Source	D.F.	1963 cut		1964 cut	
		M.S.	F.	M.S.	F.
Replication	3	8.77	0.83	4.44	0.19
Stand (spacing within row)	1	0.20	0.02	158.45	6.84^{+}
Spacing between row	1	3.85	0.36	295.41	12.76^{++}
Spacing x stand	1	10.23	0.97	3.19	0.13
Error	9	10.59		23.14	

$^{+}$ Denotes F values significant at the five percent level.

$^{++}$ Denotes F values significant at the one percent level.

in table 9. The half stand showed a germination percentage significantly higher than did the full stand. The plants grown in rows spaced 100 cm. apart produced seeds with a significantly higher germination percentage as compared to those grown in rows 50 cm. apart.

There was no difference in germination percentage of alfalfa seed as influenced by any of the treatments in 1963.

The increase in germination percentage of the seed produced from the widely spaced plants of the 1964 harvest may be due to the greater area from which the plants were able to draw upon for moisture.

SUMMARY AND CONCLUSIONS

A two-year trial was conducted under dryland conditions during the 1962-63 and 1963-64 seasons. The effects of various plant populations on yield and percent germination of seed, yield and percent protein of forage, number of stems per meter of row, and plant height were evaluated. The alfalfa variety used for this study was A.U.B. Composite. The between-row spacings were 50 and 100 cm. and the within-row spacings were designated as full stand and half stand.

Seed and forage yields per dunum were significantly higher where the distance between the rows was 50 cm. Higher seed and forage yields might have resulted from more plants per unit area where more efficient use of nutrients and moisture would have been possible. The two stands, full and half, were found to have little influence on the yields of the above two characters.

Neither the between-row nor the within-row spacings had any significant effect on the number of stems per meter of row. Statistically, the same numbers of stems per meter of row were produced by both the half stand and the full stand. On the other hand, the plants thinned within the row produced a significantly higher percentage of stems than did the unthinned treatment (that is full stand). Thus the plants in the half stand treatment compensated for the thin populations by producing more stems per plant.

The height of alfalfa plants was not affected statistically by the within- and between-row spacings chosen in this trial. Similarly, the protein percentage of alfalfa plants was not influenced by the different populations in either year.

The germination percentage of alfalfa seed of the 1964 harvest was found to be affected significantly by both within- and between-row spacing treatments. The highest germination percentage was obtained where the plants were spaced in rows 100 cm. apart combined with half stand.

On the basis of the results of this research, it appears that alfalfa plants in rows spaced closely together will give greater forage yields than where the plants are spaced widely apart. It is also suggested that rows spaced less than 50 cm. apart might have produced a higher forage yield. Regarding the 1964 yield, no conclusion can be drawn. The seed yield from the 1964 harvest was lost because of animal damage to the plants prior to harvest. From the 1963 data, it appears that the between row spacings of 50 cm. combined with half stand may be the best spacing combination for total seed yield under the conditions of this experiment.

It appears from the present study that seeding an equivalent of 227 gms. of alfalfa seed per dunum followed by thinning within rows after establishment of the plants may be suitable for both seed and forage production under non-irrigated conditions of Beqa'a plain. However, direct seeding of the equivalent of 113 gms. of seed may be suitable for seed and forage production of alfalfa. This problem needs investigation in this respect.

LITERATURE CITED

1. Anonymous. Agricultural and Horticultural Seed. F.A.O. Agricultural studies No. 55. Food and Agricultural Organization of the United Nations. Rome. 1961.

2. Bolton, J.L. Alfalfa. Interscience Publishers, Inc. New York. 1962.

3. Carlson, J.W. Pollination, lygus infestation, genotype and size of plants as affecting seed setting and seed production in alfalfa. Jour. Amer. Soc. Agron. 38: 502-514. 1946.

4. Carlson, J.W., and Stewart, G. Alfalfa seed production. Utah Agr. Exp. Sta. Tech. Bul. 226. 1931.

5. Carlson, J.W., Evans, R.J., Pedersen, M.W., and Stoker, G.L. Growing alfalfa for seed in Utah. Utah Agr. Sta. Cir. 125. 1950.

6. Carmer, S.G., and Jackobs, J.A. Establishment and yield of late-summer alfalfa seedings as influenced by placement of seed and phosphate fertilizers, seeding rate and row spacing. Agron. J. 55:28-30. 1963.

7. Cowett, E.R., and Sprague, M.A. Factors affecting tillering in alfalfa. Agron. J. 54:294-297. 1962.

8. Delorit, R.J., and Ahlgren, H.L. Crop Production. Prentice-Hall, Inc. New York. 1953.

9. Edward, S.W., and Welbert, R.T. Text book of Biochemistry. The Macmillan Comp. New York. 2nd ed. 1955.

10. Engelbert, V.A. A study of various factors influencing seed production in alfalfa. Sci. Agr. 12:593-603. 1932.

11. Garner, M.A., and Sanders, H.G. Studies with lucerne (Medicago sativa) - row distances and 'smother' crops. J. Agr. Sci. 30: 182-188. 1940.

12. Grandfield, C.O. Alfalfa in Kansas. Kan. Agr. Exp. Sta. Bul. 346. 1951.

13. Grandfield, C.O., and Franklin, W.W. Alfalfa seed production in Kansas. Kan. Agr. Exp. Sta. Cir. 290. 1952.

14. Graumann, H.O., and Henson, C.H. Growing alfalfa. U.S.D.A. Farmers Bull. 1722. 1954.

15. Horwitz, W. (Chairman). Official Methods of Analysis. Assoc. of Agr. Chem. Inc., Washington, D.C. 9th ed. 1960.

16. Hosterman, W.H. High-grade alfalfa hay. Methods of producing, baling and loading for market. U.S.D.A. Farmers Bull. 1539. 1929. Revised 1952.

17. Hughes, H.D., and Henson, E.R. Crop Production. The Macmillan Co., New York. 1947.

18. Hutcheson, T.B., McVicker, M.H., and Smith, T.J. Alfalfa production in Virginia. Va. Agr. Exp. Sta. Bull. 393. 1946.

19. Jarvis, R.H. Studies on lucerne and lucerne-grass leys. V. Plant populations studies with lucerne. J. Agr. Sci. 59:281-286. 1962.

20. Jones, L.G., and Pomery, C.R. Effect of fertilizer, row spacing and clipping on alfalfa seed production. Cal. Agr. 16:8-10. 1962.

21. Kramer, H.H., and Davis, R.L. The effect of stand and moisture content on computed yields of alfalfa. Agron. J. 41:470-473. 1949.

22. LeClerg, E.L., Leonard, W.H., and Clark, A.G. Field Plot Technique. Burgess Publishing Co. Minneapolis 23, Minnesota, 2nd ed. 1962.

23. Marten, G.C., Wedin, F.W., and Hueg, Jr., W.F. Density of alfalfa plants as a criterian for estimating productivity of an alfalfa-bromegrass mixture on fertile soil. Agron. J. 55:343-344. 1963.

24. Panse, V.G., and Sukhatme, P.V. Statistical Methods for Agricultural Workers. Ind. Coun. Agr. Res. New Delhi. 1957.

25. Pederson, M.W. Growing alfalfa for seeds. U.S.D.A. Cir. 135. 1955.

26. Pederson, M.W. What's new in alfalfa seed production. Crops and Soils. 8:15. 1955.

27. Pederson, M.W. Effects of thinning an established stand, of nitrogen supply, and of temperature on nectar secretion in alfalfa. Bot. Gaz. 119:119-122. 1957.

28. Pederson, M.W. Alfalfa seed production studies. Utah Agr. Exp. Sta. Bul. 436. 1962.

29. Pederson, M.W., and Mcallister. Alfalfa for Utah drylands. Farm and Home Science. 19:36-37. Utah Agr. Exp. Sta. 1958.

30. Pederson, M.W., Bohart, G.E., Levin, M.D., Nye, W.L., Taylor, S.A., and Haddock, J.L. Cultural practices for alfalfa seed production. Utah Agr. Exp. Sta. Bull. 408. 1959.

31. Pillai, K.C.S. Concise Tables for Statisticians. The statistical center, Univ. of Phillipines, Manila, 1st ed. 1957.

32. Ronningen, T.S., and Hess, A.G. Relationship between stand and yield in alfalfa variety comparisons. Agron. J. 47:92-93. 1955.

33. Rumbaugh, M.D. Effects of population density on some components of yield of alfalfa. Crop Sci. 3:423-424. 1963.

34. Sandal, P.C., and Jacks, J.F. Alfalfa production experiments-1950-1954. Ark. Agr. Exp. Sta. Report Series 48. 1955.

35. Shaikh, A.Q. Effect of population and spacing on yield and other characteristics in soybeans. M.S. Thesis, A.U.B. 1964.

36. Southworth, W. Influences which tend to affect seed production in alfalfa and an attempt to raise a high seed-producing strain by hybridization. Sci. Agr. 9:1-27. 1928-1929.

37. Tysdal, H.M. Influence of tripping, soil moisture, plant spacing and lodging on alfalfa seed production. Jour. Amer. Soc. Agron. 38:515-535. 1946.

38. Weihing, R.M., and Robertson, D.W. Forage yield of five varieties of alfalfa grown in nursery rows and field plots. Jour. Amer. Soc. Agron. 33:156-163. 1941.

39. Weihing, R.W., Robertson, D.W., Coleman, O.H., and Gardner, R. Growing alfalfa in Colorado. Colo. Agf. Exp. Sta. Bull. 480. 1943.

40. Westgate, J.M. Alfalfa. U.S.D.A. Farmers Bull. 339. 1916.

41. Westover, H.L. Growing alfalfa. U.S.D.A. Farmers Bull. 1722. 1934.

42. Zaleski, A. Lucerne investigations. Effect of germination and seed rates on establishment, mortality and yield of dry matter and protein per acre. J. Agr. Sci. 53:260-267. 1959.

43. Zaleski, A. Lucerne, Part-2. World Crops. 15:492-496. 1963.