EFFECT OF IRRIGATION INTERVALS AND PLANT POPULATION ON SEED PRODUCTION IN ALFALFA

By

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A THESIS

Submitted to the

AMERICAN UNIVERSITY OF BEIRUT

In partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE IN
AGRICULTURE
February 1968

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Date Thesis is presented: January 26, 1968

SEED PRODUCTION IN ALFALFA

AKHTAR

ACKNOLEDGMENTS

The author wishes to acknowledge his gratitude to Dr. Salah Abu Shakra for his encouragement and cooperation in the course of the present investigation and the final correction of this manuscript.

Thanks are also due to the Crop Production staff at the Agricultural Research and Education Center, for their assistance and cooperation in the field work.

The author also appreciates the efforts of Miss Rose Hugo in typing this manuscript.

AN ABSTRACT OF THE THESIS OF

Mahboob Akhtar For M.S. in Agronomy-Seed Technology

Title: Effect of irrigation intervals and plant population on seed production in alfalfa.

Experiments were conducted to study the effect of four irrigation intervals and three within-row spacings on the seed yields and other associated characteristics of three alfalfa varieties, namely African, Chilean, and Hairy Peruvian. Irrigation intervals were of one, two, three, and four weeks; and the within-row spacings were of 25, 50 and 75 cm. The work was done in 1966 and 1967 at the Agricultural Research and Education Center of the American University of Beirut in the Beqa'a plain, Lebanon.

Irrigation applied once every two weeks produced the largest amount of seed, as well as an increase in the number of pods per raceme, number of seeds per pod, and seed weight. Plants irrigated at three and four week intervals produced the highest number of hard seeds. The 50 cm within-row spacing produced vigorous and well developed plants which gave relatively high seed yields of 79.8 and 65.4 kg per dunum during 1966 and 1967 respectively. Irrigation intervals of two weeks and 50 cm within-row spacings proved to be the best combination for the production of high seed yield in alfalfa.

The Hairy Peruvian variety produced relatively shorter plants, more number of pods per raceme, and seeds per pod which resulted in higher seed yield than the African and Chilean varieties.

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I. INTRODUCTION

Alfalfa, *Medicago sativa* L., is one of the most important forage crops throughout the world agriculture. It furnishes high tonnage of good quality feed which is rich in protein, minerals, and vitamins. These qualities make it an excellent forage crop for farm animals. Alfalfa is also known for its role in building and conserving soil to give permanency to agriculture.

Even though, alfalfa grows satisfactorily over a wide range of soil and climatic conditions, the acreage under this crop in most of the Middle Eastern countries is negligible. The lack of knowledge of quality seed production may be considered as an important factor in the way of the popularity and status of this legume in the area.

Successful seed production of alfalfa requires special climatic conditions and management practices. A combination of knowledge, skills, and timeliness of operations are essential for satisfactory seed yields. High seed production has been obtained by having normal growth of an adapted variety sown in rows; applying fertilizers and a sufficient amount of water; controlling weeds, diseases and insect pests; and the presence of sufficient numbers of pollinating insects at the blooming stage. Bright, warm, and sunny days during the period of pollination and seed setting are conducive to higher seed yields.

The present investigation was undertaken at the Agricultural Research and Education Center of the American University of Beirut to study the effects of irrigation interval, plant population, variety, and tripping on seed production of alfalfa.

II. REVIEW OF LITERATURE

Seed production of perennial legumes such as alfalfa is markedly influenced by a number of climatic and biotic factors. Proper photoperiod, good light intensity, and moderate temperature are necessary for higher seed yields. Bright dry weather at the time of pollination and seed setting accelerates insect activity which plays a vital role in seed production. Proper cultural practices such as spacing and irrigation have great influence on seed yield and its quality. The purpose of this section is to review the literature pertaining to moisture requirements, plant density, and tripping and pollination in the seed production of alfalfa.

Tripping and Pollination

The low seed yields of alfalfa in many seed producing areas has been ascribed by many workers to be mainly due to the failure of blossom tripping. Insufficient tripping is either due to the scarcity of pollinating insects or to unfavourable climatic factors, especially temperature and humidity. Different strains of alfalfa show variations in the extent of tripping when grown under the same environmental conditions. This led to the belief that the phenomenon of tripping is genetically controlled.

Tripping: Tripping may be defined as the release of the sexual column from the keel of the flower. The staminal column includes the style, stigma, and part of the ovary surrounded by the 10 stamens and diadelphous filaments. This release must take place when the flower is in a turgid condition and thus it is accomplished by an explosive force as if a spring under tension is released.

White (53, p. 205) reviewed the work of several investigators on the importance of tripping and cross-pollination of the alfalfa flower. The results of these workers indicate that about one percent of untripped flowers may set pods. A number of bees belonging to the genera Apis, Bombus, Nomia and Megachile are important in tripping and cross-pollinating the alfalfa flower. Armstrong and White (4, p. 176) reported that alfalfa flowers must be tripped and cross-pollinated to produce a commercial seed crop. The act of tripping aids fertilization by rupturing the stigmatic membrane that provides a liquid medium for the germination of pollen grains. Carlson (11) found that artificially-tripped flowers set 2.5 times more pods than those flowers which developed under natural conditions. Southworth (42) working in Canada, obtained a gain of 3.6 times in the percentage of flowers forming pods in favor of artificial tripping when compared with no tripping and flowers enclosed.

Hay (22) found that 9.48 percent of the mechanically tripped flowers and 5.94 percent of the untripped flowers formed seed pods. It was concluded that lack of tripping was not the only limiting factor in bringing about satisfactory seed set, but cross-pollination of the tripped flower is also essential. Some pod setting without tripping was recorded by Carlson (13, p. 503). It was established by histological examination that pollen tubes and embryos were present in 13 flowers out of 84 untripped flowers that were studied. Tysdal (46) pointed out that for some strains of alfalfa tripping was not necessary for pod seeting. Tysdal and Kiesselbach (48, pp. 649-655) have shown great interplant variation in alfalfa for the percentage of flowers forming pods upon selfing the tripped flowers.

Jones and Olson (26) stated that cross-pollination of artificially tripped flowers increased pod setting more than four-fold. High seed yields upon crossing were due to the combined effect of high proportions of flowers setting pods and large numbers of seeds per pod. Similar results were reported by Bolton (7, p. 119). Tysdal (45, p. 583) concluded that the alfalfa flower must be tripped to produce a satisfactory seed set. An abundant supply of pollinating insects is the most effective way of insuring a seed crop of alfalfa.

Pharis and Unrau (39), compared the effectiveness of a locally built mechanical tripper with three kinds of insects in bringing about flower tripping. It was found that an average of 37.2 percent of the exposed flowers was tripped by the use of the mechanical tripper. Bombus Spp. (Bumble bee) tripped 90.2 percent and Megachile rotundata (leaf cutter bee) 61 percent of the flowers visited. Apis mellifera L. (honey bee) was inefficient both as a tripper and cross-pollinator of alfalfa flowers, because it tripped very few of the flowers it visited.

Pedersen (33) reported that increasing pollination by caging the alfalfa plants with honey bees increased the seed yields to 1020 pounds per acre as compared to 666 pounds produced on uncaged plots. Hobbs and Lilly (23) revealed during their two years study that seed yields of alfalfa were much higher in plots having honey bees as compared to those with no honey bees. Laboratory studies showed that automatic tripping began to take place when the relative humidity was between 30 to 40 percent and the temperature was at 90°F. Such conditions are conducive to the high efficiency of bees. Zaleski (54) reported that pollen collecting honey bees were more effective in tripping alfalfa flowers than nectar collecting honey bees. Bohart and Knowlton (6) concluded that honey bees and some wild bees are the only effective trippers of alfalfa flowers in Utah. An abundant supply of honey bees was recommended for having higher seed yields. Bradner et al. (9) indicated that the amount of crosspollination depends upon the bee species and the distance between alfalfa plots. It was observed that honey bees carried pollen to a greater distance from the base plot as compared to leaf cutter bees. Some bumble bees carried pollen even to one mile distance from the pollen source.

Knowles (27, p. 38) working in Saskatoon, South West Canada, found a significant correlation between the amount of tripping, the amount of seed setting and the abundance of leaf cutter bees. These bees were observed to visit alfalfa flowers at an average rate of 17.3 flowers per minute, and tripped nearly all the flowers they visited. It was further reported that proper temperature was the most important of the weather factors that influence the tripping of alfalfa flowers. Laberge et al. (28) concluded from a field experiment in Nebraska that Megachile camptoides (anthophorid leaf cutter bee) and Compsomeris plumipes (large scoliid wasp.) were the most effective crosspollinators of alfalfa in that area. Data for seeds per pod and pods per plant indicated that the latter was a better pollinator.

Linsley and Macswain (30) indicated that a number of physical factors like temperature, light intensity, cloudiness, moisture, and wind influence the activity of both honey bees and solitary bees such as Nomia and Megachile spp. It was further observed that honey bees and bumble bees tended to work completely on the flowers of a single raceme and the racemes of a single plant while solitary bees visited more plants per unit time leading to more cross-pollination.

Bohart (5) suggested that nesting sites, made of six millimeter diameter straw tubes embedded in wooden containers or wooden logs with tubular holes in them, should be placed around alfalfa fields to increase the population of leaf cutter bees. Similar types of nesting sites were recommended by Peck and Bolton (32, pp. 399-404).

Pankiw and Bolton (31) revealed that bees are the most effective agents for transferring pollen from one plant to the other. It was suggested that the extent of honey bee pollination can be improved by producing alfalfa varieties with flowers having an exposed stigma or with a vestigial standard petal. It was expressed by Busbice and Wilsie (10) that there is a possibility of breeding alfalfa varieties in which the flower can be tripped easily.

Irrigation

Irrigation is one of the most important cultural practices for alfalfa seed production. Moisture is the main factor controlling the over-all plant growth. Optimum moisture supply is an essential for having normal, and sufficient plant growth in order to have good seed yields. Research investigations have shown that for legume seed production, fequency of irrigation is more important than the amount of irrigation water applied.

Westgate (50) reported that alfalfa sets a good seed crop when there is a control over moisture supply. Soil moisture must be sufficient to enable the plant to mature its seeds but not so much as to induce new growth from the crown before the seeds are matured. Carlson (12) stated that a hot dry climate with frequent light summer rains was found to be better for alfalfa seed production in the valley land of Utah. It was reported by Zaleski (55) that in dry seasons, alfalfa seed raised in Cambridge, England, had only 23 percent germination and as much as 72 percent hard seeds. It was concluded that dry climate was conducive to hard seed production. According to a report of the Food and Agriculture Organization (2, p. 310), irrigation is necessary in dry areas for seed production of alfalfa. There should be light application of water from the time of sowing to flowering. Some additional water is beneficial at blooming time. Tysdal (46) found out in a field experiment that alfalfa plants grown under some limited amount of moisture supply produced more seed yield than those grown at high moisture level conditions.

Wheeler (52, pp. 345-346) reported that a seed crop of alfalfa should receive only enough water to make a slow, vigorous, and erect growth. Some additional supply of water at blooming time increased the vigor of the plant and prolonged the blooming period. It was suggested that irrigation should not be applied during the bud stage except when stress from the lack of moisture is observed. Grandfield (19) reviewed Alter's work that a certain amount of moisture stress is necessary at blooming time to force the alfalfa plant into setting seed. Engelbert (17) concluded that sufficient moisture must be provided to alfalfa plants to have vigorous growth. Near and during the initial blooming stage, irrigation should be withheld to give the plants a moisture stress. Some light application of water is beneficial during the rest of the blooming and seed setting period to have a better filling of the pods. It was suggested by Pedersen and McAllister (37) that heavy irrigation should not be applied to the alfalfa crop after the early bud stage. Furthermore, after the commencement of flowering only enough water should be applied to keep the plants in a healthy condition. Grandfield (19) summarized the effects of the environmental factors that influence the seed yield of alfalfa as follows: "Moderate air temperature, low humidity, and soil moisture below optimum produced the type of vegetative growth of alfalfa plants that was conducive to the storage of high organic reserves, resulting in a physiological condition favorable to seed setting". Zaleski (56) found that irrigation was useful for seed production of white clover when it was applied between the period of the stopping of vegetative growth and the start of flowring. An excess supply of water during the flowering period had an adverse effect on seed production. It caused an excess of vegetative growth and reduced the number of inflorescences and the total seed yield.

Pedersen (33) reviewed Shuel and Pedersen's work on the effect of environmental factors on nectar secretion and reported that wide deviations in the soil moisture from the moisture equivalent (Field capacity) in a loam soil were associated with a reduction in nectar yield of alfalfa flowers. Pedersen (33) reported that high nectar content in the alfalfa flower is inducive to pollinators which are absolutely necessary for high seed yields. It was found that irrigated plants had on the average 0.457 mg of sugar per flower as compared to 0.371 mg of sugar in the flowers of the plants which were not irrigated. Pedersen and Nye (38) found a depressive effect on nectar secretion, honey bee population, and seed yields as a result of low temperature and high moisture conditions.

Cowett and Sprague (16) studied the effect of soil moisture on plant and flower development. It was observed that when the moisture tension was decreased from ten to approximately one half atmospheres, there was an increase in the number of stems, buds, height, root weight, and top weight of alfalfa plants.

Sterling et al. (44) found that the seed yields of alfalfa plants were maximum when the mean soil moisture suction was between two and eight bars. So it was suggested that for good seed production of alfalfa, mean soil moisture suction should not be allowed to exceed two bars until the time of full bloom. A sufficient amount of water should be applied at the time of early bloom to restore the moisture in the root zone. This will lead to a condition of growth for maximum seed production.

Spacing

A suitable environment around the plant is necessary for better plant and flower development. Density of plant population is an important factor affecting micro-climate around the plant.

Cultural practices such as between and within row spacings play a great role in conditioning the proper environment around the plant.

Westgate (50) found that thin stands are better than solid stands for alfalfa seed production and stated that the most promising method for seed production is to seed the alfalfa in rows 30 to 40 inches apart and practice thinning within rows after the plants become well established. Engelbert (17) reported that thin stands were better for seed production in alfalfa as these provide more space for good plant development. Southworth (42, p. 1) indicated that alfalfa plants grown in rows three feet apart gave more seed yield than those which were more or less crowded together in a broadcast plot. The spacing helped to produce vigorous and healthy flowers with an increased tendency to become fertilized, and consequently gave more seed yield. Westover (51) concluded that under low rainfall areas with limited moisture supply, the seed yield of alfalfa plants grown in rows was higher than those of close drilling or broadcasting. Tysdal and Kiesselbach (47) found that planting alfalfa in spaced hills or in rows gave good seed yield both under irrigated and dryland conditions.

Tysdal (46, p. 532) believes that in thick stands the competition of plants for light, air, space, and food produces slow growth, poor flower development, and low seed yields. Spencer and Stewart (43) got 76 percent more seed yield by planting alfalfa in rows 28 inches apart as compared to the broadcasting method. According to Carlson (13) wide spacing helps to produce large sized vigorous alfalfa plants which produce high seed yields when the pollination is adequate.

Pedersen (35) reported that drill plantings thinned to 24 inches between rows without any within-row thinning yielded slightly more nectar per flower than those plants which were obtained from drilling in rows eight inches apart. However, when similar 24 inch rows were cross thinned to 12 inch hills, higher nectar production and seed yields were obtained. The same author working at the United States Legume Research Laboratory in 1955 (34) reported that alfalfa seeded in rows 24 inches apart at a rate of one pound of seed per acre produced 147 percent more seed per acre than that of a hay-type stand obtained by sowing three pounds of seed per acre. Proper spacing favored nectar secretion, bee visitation, and better pod development.

Graumann and Henson (21, pp. 26-30) described thin planting as one of the essentials for higher seed yields in alfalfa. The crop planted thin in spaced rows both under irrigated and semi-arid conditions, produced a higher seed yield than when sown broadcast or cross drilled. It was suggested by Jones _et al_. (25) that for higher seed yields of alfalfa in California, it should be planted in rows 36 X 21 inches apart at a rate of one pound of seed per acre. In addition to high seed yields, alfalfa planted in rows economizes on water use, and makes mechanical cultivation possible for controlling weeds. Similarly, Weighing _et al_. (49) in Colorado found that spaced alfalfa plants gave much better seed yield than did those in solid stands. Pedersen and McAllister (37, pp. 7-15) reported that crowding of plants was harmful to seed production. In comparing hills 48 inches apart with a dense hay-type stand, it was found that spacing helped to produce twice as much seed as that produced by the hay-type stand. Zaleski (55) reported that on heavy soils lucerne can be drilled in rows 24 inches apart at a seed rate of two to three pounds per acre while on light soils three pounds of seed should be drilled in rows 18 inches apart for good seed yields. Carrison (18, p. 41) concluded from the findings of several workers that for good seed yields in alfalfa, the optimum stand density is one established plant per foot of row. Pedersen and Nye (38, p. 8) stated that for satisfactory management of the seed crop, alfalfa should be planted in rows 24 inches apart at a rate of one and a half pounds of seed per acre. In the second year the stand should be thinned by cutting out every other foot of plants in the row to stimulate seed yields. Jones and Pomery (24) found that seed yields of alfalfa, grown on light soils under irrigation, were improved to the extent of 20 to 30 percent by skip-row planting in 24 or 36 inches apart. On heavy soils, 36 inch rows with no skipped rows proved to be good for seed production. Cowett and Sprague (16) stated that stand density had a pronounced effect on tillering of alfalfa plants. It was found that in a stand established at the rate of one plant per square foot, plants produced approximately double the number of tillers as those having a stand density of eight plants per square foot.

In summary, seed production in alfalfa is dependent upon a number of climatic and biotic factors. Proper temperature and moisture conditions are necessary for high seed yields. High moisture level in the soil leads to a luxurious vegetative growth that results in plant lodging. On the other hand, low moisture level leads to poor nectar production. Fairly wide spacing between plants is necessary to eliminate competition for light, space, and nutrients. Since alfalfa is a crosspollinated crop, therefore, an abundant supply of bees at the blooming stage is very important to insure good seed yields.

III. MATERIALS AND METHODS

An irrigation and within-row spacing experiment was conducted during the 1966 and 1967 growing seasons at the Agricultural Research and Education Center of the American University of Beirut, Beqa'a plain, Lebanon. In general the soil is calcareous in nature; high in potassium content; low in organic matter, nitrogen and phosphorus; and has a pH value of 8.0. Three alfalfa varieties African, Chilean, and Hairy Peruvian were used in the study.

The experiment was laid out in a split-split-plot design with four replications. The main plots were the irrigation treatments and the subtreatments of within-row spacing were randomized and superimposed on each of the main treatment. Each spacing had one row, five meter long, of each of the three varieties as the sub-sub-effect. All the rows were 50 cm apart from each other. One border row was maintained on each side of the subplots. Seventy-five centimeters alleys were kept between replications. The details of the experiment are as follows:

<u>Within-row spacing and stand establishment</u>: The experiment was started in the year 1965. Seedlings were raised in wooden flats under green house conditions. The young seedlings were transferred to the field and planted on the top of ridges spaced 50 cm apart. The within-row spacings between the plants were 25, 50, and 75 cm.

The number of plants per row, and the plant population per dunum of the different spacings are given below:

Within-row spacing (cm)	Number of plants per 5-meter row	Plant population per dunum
25 (S_1)	20	8000
50 (S_2)	10	4000
75 (S_3)	7	2800

Sprinkler irrigation was used during the early stages of plant establishment.

Irrigation intervals; The four irrigation intervals and the symbols used are as follows:

Symbol	Irrigation interval
I_1	Irrigation once every week.
I_2	Irrigation once every two weeks.
I_3	Irrigation once every three weeks.
I_4	Irrigation once every four weeks.

Irrigation water was applied by the furrow method through surface gated pipes. Sufficient water was applied in each irrigation to return the moisture content of the soil to its moisture equivalent (field capacity). The amount of water applied in each irrigation was measured by the Sparling flow meter. The total amount of water recorded under each treatment was as follows:

Irrigation Interval	Total inches of water applied during the growing season
I_1	19.68 inches, in 10 irrigations
I_2	10.14 inches, in 5 irrigations
I_3	6.56 inches, in 3 irrigations
I_4	3.58 inches, in 2 irrigations

Spacing and varietal effects were randomized separately in each replication. But irrigation treatments were not randomized due to the fact that it is very difficult to apply water to part of the furrows at different times.

Cultural practices during the growing season: In the spring seasons of 1966 and 1967, the crop was sprayed with 1.25 percent Malathion to control the alfalfa weevil. A top dressing of superphosphate was applied in the early spring at the rate of 20 kg of P_2O_5 per dunum. Weed control was done by means of one mechanical cultivation after the winter season was over, and by hand hoeing later during the growing season.

Data collection and harvesting: Data were recorded on plant height, number of pods per raceme, seeds per pod, seed yield, seed weight, and seed germination.

Average plant height was recorded by measuring the height of five plants, selected at random from each row, with a centimeter granduated rod. Fifteen normal and matured racemes from each of the treatments were collected in envelopes a day before harvesting. The number of pods in each raceme was counted and recorded. The representative pods from each treatment were threshed and their seeds were counted.

A week before harvesting, the plants were sprayed with a defoliant mixture that consisted of 100 grams dinitrocresol, five gallons of diesel oil, and five gallons of water. Harvesting was done with a hand sickle. One and a half meters from the center of each row was harvested. This involved the harvesting of six, three and two plants from the 25, 50, and 75 cm within-row spacings respectively. The plants were cut at a height of approximately ten centimeters from the ground level. The stems bearing the seed pods were put in cloth sacs and hung in the open air for drying. Threshing and cleaning of seeds was done with the available nursery equipment present at the Agricultural Research and Education Center. The clean seeds were weighed and seed yields were computed on dunum basis. Representative samples of clean seeds were taken for the 1000-seed weight and the germination tests done at the seed laboratory of the American University of Beirut. These tests were done according to the International Rules for Seed Testing, proceedings of the International Seed Testing Association, 1966. (3, pp. 498, 542).

Statistical methods appropriate to the Split-Split-plot design were used to analyse the data. The analysis of variance and t-test were applied to determine the differences between treatments and their interactions. In the analysis of variance, the error term for irrigation was reduced by one because the irrigation treatments were confounded due to management difficulties.

Tripping and Pollination Study

A preliminary study on tripping and pollination phenomenon was conducted. One plant of each of the three varieties used in the study was covered with screen cage of 2 X 1.5 X 1.5 meter size before the start of blooming, in order to eliminate tripping and cross pollination by bees. At the full bloom stage, 50 racemes of about the same age were tagged and the number of flowers on them were counted. Small and immature flowers were trimmed off by a pair of scissors. Twenty five racemes were tripped mechanically by a tooth pick while the remainding 25 were left untripped. Plants so worked remained caged until the whole crop was matured. Racemes of tripped and untripped flowers were harvested by hand and the number of pods set per raceme were counted and recorded. Pods of racemes set by mechanically tripped and naturally tripped flowers were kept separately for further study. Seeds per pod, germination percentage, and vigor tests were done on seeds collected from tripped and untripped flowers.

A record on insects causing tripping and pollination of alfalfa flower was kept throughout the blooming period of the crop. This was achieved by collecting pollinators with a screen net during the late morning hours.

IV. RESULTS AND DISCUSSION

This experiment was conducted during the years 1966 and 1967 at the Agricultural Research and Education Center of the American University of Beirut, to study the effects of four irrigation intervals and three within-row spacings on alfalfa seed yield and its associated components. Three commonly grown alfalfa varieties African, Chilean, and Hairy Peruvian were used in the study. The results of the effects of these treatments on seed yield, plant height, pods per raceme, seeds per pod, 1000-seed weight, germination percentage, and hard seed production are reported in tables 1-14.

The abbreviations used in these tables are I, for irrigation and S for within-row spacing. The suffixes 1, 2, 3 and 4 with I represent irrigations after one, two, three and four weeks respectively, and the numbers 1, 2 and 3 with S represent within-row spacings of 25, 50 and 75 cm respectively. Analysis of variance tables are given in the appendix. The LSD values, at 5% and 1% level, are given for those treatments which are statistically significant. For statistical comparisons, weekly irrigation interval, 25 cm within-row spacing and the variety African were treated as control.

Seed Yield

The data for the seed yields during 1966 and 1967 are given in Tables 1 and 2 respectively. In both years, the seed yields differed significantly with respect to the irrigation treatment. The highest

Table 1. Effect of irrigation interval and within-row spacing on seed yield of alfalfa in kg per dunum - 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	64.8	64.0	73.2
	S_2	63.0	82.2	109.2
	S_3	56.2	65.5	81.0
I_2	S_1	52.5	93.0	99.2
	S_2	84.5	108.0	98.0
	S_3	87.0	71.0	84.2
I_3	S_1	46.2	62.5	74.8
	S_2	57.0	52.8	92.2
	S_3	39.0	41.5	60.5
I_4	S_1	52.5	42.2	69.0
	S_2	51.8	75.2	83.5
	S_3	40.2	41.2	57.5

LSD	5%	1%
Irrigation interval	13.7	19.9
Within-row spacing	11.1	15.1
Variety	6.8	9.0

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	73.2	S_1	66.2	African	57.9
I_2	86.4	S_2	79.8*	Chilean	66.6*
I_3	58.5*	S_3	60.4	H. Peruvian	81.8**
I_4	57.0*				

* Significant at 5% level.

** Significant at 1% level.

Table 1. Effect of irrigation interval and within-row spacing on seed yield of alfalfa in kg per dunum - 1966.

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		African	Chilean	Hairy Peruvian
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	S_2	63.0	82.2	109.2
	S_3	56.2	65.5	81.0
I_2	S_1	52.5	93.0	99.2
	S_2	84.5	108.0	98.0
	S_3	87.0	71.0	84.2
I_3	S_1	46.2	62.5	74.8
	S_2	57.0	52.8	92.2
	S_3	39.0	41.5	60.5
I_4	S_1	52.5	42.2	69.0
	S_2	51.8	75.2	83.5
	S_3	40.2	41.2	57.5

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I_1	73.2	S_1	66.2	African	57.9
I_2	86.4	S_2	79.8*	Chilean	66.6*
I_3	58.5*	S_3	60.4	H. Peruvian	81.8**
I_4	57.0*				

* Significant at 5% level.

** Significant at 1% level.

Table 2. Effect of irrigation interval and within-row spacing on seed yield of alfalfa in kg per dunum - 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	58.5	61.5	61.8
	S_2	63.8	64.8	82.2
	S_3	61.0	59.5	63.8
I_2	S_1	61.0	60.0	64.2
	S_2	67.8	73.0	78.5
	S_3	56.0	56.0	69.8
I_3	S_1	53.8	63.5	63.2
	S_2	69.8	67.5	71.5
	S_3	57.2	59.8	64.0
I_4	S_1	36.5	37.5	52.2
	S_2	43.8	47.2	55.5
	S_3	47.5	46.5	39.2

LSD	5%	1%
Irrigation interval	8.6	12.6
Within-row spacing	2.6	3.6
Variety	1.9	2.5
Irrigation X within-row spacing	5.2	7.1

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	64.1	S_1	56.1	African	56.4
I_2	65.2	S_2	65.4**	Chilean	58.1
I_3	63.4	S_3	56.7	H. Peruvian	63.8**
I_4	45.1**				

** Significant at 1% level.

seed yields were obtained from those plots which were irrigated at fortnight interval. During 1966, there was no statistical difference between the seed yields of plots irrigated at fortnight interval and the one irrigated weekly (Control). Plots receiving irrigation after three and four weeks intervals produced significantly lower seed yields than that of the Control. However during 1967, plots receiving irrigation after two or three weeks intervals did not differ significantly from the Control. Only the plot receiving irrigation after four weeks interval gave significantly lower seed yields.

The maximum seed yields achieved under fortnightly irrigation treatment can be explained as due to normal, sufficiently vigorous, and upright healthy growth of the plants. This type of growth leads to uniformity of flowering, proper nectar secretion and attractiveness to pollinators. Under weekly irrigation regime, the plants had excessive vegetative growth which resulted in lodging of the plants. This led to prolonged period of flowering and poor seed setting. The low seed production from the plots irrigated after three and four weeks intervals can be attributed to the poor plant development that resulted from insufficient amount of moisture. These results are in line with the findings of many workers (1, 17, 19, 37, 44, 46, and 50).

The seed yields were also influenced by within-row spacings. In both years, the highest seed yields were obtained from the 50 cm spacing. On two year's average, 50 cm spacing produced about 19 percent more seed yield than the 25 cm spacing (Control). In both years, the seed yields from the 75 cm spacing did not differ significantly from those of the control.

The highest seed yields in the 50 cm spacing can be attributed to the fact that the plants in this treatment had sufficient space around them for having vigorous growth with a tendency to lateral development. In the 25 cm spacing the plants were more or less crowded together with competition for space, light, and nutrients. This led to slow growth, poor development of the flowers, and consequently low seed yields. The low seed yields obtained from the 75 cm spacing can be explained as due to the failure of the plants to utilize the wide space provided around them. These results are in agreement with the findings of many workers (16, 17, 35, 37, 42, 46, and 50).

During 1967, the interaction between irrigation and within-row spacing was significant. The highest seed yield of 73.1 kg per dunum was obtained when the plants were spaced 50 cm apart and were irrigated once every two weeks (Table 19 in the appendix).

Alfalfa varieties also showed significant differences in the seed yielding ability. The Chilean variety in 1966 differed significantly from the control, but the difference during 1967 was not statistically significant. In both years, the Hairy Peruvian variety out-yielded the African and Chilean varieties. This significant difference can be attributed to the better adaptability of the Hairy Peruvian variety to the Beka'a area.

Plant Height

The plant height as affected by different irrigation intervals and within-row spacings is shown in Tables 3 and 4. In both years, it

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Table 3. Effect of irrigation interval and within-row spacing on the plant height of alfalfa in cm 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	127.0	125.5	130.2
	S_2	114.5	117.5	114.2
	S_3	108.5	119.2	109.8
I_2	S_1	115.8	112.0	108.2
	S_2	113.5	110.0	116.2
	S_3	118.2	115.5	111.2
I_3	S_1	100.0	92.5	95.0
	S_2	86.2	92.5	84.5
	S_3	85.8	82.8	92.5
I_4	S_1	96.2	95.5	94.8
	S_2	87.2	91.2	90.0
	S_3	85.0	87.5	87.2

LSD	5%	1%
Irrigation interval	6.8	9.9
Within-row spacing	3.7	4.9

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	118.5	S_1	107.7	African	103.2
I_2	113.4	S_2	103.6*	Chilean	103.5
I_3	90.2**	S_3	100.3**	H. Peruvian	102.8
I_4	90.5**				

* Significant at 5% level.
** Significant at 1% level.

Table 4. Effect of irrigation interval and within-row spacing on the plant height of alfalfa in cm 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	130.5	127.2	124.0
	S_2	124.8	123.2	126.0
	S_3	123.0	124.2	129.2
I_2	S_1	128.0	128.0	119.8
	S_2	124.5	123.5	117.8
	S_3	117.2	120.5	119.2
I_3	S_1	116.8	113.5	113.8
	S_2	105.5	102.2	107.0
	S_3	108.2	103.2	101.2
I_4	S_1	116.5	110.0	105.5
	S_2	101.2	97.2	96.5
	S_3	95.5	94.2	92.5

LSD	5%	1%
Irrigation interval	5.5	8.1
Within-row spacing	2.8	3.9
Variety	2.5	3.3
Irrigation X within-row spacing	5.7	7.7

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	125.8	S_1	119.5	African	115.9
I_2	122.1	S_2	112.4**	Chilean	113.9
I_3	107.9**	S_3	110.7**	H. Peruvian	112.7*
I_4	101.0**				

* Significant at 5% level.
** Significant at 1% level.

was found that irrigation treatments had significant effect on plant height. The highest plants (118.5 cm in 1966 and 125.8 cm in 1967) were produced in the plots which were irrigated at weekly intervals. Fortnightly irrigation did not produce significantly different plant height from the control. Plots receiving irrigation after three and four weeks intervals produced significantly shorter plants. The short plants produced under I_3 and I_4 may be due to the moisture stress in the soil. Sufficient water supply in I_1 and I_2 treatments resulted in taller plants.

Differences in plant height due to the effect of within-row spacing were also significant. It can be seen from Tables 3 and 4 that the plants of 50 and 75 cm spacings were significantly shorter than those of 25 cm spacing (control). The tall plants produced by 25 cm spacing were probably due to the crowding and shading effects of close plantings. The widely spaced alfalfa plants in the 50 and 75 cm spacings had a tendency to produce lateral branches and less vertical growth.

The interaction between irrigation and within-row spacing was significant during 1967. It can be seen from Table 20 that the tallest plants (127.2 cm) were produced by the 25 cm within-row spacing under the weekly irrigation regime.

No significant differences in plant height were observed among the three varieties during the year 1966. But during 1967, the Hairy Peruvian variety produced significantly shorter plants than the African (The control variety).

In general the overall plant height was more in 1967 as compared with that of 1966. This could be due to excessive moisture in the soil obtained from high rainfall in that year (Table 26 in the appendix), or due to the fact that the plants were one year older in 1967 and therefore were better established.

Pods Per Raceme

It appears from the data given in Tables 5 and 6 that irrigation had its effect on pod development. The number of alfalfa pods per raceme was more in the case of plants which were irrigated after two weeks as compared with those obtained from weekly irrigation interval. During 1966, both three and four weeks irrigation intervals produced significantly lower number of pods per raceme than did the control. However during 1967, only those plants receiving irrigation after four week intervals differed significantly from the control.

Within-row spacing treatment also exerted its influence on the number of pods per raceme. Plants spaced 75 cm apart produced the largest number of pods, 9.93 and 7.62 during 1966 and 1967 respectively, and these values were significantly greater than those of the control. Plants spaced 50 cm apart did not show any difference from the control plants.

The results can be explained by the fact that both irrigation and spacing have their effects in conditioning the micro-environment around the plants. Excessive irrigation in the control treatment caused lodging of the plants and this was more pronounced in close plantings. Under low moisture treatments, low pod set could be due to the wilting of flowers and ovary abortion as reported by Grandfield (19), Pedersen and Nye (38) and Tysdal (46). Variations as to the

Table 5. Effect of irrigation interval and within-row spacing on the number of pods per raceme of alfalfa - 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	9.9	9.2	10.2
	S_2	11.2	10.1	10.8
	S_3	10.2	10.4	10.5
I_2	S_1	9.8	11.1	11.5
	S_2	10.9	10.5	11.6
	S_3	10.6	10.8	11.5
I_3	S_1	9.5	8.9	9.9
	S_2	9.2	8.8	8.7
	S_3	8.9	9.6	10.6
I_4	S_1	7.4	7.6	8.0
	S_2	8.0	8.4	9.2
	S_3	8.2	8.6	9.3

LSD	5%	1%
Irrigation interval	0.48	0.70
Within-row spacing	0.39	0.53
Variety	0.10	0.13

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	10.31	S_1	9.44	African	9.51
I_2	10.92*	S_2	9.78	Chilean	9.48
I_3	9.33**	S_3	9.93*	H. Peruvian	10.16**
I_4	8.31**				

* Significant at 5% level.
** Significant at 1% level.

Table 6. Effect of irrigation interval and within-row spacing on the number of pods per raceme of alfalfa - 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	6.4	6.6	7.1
	S_2	6.7	6.5	7.8
	S_3	6.4	7.1	7.6
I_2	S_1	7.6	7.6	7.7
	S_2	8.2	8.4	8.7
	S_3	8.7	8.7	9.1
I_3	S_1	7.6	6.9	7.4
	S_2	6.7	6.5	6.6
	S_3	7.8	7.9	8.1
I_4	S_1	5.4	5.7	5.8
	S_2	6.5	6.6	6.4
	S_3	6.7	6.6	6.8

LSD	5%	1%
Irrigation interval	0.58	0.84
Within-row spacing	0.51	0.70
Variety	0.18	0.24
Irrigation X Variety	0.38	0.50

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	6.91	S_1	6.82	African	7.06
I_2	8.30**	S_2	7.13	Chilean	7.09
I_3	7.28	S_3	7.62**	H. Peruvian	7.42**
I_4	6.28**				

* Significant at 5% level.
** Significant at 1% level.

number of pods per raceme were also observed among the three varieties. In both years, the Hairy Peruvian variety produced significantly higher number of pods than the African (control).

Significant interaction between irrigation interval and variety was obtained during 1967. The highest number of 8.5 pods per raceme were produced by the Hairy Peruvian variety when irrigated once every two weeks. The lowest number of 6.2 pods per raceme were produced by African variety under the four week irrigation interval (Table 21 in the appendix).

Seeds Per Pod

The data for the number of seeds per ten pods are summarized in Tables 7 and 8. The largest number of seeds per pod were produced under fortnightly irrigation interval during 1966, but it was not significantly different from the control. Three and four week irrigation intervals produced significantly smaller number of seeds than the control. During 1967, only those plants receiving irrigation once every four weeks produced significantly smaller number of seeds per pod. I_2 and I_3 treatments did not show any significant differences from the control. The low number of seeds produced under low moisture conditions could be due to the moisture stress on the normal physiology of the reproductive parts of the plants as reported by Grandfield (19).

In both years spacing did not show any significant difference for the number of seeds per pod. However, significant variations were observed among the three varieties. Hairy Peruvian variety produced more seeds per pod than African (control). Chilean variety did not

Table 7. Effect of irrigation interval and within-row spacing on the number of seeds per 10 pods of alfalfa - 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	63.5	63.0	65.0
	S_2	64.5	57.8	66.0
	S_3	57.5	64.5	66.2
I_2	S_1	63.0	67.0	69.5
	S_2	59.5	61.8	69.2
	S_3	62.0	63.8	67.0
I_3	S_1	54.0	50.5	59.2
	S_2	52.8	56.0	57.2
	S_3	50.0	51.5	55.8
I_4	S_1	54.8	53.8	56.8
	S_2	52.0	57.0	57.2
	S_3	48.2	50.2	57.5

LSD	5%	1%
Irrigation interval	6.4	9.4
Variety	1.5	1.9

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	63.1	S_1	60.0	African	56.8
I_2	64.8	S_2	59.2	Chilean	58.1
I_3	54.1*	S_3	57.8	H. Peruvian	62.2**
I_4	54.1*				

* Significant at 5% level.
** Significant at 1% level.

Table 8. Effect of irrigation interval and within-row spacing on the number of seeds per 10 pods of alfalfa - 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	57.2	66.8	65.8
	S_2	62.5	62.8	66.8
	S_3	70.5	63.8	69.2
I_2	S_1	63.0	61.5	65.5
	S_2	64.2	61.5	64.5
	S_3	56.0	59.5	62.8
I_3	S_1	65.5	61.8	61.5
	S_2	66.5	68.0	70.8
	S_3	63.2	64.2	69.8
I_4	S_1	58.8	61.2	62.0
	S_2	55.2	62.0	56.8
	S_3	56.0	56.0	59.0

LSD	5%	1%
Irrigation interval	4.3	6.2
Variety	2.3	3.1

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	65.0	S_1	62.6	African	61.6
I_2	62.1	S_2	63.5	Chilean	62.4
I_3	65.7	S_3	62.5	H. Peruvian	64.5*
I_4	58.6**				

* Significant at 5% level.
** Significant at 1% level.

differ statistically from the control.

1000-Seed Weight

It can be indicated from the data presented in Tables 9 and 10 that irrigation treatment had the significant effect on the seed weight in 1966, but not in 1967. During 1966 (Table 9) the heavy seeds were obtained from plants receiving irrigation after weekly and fortnightly interval. Three and four weeks intervals produced significantly lighter seeds as compared with the control.

The results may be explained by the fact that under wide irrigation intervals the plants suffered from moisture stress and produced small and shrivelled seeds. The shrivelled seeds were lighter in weight than the normal plump seeds that were produced from the plants under the weekly irrigation treatment. These results are in line with the findings of Pedersen and Nye (38) and Tysdal (46).

In both years the differences in seed weight obtained by the spacing and variety treatments were not significant.

Germination Percentage

The data for the germination percentages of 1966 and 1967 crop seeds are presented in Tables 11 and 12 respectively. It can be seen that there was no significant effect of irrigation interval and within-row spacing on the germination capacity of alfalfa seeds. However, the variety differences were significant in both years. Chilean and Hairy Peruvian varieties gave lower germination percentages than did the African. During 1966 these differences were significant at 5% level, but were highly significant during 1967.

Table 9. Effect of irrigation interval and within-row spacing on the 1000-seed weight of alfalfa in grams - 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	2.48	2.32	2.19
	S_2	2.34	2.24	2.31
	S_3	2.39	2.27	2.32
I_2	S_1	2.26	2.29	2.41
	S_2	2.38	2.24	2.27
	S_3	2.48	2.25	2.21
I_3	S_1	1.98	1.99	2.05
	S_2	1.96	1.96	1.94
	S_3	2.06	1.89	2.03
I_4	S_1	2.04	2.02	1.95
	S_2	2.16	1.94	1.94
	S_3	1.94	1.90	1.88

LSD	5%	1%
Irrigation interval	0.07	0.10

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	2.32	S_1	2.16	African	2.20
I_2	2.31	S_2	2.14	Chilean	2.11
I_3	1.98**	S_3	2.13	H. Peruvian	2.12
I_4	1.97**				

** Significant at 1% level.

Table 10. Effect of irrigation interval and within-row spacing on the 1000-seed weight of alfalfa in grams - 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	2.13	2.11	2.17
	S_2	2.18	2.21	2.23
	S_3	2.15	2.25	2.26
I_2	S_1	2.15	2.15	2.23
	S_2	2.12	2.14	2.08
	S_3	2.10	2.14	2.14
I_3	S_1	2.15	2.11	2.08
	S_2	2.16	2.22	2.29
	S_3	2.18	2.14	2.22
I_4	S_1	2.09	2.08	2.06
	S_2	2.04	2.10	2.09
	S_3	2.03	2.06	2.08

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	2.19	S_1	2.13	African	2.12
I_2	2.14	S_2	2.16	Chilean	2.14
I_3	2.17	S_3	2.15	H. Peruvian	2.16
I_4	2.07				

Table 11. Effect of irrigation interval and within-row spacing on the germination percentage of alfalfa seeds - 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	85.8	81.2	85.2
	S_2	88.8	84.5	85.8
	S_3	88.5	84.8	82.5
I_2	S_1	89.8	84.2	85.2
	S_2	90.5	87.5	87.2
	S_3	87.2	86.5	86.5
I_3	S_1	84.8	85.8	88.2
	S_2	85.8	82.2	83.5
	S_3	84.5	83.5	82.8
I_4	S_1	85.8	86.2	84.2
	S_2	84.5	84.5	82.2
	S_3	85.5	87.2	83.5

LSD	5%	1%
Variety	1.4	1.8

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	85.2	S_1	85.5	African	86.8
I_2	87.2	S_2	85.6	Chilean	84.8*
I_3	84.6	S_3	85.3	H. Peruvian	84.7*
I_4	84.8				

* Significant at 5% level.

Table 12. Effect of irrigation interval and within-row spacing on the germination percentage of alfalfa seeds - 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	87.8	84.2	80.2
	S_2	86.5	85.2	81.8
	S_3	86.8	82.2	80.5
I_2	S_1	88.5	78.2	82.2
	S_2	83.8	82.5	83.5
	S_3	82.8	85.2	79.8
I_3	S_1	87.8	83.2	84.2
	S_2	85.8	84.5	82.8
	S_3	83.5	77.5	79.2
I_4	S_1	86.2	79.2	78.2
	S_2	80.8	78.5	80.5
	S_3	83.8	81.8	81.8

LSD	5%	1%
Variety	1.6	2.2

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	83.9	S_1	83.3	African	85.3
I_2	82.9	S_2	83.0	Chilean	81.8**
I_3	84.3	S_3	82.1	H. Peruvian	81.2**
I_4	81.2				

** Significant at 1% level.

Hard Seeds

The data for hard seeds of 1966 and 1967 crops are summarized in Tables 13 and 14 respectively. In both years, the effect of irrigation treatment was highly significant on the number of hard seeds produced. During 1966, irrigation after three and four weeks intervals resulted in a higher number of hard seeds as compared to the weekly irrigation (control). But during 1967, only the irrigation after four week intervals resulted in significantly higher number of hard seed production. Fortnightly and three weeks intervals did not differ significantly from the control. No significant differences in the number of hard seeds were observed due to the within-row spacing treatment. Varietal differences in the number of hard seeds produced were significant in 1966. The Chilean variety produced significantly higher number of hard seeds than the control. The differences in 1967 were not significant. In both years the number of hard seeds produced by the Hairy Peruvian variety was not statistically different from that of the control.

It can be seen from Tables 13 and 14 that the number of hard seeds obtained during 1967 was more than that of 1966. The low number of hard seeds reported in Table 13 as compared to the relatively high number reported in Table 14 may be attributed to the fact that the hard seed test of 1966 crop was done two months after harvesting, whereas in 1967 the test was done immediately after harvesting. It is well-known that the high percentage of hard seeds in freshly harvested alfalfa crop decreases with age.

Table 13. Effect of irrigation interval and within-row spacing on hard seed production - 1966.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	2.2	3.5	2.6
	S_2	2.5	3.8	2.2
	S_3	2.8	3.8	3.8
I_2	S_1	5.2	6.2	5.7
	S_2	3.8	8.8	5.0
	S_3	4.2	8.5	4.8
I_3	S_1	9.5	12.8	6.2
	S_2	6.0	13.5	8.5
	S_3	10.0	12.5	6.5
I_4	S_1	12.5	15.0	10.0
	S_2	10.5	15.8	10.8
	S_3	14.0	12.5	9.0

LSD	5%	1%
Irrigation interval	4.1	6.0
Variety	1.9	2.6

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	3.0	S_1	7.6	African	6.9
I_2	5.7	S_2	7.6	Chilean	9.9**
I_3	9.5**	S_3	7.7	H. Peruvian	6.3
I_4	12.3**				

** Significant at 1% level.

Table 14. Effect of irrigation interval and within-row spacing on hard seed production - 1967.

Irrigation interval	Within-row spacing	Variety		
		African	Chilean	Hairy Peruvian
I_1	S_1	6.0	6.5	6.5
	S_2	6.8	5.6	5.8
	S_3	5.5	6.2	7.0
I_2	S_1	9.5	10.8	11.2
	S_2	10.2	13.5	12.0
	S_3	10.5	9.0	9.5
I_3	S_1	13.5	12.5	11.5
	S_2	14.0	10.5	12.2
	S_3	12.8	13.0	8.0
I_4	S_1	16.5	17.8	15.8
	S_2	18.8	17.2	18.5
	S_3	18.2	18.0	16.8

LSD	5%	1%
Irrigation interval	6.9	10.1

Treatment Means

Irrigation interval		Within-row spacing		Variety	
I_1	6.2	S_1	11.5	African	11.9
I_2	10.7	S_2	12.1	Chilean	11.7
I_3	12.0	S_3	11.2	H. Peruvian	11.2
I_4	17.5**				

** Significant at 1% level.

Tripping and Pollination

A preliminary study on natural and artificial tripping, in the absence of pollinating insects, was conducted on caged plants of the African, Chilean, and Hairy Peruvian varieties. The data collected on pod setting percentage, number of seeds per pod, germination percentage, and seed vigor, are presented in Tables 15-18.

Pod setting percentage: It appears from the data given in Table 15 that there was a great difference in the percentage of flowers forming pods as affected by the cause of tripping. The data have not been analyzed statistically but it is clear that mechanical tripping increased the pod setting percentage considerably over natural tripping. The two years averages showed 5.99 and 17.49 percent pod setting of natural tripping and mechanical tripping respectively. The ratio was 1:2.9 in favor of mechanical tripping.

There was very little difference among the three varieties with respect to the pod setting percentage due to natural or mechanical tripping. Hairy Peruvian variety showed the least percent pod setting among the three varieties under natural tripping method. Chilean variety gave relatively higher pod setting percentage by mechanical tripping.

In general, a higher pod setting was observed in 1966 in the three varieties as compared to that of 1967. This difference may be attributed to the fact that the season of 1966 was more favourable to alfalfa seed production than that of 1967.

It is clear from the data presented that artificial tripping of alfalfa flowers results in better pod setting. These results are in agreement with (11, 26, 39 and 42).

Table 15. Percentage of flowers forming pods due to natural and artificial tripping - 1966, 1967.

Variety	Treatment					
	Natural tripping			Artificial tripping		
	1966	1967	Variety mean	1966	1967	Variety mean
African	8.23	4.62	6.44	18.28	16.00	17.14
Chilean	7.29	5.32	6.31	20.55	15.19	17.87
H. Peruvian	6.09	4.32	5.21	20.07	14.76	17.46
Year Mean	6.87	4.76		19.63	15.32	
Treatment Mean			5.99			17.49

<u>Seeds per pod</u>: It is apparent from Table 16 that pods formed by open pollination set considerably more seeds than those tripped by either natural or mechanical means. The mean values of natural tripping, mechanical tripping and insect pollination of the three varieties are 1.73, 1.89 and 6.09 respectively. Not much difference was observed in the number of seeds set per pod between natural and mechanical tripping. Insect pollination produced about 3.5 times more seeds per pod than those of either natural or mechanical tripping.

The higher number of seeds per pod set by insect pollination may be attributed to the advantage of cross pollination over selfing. Natural and mechanical tripping lead to selfing, whereas insects result in tripping and cross pollination at the same time. The results obtained are in line with the findings of (7, 26, 27 and 39).

Table 16. Number of seeds per pod set by natural tripping, artificial tripping and open pollination - 1966, 1967.

Variety	Treatment								
	Natural tripping			Artificial tripping			Open pollination		
	1966	1967	Variety mean	1966	1967	Variety mean	1966	1967	Variety mean
African	1.71	1.72	1.72	1.94	1.69	1.82	5.68	6.14	5.19
Chilean	1.52	1.70	1.61	1.97	1.73	1.85	5.81	6.24	6.02
H. Peruvian	2.05	1.67	1.86	2.16	1.84	2.00	6.20	6.47	6.34
Year Mean	1.76	1.69		2.02	1.75		5.56	6.28	
Treatment Mean			1.73			1.89			6.09

Germination percentage: It can be seen from Table 17 that seeds resulting from open pollination gave higher germination percentages than those seeds obtained from either natural or mechanical tripping. Not much difference was obtained between natural and mechanical tripping. The differences in the germination percentages between the seeds set after open pollination and natural or mechanical tripping may be due to some partial incompatibility factors present among the plants.

Seedling vigor: The data for seedling vigor, as measured by the length of the seedlings, are given in Table 18. It is apparent that seeds produced by insect pollination were more vigorous than those produced by natural and artificial tripping. These results emphasize the beneficial effects of cross-pollination in alfalfa seed production.

Table 17. Germination percentage of seeds set by natural tripping, artificial tripping, and open pollination - 1966, 1967.

Variety	Treatment								
	Natural tripping			Artificial tripping			Open pollination		
	1966	1967	Variety mean	1966	1967	Variety mean	1966	1967	Variety mean
African	49	34	41.5	57	37	47.0	75	63	69.0
Chilean	53	38	45.5	59	32	45.5	69	59	64.0
H. Peruvian	61	31	46.0	53	36	44.5	76	59	67.5
Year Mean	54.3	34.3		56.3	35.0		73.3	60.0	
Treatment Mean			44.3			45.7			66.8

Table 18. Seedling vigor in mm of seeds set by natural tripping, artificial tripping, and open pollination - 1967.

Variety	Treatment			Variety Mean
	Natural tripping	Artificial tripping	Open pollination	
African	21.6	18.7	43.7	28.0
Chilean	19.5	21.2	41.6	27.4
H. Peruvian	22.7	20.9	42.5	28.7
Treatment Means	21.3	20.3	42.6	

<u>Alfalfa pollinators</u>: A record of the alfalfa pollinators, throughout the growing season of the crop, indicated that honey bees and some species (unidentified) of wild bees are the important pollinators of alfalfa crop in the Beqa'a area. Honey bees were present throughout the growing season, while the wild bees were more abundant at the full bloom stage of the crop.

V. SUMMARY AND CONCLUSIONS

The experiment was conducted during the 1966 and 1967 growing season at The Agricultural Research and Education Center of The American University of Beirut, to study the effects of four irrigation intervals and three within-row spacings on seed production in alfalfa. Three alfalfa varieties namely African, Chilean, and Hairy Peruvian were used in the experiment. The characters studied were seed yield, plant height, pods per raceme, seeds per pod, seed weight, germination percentage, and hard seeds.

The irrigation intervals and within-row spacings had their effects on seed yield. The highest seed yield was obtained by the fortnightly irrigation interval. The 50 cm spacing proved to be better than 25 and 75 cm spacings. The Hairy Peruvian variety outyielded the African and Chilean varieties. During 1967, the interaction between irrigation and within-row spacing was significant and the highest seed yield of 73.1 kg per dunum was obtained from the plants spaced 50 cm apart and irrigated once every two weeks.

The plots receiving irrigation at weekly interval produced the tallest plants with a tendency towards lodging. The 25 cm within-row spacing produced tall plants as a result of the crowding and shading effects. The interaction between irrigation and within-row spacing was significant during 1967 and the tallest plants were produced by the 25 cm within-row spacing under the weekly irrigation regime.

The fortnightly irrigation interval and the 75 cm within-row spacing treatments produced large number of pods per raceme. Out of the three alfalfa varieties, the Hairy Peruvian out-numbered African and Chilean. During 1967, the fortnightly irrigation and the Hairy Peruvian variety interaction gave the highest number of 8.5 pods per raceme.

The number of seeds per pod was affected by the irrigation interval and not by within-row spacing. Plants which were irrigated once every two weeks produced more number of seeds per pod. Significantly small number of seeds per pod were produced by those plants which were irrigated at three and four week intervals during 1966 and at four week intervals during 1967. Among the three varieties used in the study, the Hairy Peruvian produced the largest number of seeds per pod.

During 1966, the heavy seeds were obtained from those plants which were irrigated at weekly and fortnightly intervals. However, there was no difference in seed weight during 1967.

Germination percentage was not affected by either irrigation or within-row spacing treatment. In both years, however, the African variety gave a higher germination percentage than the Chilean and Hairy Peruvian.

The plants which were irrigated at three and four week intervals produced significantly higher number of hard seeds than did those irrigated at weekly intervals. During the 1966 growing season, the Chilean variety produced significantly larger number of hard seeds than the African (control).

The preliminary study on tripping of alfalfa flowers indicated that mechanical tripping increased pod setting by three-fold of the untripped flowers. Tripped and untripped flowers produced the same number of seeds per pod. These seeds gave very low germination percentages, and week seedlings as measured by the length of the seedling obtained in the germination test.

Collection of alfalfa pollinators throughout the growing seasons indicated that honey bees and some unidentified species of wild bees are the important pollinators of alfalfa in the Beqa'a area.

On the basis of the above mentioned results it may be concluded that:

i. Alfalfa plants spaced 50 X 50 cm apart and irrigated at two week intervals produced high seed yield.

ii. The alfalfa variety Hairy Peruvian was found to be better adapted than the African and Chilean for seed production in the Beqa'a area.

iii. The number of pods per raceme and seeds per pod were found to be directly related to seed yield.

iv. Low moisture content in the soil was conducive to hard seed production.

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A P P E N D I X

Table 19. Analysis of variance for seed yield of alfalfa during 1966 and 1967.

Source	D.f.	M.S. 1966	M.S. 1967
Replication	3	4552.66**	109.10
Irrigation	3	6893.03**	3297.27**
Error (a)	8[+]	632.08	251.74
Within-row spacing	2	4755.35**	1368.75**
Irrigation X within-row spacing	6	165.26	143.87*
Error (b)	24	697.00	39.40
Variety	2	7059.20**	731.50**
Irrigation X variety	6	239.10	24.61
Within-row spacing X variety	4	381.70	24.00
Irrigation X within-row spacing X variety	12	533.75	35.53
Error (c)	72	284.41	22.43

Irrigation X within-row spacing - 1967.

	I_1	I_2	I_3	I_4
S_1	60.6	61.7	60.2	42.1
S_2	70.3	73.1	69.6	48.8
S_3	61.4	60.8	60.3	44.4

* Significant at 5% level.

** Significant at 1% level.

+ The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 20. Analysis of variance for plant height of alfalfa during 1966 and 1967.

Source	D.f.	M.S. 1966	M.S. 1967
Replication	3	913.13*	32.20
Irrigation	3	8026.73**	4898.03**
Error (a)	8†	156.15	102.62
Within-row spacing	2	764.60**	1018.55**
Irrigation X within-row spacing	6	187.23	137.27*
Error (b)	24	77.07	45.58
Variety	2	5.30	131.60*
Irrigation X variety	6	39.66	43.18
Within-row spacing X variety	4	42.44	52.55
Irrigation X within-row spacing X variety	12	61.20	20.48
Error (c)	72	59.64	38.19

Irrigation X within-row spacing - 1967.

	I_1	I_2	I_3	I_4
S_1	127.2	124.9	114.7	110.7
S_2	124.7	121.9	104.9	98.3
S_3	125.5	118.9	104.2	94.1

* Significant at 5% level.
** Significant at 1% level.
† The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 21. Analysis of variance for number of pods per raceme during 1966 and 1967.

Source	D.f.	M.S. 1966	M.S. 1967
Replication	3	5.03	1.40
Irrigation	3	47.34**	25.66**
Error (a)	8†	0.80	1.20
Within-row spacing	2	3.00*	8.40*
Irrigation X within-row spacing	6	1.72	2.08
Error (b)	24	0.83	1.57
Variety	2	7.15**	2.00**
Irrigation X variety	6	0.70	0.60*
Within-row spacing X variety	4	0.90	0.08
Irrigation X within-row spacing X variety	12	0.67	0.17
Error (c)	72	0.66	0.22

Irrigation X variety - 1967.

	I_1	I_2	I_3	I_4
African	6.5	8.2	7.4	6.2
Chilean	6.7	8.2	7.1	6.3
H. Peruvian	7.5	8.5	7.4	6.3

* Significant at 5% level.
** Significant at 1% level.
† The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 22. Analysis of variance for number of seeds per 10 pods of alfalfa during 1966 and 1967.

Source	D.f.	M.S. 1966	M.S. 1967
Replication	3	19.93	61.20
Irrigation	3	1166.66**	382.86*
Error (a)	8÷	140.85	62.36
Within-row spacing	2	56.90	14.10
Irrigation X within-row spacing	6	15.72	85.00
Error (b)	24	242.73	40.39
Variety	2	386.10**	142.95*
Irrigation X variety	6	7.33	1.87
Within-row spacing X variety	4	15.22	24.25
Irrigation X within-row spacing X variety	12	17.28	36.80
Error (c)	72	12.90	32.54

* Significant at 5% level.
** Significant at 1% level.
÷ The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 23. Analysis of variance for 1000-seed weight of alfalfa during 1966 and 1967.

Source	D.f.	M.S.	
		1966	1967
Replication	3	0.003	0.001
Irrigation	3	1.320**	0.07
Error (a)	8÷	0.16	0.05
Within-row spacing	2	0.015	0.02
Irrigation X within-row spacing	6	0.013	0.04
Error (b)	24	0.014	0.02
Variety	2	0.115	0.06
Irrigation X variety	6	0.012	0.04
Within-row spacing X variety	4	0.010	0.05
Irrigation X within-row spacing X variety	12	0.026	0.04
Error (c)	72	0.440	0.03

** Significant at 1% level.

÷ The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 24. Analysis of variance for germination percentage of alfalfa seeds during 1966 and 1967.

Source	D.f.	M.S. 1966	M.S. 1967
Replication	3	2.10	4.20
Irrigation	3	49.56	40.44
Error (a)	8÷	22.81	22.00
Within-row spacing	2	12.10	26.90
Irrigation X within-row spacing	6	7.20	19.80
Error (b)	24	12.29	24.99
Variety	2	59.80*	102.25**
Irrigation X variety	6	12.20	9.97
Within-row spacing X variety	4	4.22	23.50
Irrigation X within-row spacing X variety	12	21.67	11.98
Error (c)	72	12.41	16.16

* Significant at 5% level.
** Significant at 1% level.
÷ The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 25. Analysis of variance for hard seeds of alfalfa during 1966 and 1967.

Source	D.f.	M.S. 1966	M.S. 1967
Replication	3	220.00	25.20
Irrigation	3	4414.23**	1272.77**
Error (a)	8†	58.10	161.59
Within-row spacing	2	5.75	96.55
Irrigation X within-row spacing	6	38.69	22.43
Error (b)	24	32.68	78.59
Variety	2	315.10**	56.25
Irrigation X variety	6	52.67	61.92
Within-row spacing X variety	4	32.98	55.80
Irrigation X within-row spacing X variety	12	33.43	54.22
Error (c)	72	23.94	36.55

** Significant at 1% level.

† The number of degrees of freedom for error (a) has been reduced by one because of the confounding of the irrigation treatments.

Table 26. Average monthly temperatures, relative humidity, and total rain fall in mm at the Agricultural Research and Education Center, Beqa'a plain, Lebanon, during the growing seasons of 1966 and 1967.

Month	1966			1967		
	Temperature C°	Relative Humidity	Rain fall (mm)	Temperature C°	Relative Humidity	Rain fall (mm)
January	5.7	75.2	70.9	4.1	72.8	139.3
February	6.4	72.8	68.7	4.2	78.3	85.1
March	7.0	67.9	96.7	5.9	71.4	167.1
April	11.8	62.1	0.0	10.5	58.6	20.5
May	14.4	57.9	2.6	15.1	56.6	34.5
June	19.5	53.2	0.0	17.9	48.2	0.0
July	22.8	53.3	0.0	20.7	45.1	0.0
August	23.7	53.5	0.0	20.5	48.7	0.0
September	20.2	62.2	0.9	18.3	56.5	0.0
Total			239.8			446.5