THE EFFECT OF PLANT SPACING
ON
THE BUSH BEAN PLANT DEVELOPMENT AND YIELD

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Snap Bean Spacing

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ABSTRACT

An experiment was conducted to determine the effects of snap bean spacings on percent of seed germination, plant height, relative vigor, pod weight, pod length and width and yield. The results showed that spacings of 65 or 80 cms. between rows and spacings of 5, 8 or 11 cms. between plants in the rows were more favorable to plant development than closer row or plant spacings. The local variety Kassas and the American variety Tender Pod produced equally well and had the highest production. Row spacings and plant spacings had similar effects on production as both had negative correlations with yield.

It appears advisable for maximum snap bean yields to space the plants two cms. apart in rows spaced 35 cms. apart. This results in a maximum plant population of approximately 143,000 plants per dunum (du. equal to 1000 square meters). Moreover, it is advisable to grow the early variety Tender Pod together with the late variety Kassas to maintain the yield at the desired level for fresh market sales throughout the growing season.

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INTRODUCTION

Beans, according to the evidence found in ancient new world tombs, has had a long-established culture. Improvement of the crop, however, came rather late. Modern breeding has given higher quality, greater uniformity and productiveness, and in some varieties, resistance and tolerance to some of the important diseases.

Snap beans are low in calorie rating and rank neither high nor low in other nutritive values. In the United States, their rank is seventh in the value of product among the vegetables, and they have about the same rank in Lebanon and other countries of the Middle East. Yet, with the introduction of better quality varieties, much can be achieved in making this vegetable crop more popular, in this part of the world.

This study attempted to determine answers to two important problems in snap bean production which can be summarized in the following questions:

1. What is the best-adapted variety to be grown in a particular area?
2. What are the best row and plant spacings which constitute the optimal plant population for the chosen variety?

REVIEW OF LITERATURE

Plant Growth And Development

Seed Germination:- Among the factors shown to influence snap bean seed germination in the field, the depth of planting was the most critical. Warren (19) found no differences in stands or yields when seeds were sown at a depth of one or two inches, but at a depth of four inches the stands and yields were significantly reduced. Little or no work has been done on the effect of spacing on snap bean seed germination under field conditions.

Flowering:- The number of flowers per plant was observed by Agnew (1), in Australia, to increase as plant spacing within a row increased from two inches to a maximum at six inches.

Temperature influenced flower bud differentiation and blossoming in snap beans more than spacing. In Japan, Watanabe (20) showed with Low's Champion beans that long-sustained high temperature (30 degrees C.) and high night temperature before pollen mother cell reduction division resulted in abnormal flowers, most of whose pollen was abortive. It was also shown that low night temperature (15 degrees C.) was favorable to flower bud formation but not to node formation. Binkley (4), in the United States, conducted a thorough study of the amount of blossom and pod drop on six varieties of garden beans and concluded: 1. A negative correlation existed between percent blossom and pod drop and yield per plant. 2. The blossoming and fruit setting periods appeared to be critical in the development of the snap bean plant. During these periods plants were especially sensitive to sudden or wide variations in growth conditions. 3. The causal factors for blossom and pod drop were high air temperatures, sudden fluctuations in air temperatures from high to low and an uneven soil moisture supply.

Plant height:- Vincent (17), in the United States, used the canning pea variety Perfection 10 to compare three plant spacings. He observed that a spacing of one inch by 16 inches resulted in taller plants than spacings of four inches by four inches or two inches by eight inches. In another study, he observed that, with rows spaced 16 inches apart, plants spaced one inch apart were taller than plants spaced farther apart in the rows.

Fruit set:- Montalvo (15) worked on the density of sowing of French bean crops in 1959 and observed that high seed density resulted in competition among the plants and reduced the number of pods per plant and the number of beans per pod, yet did not affect quality. In Japan, Yamazaki (22) studied the morphogenesis of the bean plant under different growing conditions and observed that the response to close spacing was similar to that of shading, and that it first became evident when the leaves began to expand rapidly. Other morphological and physiological characteristics such as opening of stomata, chlorophyll concentrations, pollen germination and their interactions were determined by Andrews (2) to be factors which affected pod set and yield. Wide-open stomata, high chlorophyll concentrations and early pollen germination were all favorable to fruit set and yield.

Wunderlich (21) studied four pea varieties planted at different spacings and found that, although all varieties yielded less with wider spacings, some responded better than others to the available space and produced more shoots and hence more pods per plant. Furthermore, the data obtained by Larson and Li Peng-fi (11), in a study of the influence of various plant spacings on pod set and yield of lima beans, indicated that plant spacings with equal dimensions were generally superior to spacings with equal area but with unequal dimensions. They concluded that plant spacings with approximately equal dimensions provided better conditions for root spread and plant development than those with unequal dimensions.

Bean Production

Yield:- Plant spacing is but one of many important factors which influence snap bean yields. Date of planting and air temperatures influenced yields considerably, as observed by Mahoney *et al* (13) and Gillis (5) in the United States. The latter also observed that the fertility and moisture content of the soil and the size of plants and their habit of growth determined the proper plant spacing to be used. For example, in the case of Refugee, a large spreading variety, overcrowding became an important factor in decreasing yield. Furthermore, he observed that if soil and moisture conditions were unfavorable, or if the rates of planting were below the optimum, the type of growth exerted a marked influence upon yields. He concluded that a seeding rate of nine seeds per foot could be used for three varieties of kidney beans without danger of overcrowding. Small increments in yield could be expected in some seasons when the rate was extended to 12 plants per foot. Finally, he believed that with favorable conditions for growth it would be profitable to plant at the thicker rate (9-12 plants per foot), depending upon the relationship between cost of seed and the price obtained from green beans.

Matthews (14) studied the influence of planting distances on the yield of snap and lima beans and concluded that a 3 inch plant spacing was better than the wider spacings for both early and total yields. He found that there was a positive correlation between close spacing and yield.

The classical studies of Halsted (7) and Jordan (8) on the optimum seeding rates for snap beans showed that the thickest rates were the most favorable for good snap bean yields. On comparing distances of 3, 6, 12 and 24 inches between plants of the Golden Wax variety grown in rows 20 inches apart, Halsted found that the 3 inch plant spacing resulted in the highest yield, in spite of increased disease incidence on the closely spaced plants. Jordan planted two varieties of snap beans at several rates and observed that with six plants per foot of row the largest percentage of the crop was produced at the first picking. The highest yield, however, was obtained from plants sown 10 to the foot. Odland (16) obtained similar results from a study of the influence of plant spacing on the yield of six varieties of snap beans. With rows spaced three feet apart, the maximum yield was obtained from all varieties with plants spaced 1-2.5 inches apart.

In Egypt, Attia and Nassar (3) studied the performance of four snap bean varieties and their response to two different methods of planting on ridges spaced 60 cms. apart. In one method, groups of seeds were sown in hills 20 cms. apart. In the other, single seeds were spaced seven cms. apart. They found that the beans planted seven cms. apart in the rows gave a 40 percent greater return and significantly higher early yields of pods than those grouped in hills.

In the United States, a number of workers studied the influence of plant spacing on lima bean yields. In an investigation to determine the relationship between the two, Lachman and Snyder (10) noted that 27 percent of the variation in yield was associated with spacing of plants. MacGillivary _et al_ (12) conducted three experiments in California which involved three varieties of lima beans sown in rows 30 inches apart with the plants 4, 8 and 16 inches apart in the rows. They concluded that yields of green lima beans were generally highest at the 4 inch spacing with the 8 inch spacing only slightly inferior.

Vittum _et al_ (18) showed with peas that, when the seeding rate increased, the yield per acre increased while the yield per plant decreased.

Number of pods per plant:- An increase in the number of fruits per plant as the space between plants increased from 3 to 12 inches was observed by Matthews (14), with snap and lima beans. However, the increase in the number of pods per plant was not proportional to the increase in the distance between plants.

Size of pods and seeds:- Matthews (14) observed a slight indication that plants spaced six inches apart within a row produced pods of larger sizes than plants spaced three inches apart. In the case of peas, however, Vittum _et al_ (18) found that seed size was significantly reduced if the spacing between rows was doubled from 7 to 14 inches.

Maturity And Quality

Working with peas, Vittum _et al_ (18) observed that maturity was not affected by plant spacing. Little or no work has been done to determine the effect of plant spacing on the maturity of snap beans.

According to Guyer _et al_ (6) the maturity of green and wax beans pods was the most important factor affecting their quality. Of lesser importance were color, size, shape and fibrousness of the pods. Among the cultural practices known to affect maturity and quality, harvesting dates were of great importance. In one investigation they showed that with late harvesting the seed, fiber and ascorbic acid contents of the pods increased, while the moisture content and the concentrations of green and yellow pigments decreased. Moreover, it was shown that harvesting beans twice, at an early stage of maturity, produced good snap bean yields of good quality. Harvesting the whole crop in one operation gave high yields but at a great sacrifice in quality. Harvesting more than twice was of doubtful economic value.

MATERIALS AND METHODS

The experiment was conducted during one growing season, in 1963, at the American University Farm located in the Beqâa plain in Lebanon. The soil at the farm is a well-drained clay relatively high in potash, low in nitrogen and phosphorus and has a pH of around 8.

The split-plot experiment arranged in a 4x4 Latin Square used in this study involved the three American bush bean (Phaseolus vulgaris L. var. humilis Alef.) varieties Brittle Wax, Bountiful and Tender Pod and the local variety Kassas, four row spacings of 35, 50, 65 and 80 cms. between rows and four plant spacings of 2, 5, 8 and 11 cms. between plants. Each row of the Latin Square was a replication and each column was a block to which a row spacing was assigned, which facilitated furrow-irrigation. A main plot consisted of four sub-plots and each sub-plot consisted of four rows, 5 meters long. Varieties were assigned to the main plots and plant spacings to the sub-plots.

Twelve kgs./du. of N in the form of Ammonium Sulfonitrate and 20 kgs./du. of P_2O_5 in the form of superphosphate were broadcast on the surface and disked into the soil in the Fall prior to planting. On May 14, when the soil was warm enough for good germination, the seeds were sown by hand at approximately 2 cms. deep. The plots were irrigated at weekly intervals throughout the growing season by sprinklers for the first three weeks after planting and by furrow-irrigation thereafter.

The field was kept free from weeds throughout the growing season by appropriate cultural methods. The bean plants were disease-free and were kept insect-free by two sprays of Heptachlor wettable powder. Leafhoppers were the only insect pests of importance.

Pods were picked at weekly intervals at the proper stage of maturity for fresh use, starting on July 11 and ending on October 4. In order to minimize border effects, the central 4 meters of the two center rows of each four-row sub-plot were harvested for this study.

Data were recorded for each sub-plot on percent of seed germination, heights of plants at the first picking, relative plant vigor, yield, weight of 100 pods (random sample) and average length and width of pods. Statistical methods appropriate to the design were employed in the analysis of data (9). Analysis of variance tables appear in the Appendix.

RESULTS

Seed Germination

Two weeks after planting, the seedlings in the two middle rows in each sub-plot were counted. The percent of germination was computed by comparing the data obtained with the number of seeds sown. A summary of the results is presented in Table 1.

Table 1. The effects of varieties, row spacings and plant spacings on the percent of germination of snap bean seeds.ǂ

Variety	Percent germ.	Row spcg. (cms.)	Percent	Plt. spcg. (cms.)	Percent
Bountiful	74	35	67	2	69
Brittle Wax	74	50	76	5	80
Kassas	81	65	82	8	79
Tender Pod	77	80	81	11	78
L.S.D. 5%	N.S.		10		5
1%	---		--		6

ǂ Average of 4 sub-plots.

The data in Table 1 shows that percent seed germination was approximately the same for all varieties. The 35 cm. row spacing resulted in significantly lower seed germination than the wider spacings which had small but non-significant differences. Similarly, the 2 cm. plant spacing resulted in highly significantly lower percent seed germination than the wider spacings which had approximately the same percent seed germinations.

Vigor And Height Of Plants

At the time of the first picking, plants of the four varieties were inspected to determine their relative vigor based upon their size and the amount of spreading of the plants. The plant-vigor for the varieties in decreasing order was: Kassas, Bountiful, Brittle Wax and Tender Pod. Plants of Brittle Wax were only slightly more vigorous than those of Tender Pod. Immediately after evaluating the varieties for vigor the heights of four plants chosen at random from each sub-plot were measured. A summary of the results is presented in Table 2.

Table 2. The effects of varieties, row spacings and plant spacings on the height of snap bean plants≠.

Variety	Plant ht. (cms.)	Row spcg. (cms.)	Plant ht. (cms.)	Plant spcg. (cms.)	Plant ht. (cms.)
Bountiful	34.50	35	34.00	2	35.56
Brittle Wax	32.81	50	33.63	5	36.25
Kassas	43.19	65	36.06	8	34.94
Tender Pod	30.38	80	37.19	11	34.13
L.S.D. 5%	3.41		N.S.		1.18
1%	5.04		----		1.58

≠ Average of 4 sub-plot samples of 4 plants each.

The data in Table 2 shows that plants of Kassas were highly significantly taller than plants of the other varieties which were approximately the same in height. There were no significant differences among the heights of plants from the different row spacings. Neither plants spaced 2 cms. or 5 cms. apart nor those spaced 8 cms. or 11 cms. apart showed significant differences in their heights, however, closer spaced plants were taller than the wider spaced plants. Plants spaced 5 cms. apart were highly significantly taller than those spaced 11 cms. apart and significantly taller than those spaced 8 cms. apart. Plants spaced 2 cms. apart were significantly taller than those spaced 11 cms. apart.

Weight Of Pods

The weight of a random sample of 100 pods was obtained during the first picking from each sub-plot. A summary of the data is presented in Table 3.

Table 3. The effects of varieties, row spacings and plant spacings on the weight of snap bean pods.≠

Variety	Wt. of 100 pods (gms.)	Row spcg. (cms.)	Wt. of 100 pods (gms.)	Plt. spcg. (cms.)	Wt. of 100 pods (gms.)
Bountiful	516.9	35	397.8	2	400.6
Brittle Wax	434.1	50	413.1	5	428.1
Kassas	321.2	65	440.0	8	425.3
Tender Pod	428.8	80	450.0	11	446.9
L.S.D. 5%	54.6		N.S.		18.3
1%	80.8		----		24.5

≠ Average of 4 sub-plot samples of 100 pods each.

The data presented in Table 3 shows that the weight of Bountiful pods was highly significantly greater than the weights of the pods of the other varieties. There were no significant differences between the weights of Tender Pod and Brittle Wax pods. The weights of pods of the latter two varieties were highly significantly greater than the weight of pods of Kassas. There were no significant differences among the different row spacings with respect to pod-weight. Yet, there was a tendency for the pod-weight to increase with the increase in row spacing. The weight of pods from plants spaced 11 cms. apart was significantly greater than the weights of pods from plants spaced 5 cms. or 8 cms.

apart, which were approximately the same. The weights of pods from plants spaced 5 cms., 8 cms. or 11 cms. apart were highly significantly greater than the weight of pods from plants spaced 2 cms. apart.

Length And Width Of Pods

A random sample of 10 pods was obtained from each sub-plot during the first picking to determine the average length and average width of the pods. The data are summarized in Tables 4 and 5.

Table 4. The effects of varieties, row spacings and plant spacings on the average length of snap bean pods.≠

Variety	Avg. length of pod (cms.)	Row spcg. (cms.)	Avg. length of pod (cms.)	Plt. spcg. (cms.)	Avg. length of pod (cms.)
Bountiful	12.58	35	10.34	2	10.28
Brittle Wax	11.66	50	10.45	5	10.90
Kassas	8.38	65	10.87	8	10.79
Tender Pod	10.18	80	11.12	11	10.82
L.S.D. 5%	0.38		0.38		0.33
1%	0.57		0.57		0.44

≠ Average of 4 sub-plot samples of 10 pods each.

An examination of the data in Table 4 shows that there were highly significant differences among the varieties with respect to length of pod. The varieties arranged in decreasing order with respect to pod-length were: Bountiful, Brittle Wax, Tender Pod and Kassas. Pods harvested from plants in rows spaced 65 cms. or 80 cms. apart and those from plants in rows spaced 35 cms. or 50 cms. apart showed no significant differences between their lengths, however, pods from plants in the wider spaced rows were significantly longer than those from plants in the closer spaced rows. Moreover, pods harvested from plants in rows spaced 80 cms. apart were highly significantly longer than pods from plants in rows spaced 35 cms. or 50 cms. apart. There were no significant differences among 5 cm., 8 cm. and 11 cm. plant spacings with respect to pod-length but pods from plants spaced at the wider spacings were highly significantly longer than pods from plants spaced two cms. apart.

The data presented in Table 5 shows that Bountiful produced pods highly significantly wider than pods of Brittle Wax and significantly wider than pods of Tender Pod or Kassas. The widths of pods of the latter two varieties did not differ significantly. Neither row spacings nor plant spacings differed significantly in influencing the width of pods.

Table 5. The effects of varieties, row spacings and plant spacings on the average width of snap bean pods/.

Variety	Av. width of pod (cm.)	Row spcg. (cm.)	Av. width of pod (cm.)	Plt. spcg. (cm.)	Av. width of pod (cm.)
Bountiful	1.10	35	0.94	2	0.95
Brittle Wax	0.84	50	0.93	5	0.96
Kassas	0.96	65	0.95	8	0.95
Tender Pod	0.93	80	1.02	11	0.98
L.S.D. 5%	0.11		N.S.		N.S.
1%	0.17		----		----

/ Average of 4 sub-plot samples of 10 pods each.

Yields Of Snap Bean Pods

Pods of all varieties were picked at weekly intervals. Since Kassas, the local variety, came into bearing later than the American varieties, it was picked 10 times, whereas, pods of the latter varieties were picked 13 times. However, in this study, only the yields of the first 5 pickings were included in the total yield for each sub-plot in order to conform to commercial practice. A summary of the results appears in Table 6.

The data presented in Table 6 shows that the two varieties Tender Pod and Kassas produced the same yields.

Moreover, both produced highly significantly greater yields than Brittle Wax and significantly greater yields than Bountiful. Bountiful produced a highly significantly greater yield than Brittle Wax. Plants in rows spaced 35 cms. apart produced highly significantly greater yields than those in rows spaced 50 cms. or 80 cms. apart and significantly greater yields than those in rows spaced 65 cms. apart. There were no significant differences between the yields of plants in rows spaced 50 cms. or 80 cms. apart, while plants in rows spaced 65 cms. apart produced significantly greater yields than those in rows spaced 80 cms. apart. Plants spaced 2 cms. apart produced highly significantly greater yields than those planted at the wider spacings. There were no significant differences between the 5 cm. and 8 cm. plant spacings with respect to yield, but plants from the latter two spacings produced highly significantly greater yields than those from the 11 cm. spacing.

Table 6. The effects of varieties, row spacings and plant spacings on the total yield from the first 5 pickings of snap bean pods/.

Variety	Yield (tons per du.)//	Row spcg. (cms.)	Yield (tons per du.)	Plt. spcg. (cms.)	Yield (tons per du.)
Bountiful	1.52	35	1.71	2	1.70
Brittle Wax	1.20	50	1.44	5	1.57
Kassas	1.69	65	1.55	8	1.49
Tender Pod	1.69	80	1.40	11	1.33
L.S.D. 5%	0.13		0.13		0.08
1%	0.20		0.20		0.11

/ Average of 4 sub-plots.

// A Metric ton equal to 1000 Kgs. was used.

The average yields over all varieties for all row and plant spacings were calculated in order to determine the presence of interactions between the spacing treatments. The data are presented in Table 7. The results given in this table show that, in general, combinations of close row and plant spacings result in higher yields than those of the wider row and plant spacings.

Table 7. The effects of row spacings and plant spacings on the total yield from the first 5 pickings of snap bean pods[/].

Yield in tons per dunum[//]				
Plant spcgs.	Row spacings			
	35 cms.	50 cms.	65 cms.	80 cms.
2 cms.	1.87	1.65	1.75	1.54
5 cms.	1.77	1.52	1.56	1.44
8 cms.	1.64	1.44	1.51	1.40
11 cms.	1.55	1.14	1.40	1.23

/ Average of 4 sub-plots of all varieties.

// A Metric ton equal to 1000 Kgs. was used.

It was observed that the yields of the four varieties varied from picking to picking. These yield differences are presented in a graph that appears in Figure 1.

The curves in Figure 1 show that the peaks of production of the varieties Bountiful, Kassas and Tender Pod occurred at the second picking on July 19 for Bountiful and Tender Pod and on August 8 for Kassas, while that of Brittle Wax occurred at the third picking on July 25. Lower yields were obtained from all the varieties with later pickings. Secondary peaks of production appeared at the seventh picking on August 23 for Bountiful, the eighth picking on August 30 and September 20 for Brittle Wax and Kassas res-

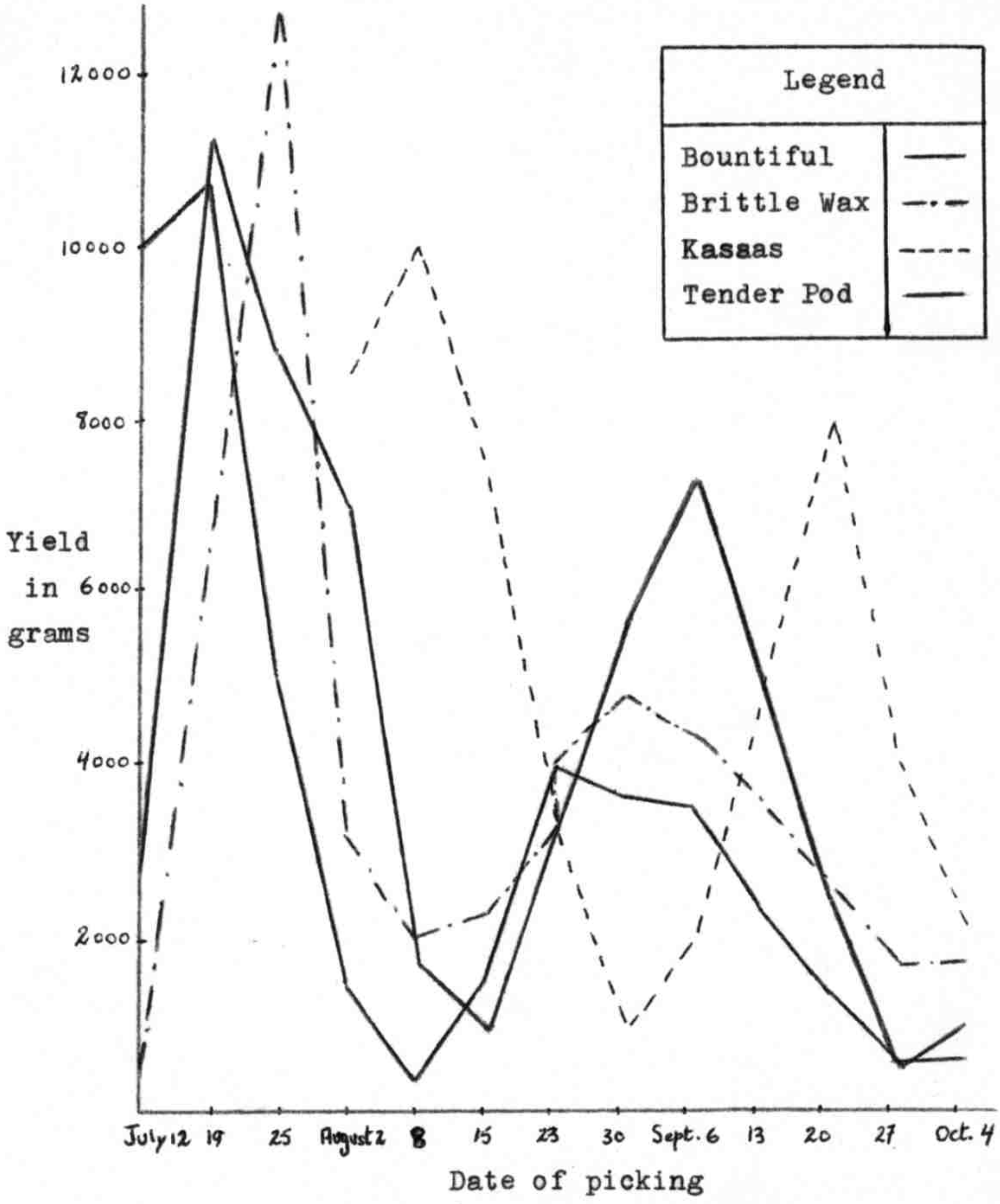

Figure 1. Yields of varieties as affected by dates of pickings.

pectively and the ninth picking on September 6 for Tender Pod. After these secondary peaks of production the decline in yields continued for all varieties until the tenth and last picking on October 4 for Kassas and the twelfth picking on September 27 for the American varieties.

DISCUSSIONS AND CONCLUSIONS

The effects of row and plant spacing on snap bean seed germination were found to be greater than the effect of varieties. The highest percentage of seed germination occurred in the rows planted 65 cms. or 80 cms. apart and in rows in which the seeds were planted 5 cms., 8 cms. or 11 cms. apart. Decidedly lower germination occurred in rows planted 35 cms. or 50 cms. apart and in rows in which the seeds were planted 2 cms. apart. It appears that both wide row spacing and wide plant spacing produce conditions favorable to seed germination.

Plant spacings appeared to play a greater role than row spacings in determining plant-height. Plants spaced 2 cms. or 5 cms. apart were taller than those spaced at the wider spacings. These results confirmed the findings of Vincent (17) who reported similar results using peas. Furthermore, it can be inferred from the findings of Yamazaki (22) that since snap bean plants had a similar response to close spacings as they did to shading then such close-spaced plants in a state of competition for light would tend to grow taller than plants with adequate light.

The weight of snap bean pods is determined in part by such characteristics as length, width, stage of maturity, amount of fill and amount of swelling of the pods. In this investigation, pods of the two varieties Kassas and Tender Pod weighed less than pods of the other two varieties. These pods were also shorter than pods of the latter two varieties yet their widths were greater than the width of Brittle Wax pods. Kassas pods for example, ranked second among pods of the varieties with respect to width of pods but were last with respect to length and weight of pods.

The plants produced pods of similar weight regardless of row spacing. However, plants from the 5, 8 or 11 cm. spacings between plants produced heavier pods than plants from the 2 cm. spacing. This confirmed the results of the effect of plant spacing on snap bean pod size reported by Matthews (14).

Plants from the rows spaced 65 or 80 cms. apart and those spaced 5, 8 or 11 cms. apart in the row produced longer pods than plants from rows spaced 35 or 50 cms. apart or from those spaced 2 cms. apart in the row. Plants from all row and plant spacings produced pods of approximately the same width. The increase in weight appears to be correlated with an increase in length of the pods produced by the plants from wide plant and row spacings. Moreover, it is apparent that pod-weight is influenced more by pod-length than by pod-width.

Although pod-size is secondary in importance to the proper stage of maturity in determining quality, a large and tender pod is always attractive. In addition, other characteristics of the pods influence quality and attractiveness. In the case of Brittle Wax pods, for example, the pods are of good size and, when picked at the proper stage of maturity, these pods are tender and of good flavor; yet, their pale waxy color make them rather unattractive to buyers in the Middle East. On the other hand, flatness in the pod appears to be a characteristic that is desired by people in the Middle East. This is one reason why Bountiful with its flat pods can be expected to be accepted more readily, in the local markets, than the other American varieties. It is the author's belief that with the help of extension workers some time will elapse before people in this part of the world will accept readily snap bean varieties of good but uncommon characteristics on their markets.

Among the three American varieties grown in this study, none was superior to the local variety Kassas in the total yield obtained from the first 5 pickings, but Tender Pod produced equally well. Row spacings and plant spacings had similar effects on production as both had negative correlations with the yield.

It has been shown in this experiment that when the seeding rate increased the yield per dunum increased; or in other words, when the plants were seeded 2 cms. apart in rows 35 cms. apart maximum yields were obtained. However, it should be noted that while wide spacings tend to cut down on the yield per dunum they tend to increase the yield per plant as was shown by Vittum et al (18) in the case of peas. It appears that no direct correlations occur between plant-height and production or between pod-weight and production. Actually, the number of pods per plant maybe the best index for production and should be employed in later research in this field.

On the basis of the findings recorded in Tables 6 and 7 it is advisable, for maximum snap bean yields, to space the plants - of any of the four varieties - 2 cms. apart in rows spaced 35 cms. apart. This will result in a maximum plant population of approximately 143,000 plants per dunum. The above recommendation is more or less in agreement with the findings of Jordan (8), Halsted (7), Gillis (5) and Matthews (14) who concluded that the high rates of planting were favorable to snap bean yields and that a positive correlation existed between close plant spacing and yield. Moreover, in order to keep snap bean production at a desireable level for fresh market sales, the farmer is advised to grow the two varieties Tender Pod and Kassas. By the time a decline in the yield of the early variety Tender Pod takes place, the late variety Kassas will compensate for this decline and will help keep the yield at the desired level.

The author believes that in future work in this field, the emphasis should be placed on relatively closer row and plant spacings.since such close spacings proved to be the most favorable to snap bean production. In addition, it is suggested that where furrow-irrigation methods are employed the use of two rows per ridge should be investigated.

SUMMARY

All varieties had approximately the same percent of seed germination. Row and plant spacings had a greater influence on snap bean seed germination or seedling emergence than the varieties. Wide row spacings of 65 or 80 cms. between rows and plant spacings of 5, 8 or 11 cms. between plants appeared to increase percent seed germination.

Plant-height appeared to be favored by the wide row spacings or the close plant spacings.

Pod-weight is determined by pod-length, pod-width, stage of maturity, amount of fill and amount of swelling of pods. Pod-weight was not affected by the different row spacings yet it increased with an increase in plant spacing.

Pod-length had a greater influence on pod-weight than pod-width had. It increased with an increase in row or plant spacings. On the other hand, pod-width was the same regardless of row or plant spacings.

None of the American varieties was superior to the local variety Kassas in production; yet, Tender Pod produced equally well. Row spacings and plant spacings had similar effects on production as both had negative correlations with yield.

It appears advisable for maximum snap bean yields to space the plants - of any of the four varieties - 2 cms. apart in rows spaced 35 cms. apart. This will result in a maximum plant population of approximately 143,000 plants per dunum. Moreover, in order to keep snap bean production at a desirable level for fresh market sales, the grower is advised to grow the two varieties Tender Pod and Kassas. About the time a decline in the yield of the early variety Tender Pod

takes place, the late variety Kassas starts to produce and compensates for this decline and the yield is maintained at the desired level.

LITERATURE CITED

1. Agnew, G. W. J. 1959. French bean variety and spacing trial. Qd. J. Agr. Sci. 16:283-290. Hort. Abs. 31:2427. 1961.

2. Andrews, F. S. 1939. Root-top ratio of the bush lima bean as an index of adaptability to ecological conditions. Proc. Amer. Soc. Hort. Sci. 37:752-758.

3. Attia, M. S. and H. Nassar. 1958. Study on the performance of some snap bean varieties to different methods of planting. Agr. Res. Rev., Egypt. 36:397-399.

4. Binkley, A. M. 1932. The amount of blossom and pod drop on six varieties of garden beans. Proc. Amer. Soc. Hort. Sci. 29:489-492.

5. Gillis, M. C. 1928. The relation between rate of planting and yield in garden beans. Proc. Amer. Soc. Hort. Sci. 25:80-86.

6. Guyer, R. B., A. Kramer and L. E. Ide. 1950. Factors affecting yield and quality measurements of raw and canned green and wax beans. Proc. Amer. Soc. Hort. Sci. 56:303-314.

7. Halsted, B. D. 1895. Report of the botanist. New Jersey Agr. Exp. Sta. Rept. pp.290-292.

8. Jordan, A. T. 1898. Thickness of planting. New Jersey Agr. Exp. Sta. Rept. pp.166-167.

9. Kempthorne, O. 1952. The design and analysis of experiments. John Wiley and Sons, Inc. N.Y. pp.378.380.

10. Lachman, W. H. and G. B. Snyder. 1943. Experiments with lima beans. Proc. Amer. Soc. Hort. Sci. 42:554-556.

11. Larson, R. E. and Li Peng-fi. 1958. The influence of various row and plant spacings on yields of lima beans. Proc. Amer. Soc. Hort. Sci. 51:479-485.

12. MacGillivary, J. H., L. J. Clemente, D. E. Creighton, V. P. Osterli and E. E. Stevenson. 1952. Spacing effect on the yield of green lima beans for freezing. Proc. Amer. Soc. Hort. Sci. 60:330-334.

13. Mahoney, C. H., H. A. Hunter and A. White. 1941. Performance trials of new baby bush lima beans grown for canning. Proc. Amer. Soc. Hort. Sci. 38:541-545.

14. Matthews, W. A. 1933. The influence of planting distances on the yield of snap and lima beans. Proc. Amer. Soc. Hort. Sci. 30:567-570.

15. Montalvo, S. R. 1960. Density of sowing French bean crops in 1959. Inf. mens. La Molina. 34:7-16. Hort. Abs. 31:4465. 1961.

16. Odland, M. L. 1950. Influence of plant spacing on yield of snap beans. Progr. Rept. Pa. Agr. Exp. Sta. 38:4. Hort. Abs. 21:1645. 1951.

17. Vincent, C. L. 1958. Pea plant population and spacing. Bull. Wash. St. Agr. Exp. Sta. 594:9. Hort. Abs. 30:2233. 1960.

18. Vittum, M. T., D. J. Lathwell, N. H. Peck and C. B. Sayre. 1958. Effect of variable row spacings and plant populations on peas grown for processing and on the subsequent crop of alfalfa. Agron. J. 50:577-580.

19. Warren, G. F. 1950. Effect of rate and depth of seeding on the yield and maturity of Henderson bush lima bean. Proc. Amer. Soc. Hort. Sci. 55:372-374.

20. Watanabe, H. 1953. Studies on the unfruitfulness of beans: influence of temperature on flower bud differentiation and blooming. J. Hort. Assn. Japan. 22:100-106. Hort. Abs. 24:463. 1954.

21. Wunderlich, G. 1953. The effect of spacing on yields in four pea varieties. Bodenkultur. 7:1-9. Hort. Abs. 23:4225. 1953.

22. Yamazaki, K. 1959. Studies on the morphogenesis of crop plants under different growing conditions. Part I. Changes of leaf structure in *Phaseolus vulgaris*. Proc. Crop Sci. Soc. Japan. 27:381-384. Hort. Abs. 31:4466. 1961.

APPENDIX

Table 8. Analysis of variance for the percent of snap bean seed germination.

Source	S.S.	d.f.	M.S.	F.
Replications	1460.17	3	486.72	3.55
Row spcgs.	2140.30	3	713.43	5.20 ≠
Varieties	580.80	3	193.60	1.41
Error (a)	823.34	6	137.22	
Plt. spcgs.	1199.67	3	399.89	10.07 ≠≠
V.x Plt. spcgs.	234.14	9	26.02	0.66
Error (b)	1429.44	36	39.71	
Totals	7867.86	63		

≠ Statistically significant at the 5% level.
≠≠ Statistically significant at the 1% level.

Table 9. Analysis of variance for the height of snap bean plants.

Source	S.S.	d.f.	M.S.	F.
Replications	226.82	3	75.61	4.56
Row spcgs.	137.82	3	45.94	2.77
Varieties	1492.32	3	497.44	30.00 ++
Error (a)	99.48	6	16.58	
Plt. spcgs.	39.32	3	13.11	4.89 ++
V.x Plt. spcgs.	68.80	9	7.64	2.85 +
Error (b)	96.38	36	2.68	
Totals	2160.94	63		

\+ Statistically significant at the 5% level.

++ Statistically significant at the 1% level.

Table10. Analysis of variance for the weight of 100 snap bean pods.

Source	S.S.	d.f.	M.S.	F.
Replications	25388.66	3	8462.89	2.01
Row spcgs.	27679.28	3	9226.43	2.17
Varieties	308816.78	3	102938.93	24.22 ≠≠
Error (a)	25505.46	6	4250.91	
Plt. spcgs.	17316.78	3	5772.26	8.92 ≠≠
V.x Plt. spcgs.	6819.12	9	757.68	1.17
Error (b)	23295.40	36	647.09	
Totals	434821.48	63		

≠≠ Statistically significant at the 1% level.

Table 11. Analysis of variance for the average length of snap bean pods.

Source	S.S.	d.f.	M.S.	F.
Replications	3.15	3	1.05	5.00 ≠
Row spacings	6.38	3	2.13	10.14 ≠≠
Varieties	161.97	3	53.99	257.10 ≠≠
Error (a)	1.28	6	0.21	
Plt. spacings	3.79	3	1.26	6.00 ≠≠
V. x Plt. spcgs.	3.79	9	0.42	2.00
Error (b)	7.40	36	0.21	
Totals	187.76	63		

≠ Statistically significant at the 5% level.

≠≠ Statistically significant at the 1% level.

Table 12. Analysis of variance for the average width of snap bean pods.

Source	S.S.	d.f.	M.S.	F.
Replications	0.20	3	0.067	3.72
Row spacings	0.07	3	0.023	1.28
Varieties	0.54	3	0.180	10.00 ##
Error (a)	0.11	6	0.018	
Plt. spacings	0.00	3	0.000	0.00
V. x Plt. spcgs.	0.06	9	0.007	1.81
Error (b)	0.13	36	0.004	
Totals	1.11	63		

Statistically significant at the 1% level.

Table 13. Analysis of variance for the total yield from the first 5 pickings of snap bean pods.

Source	S.S.	d.f.	M.S.	F.
Replications	0.89	3	0.297	13.50 ##
Row spacings	0.91	3	0.303	13.77 ##
Varieties	2.59	3	0.863	39.23 ##
Error (a)	0.13	6	0.022	
Plant spacings	1.15	3	0.383	27.36 ##
V. x Plt. spcgs.	0.21	9	0.023	1.64
Error (b)	0.51	36	0.014	
Totals	6.39	63		

Statistically significant at the 1% level.